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Part 1

Companies and Production

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NTNU
Kunnskap for en bedre verden

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Introduction

There are 14 different companies in the metallurgical industry with locations in Norway, with a total of 27 plants all over the country. This report presents an overview of the different plants. In addition to company history and updated production quantity from 2019, there is information about the raw materials and the material flow - from the mines to the plants, as well as the production processes at the plants.

A lot of the information is obtained directly from the companies. Not all of the companies were willing to share information about the plants, production process or the raw materials.

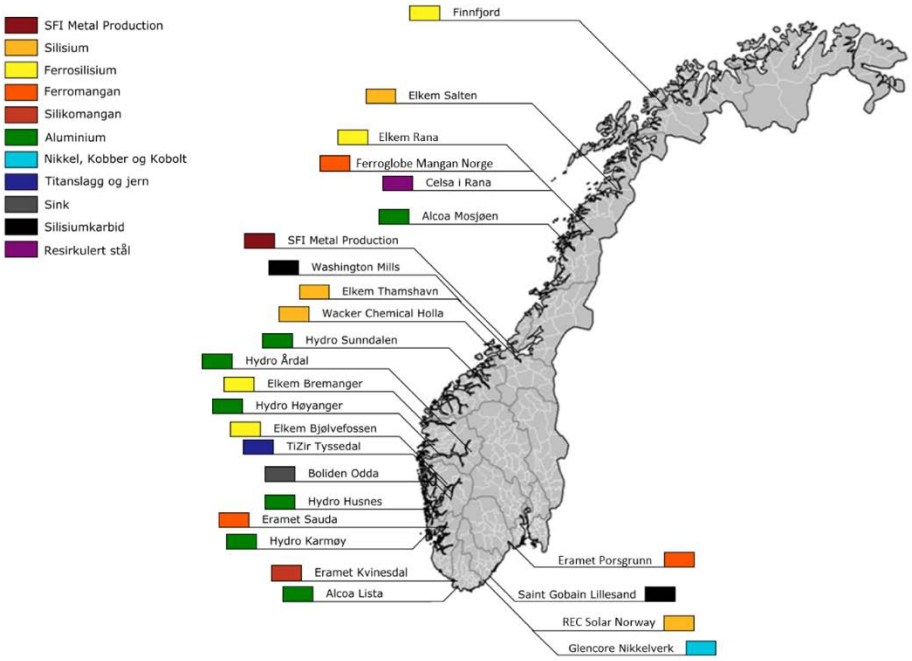

Figure 1: Map of metal producing companies in Norway.

Aluminium

Aluminium is a part of the boron group with atomic number 13. It is the third most abundant element in the world, after oxygen and silicon. The metal has several properties which make it particularly interesting. Pure aluminium is a silver-white metal with high ductility, but aluminium alloys can achieve high strength and hardness. The applications are many due to low density and high corrosion resistance, e.g. in the transport industry, construction and packaging. Aluminium occupies about 8.3wt% of the Earth's crust and is found in over 270 different minerals. Bauxite is the main source for industrial aluminium production, which is mainly found in a belt around the equator[1].

The production of aluminium is a highly energy-consuming process with several steps. First, bauxite has to be extracted from the Earth's crust. After that, the bauxite is refined to produce alumina (Al_2O_3) by the Bayer process. This process produces large quantities of waste called bauxite residue or red mud. The next step, where melted aluminium is produced from alumina by electrolysis, is called the Hall-Héroult process and this is the most energy-consuming part of the production[1]. Figure 2 shows a standard cell design for an electrolytic cell for aluminium production. The average power consumption worldwide during production of 1 kg aluminium is 14.5 kWh[1]. Hydro opened a pilot project in 2018, with electrolytic cells that consumes only 12.3 kWh/kg aluminium. They are also testing an electrolysis process where it is only needs 11.5-11.8 kWh/kg[2].

It is far less energy-consuming to recycle aluminium than to produce it through primary production. Although there are always some losses during recycling through oxidation of the molten metal as aluminium has a high affinity to oxygen. There are two companies that produces primary aluminium in Norway: Norsk Hydro and Alcoa.

The carbon anodes consumed in the electrolysis process have to be replaced regularly. The carbon materials for the anode production are received from suppliers worldwide. About 40% come from Europe, 20% from China, and 40% from the US.[3]

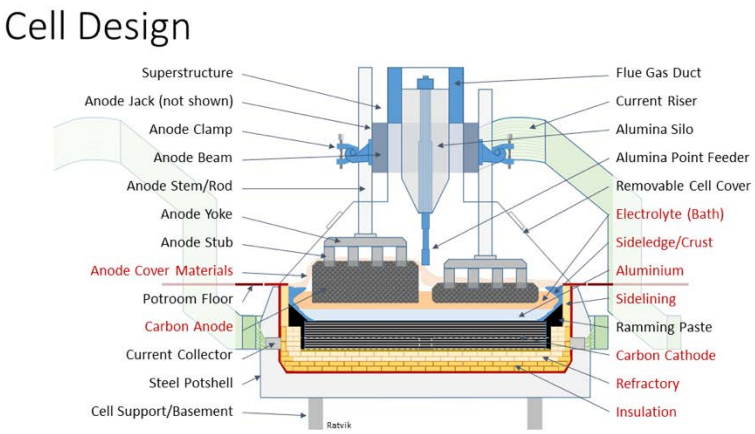

Figure 2: A standard electrolytic cell for primary production of aluminium.

Norsk Hydro ASA

Hydro is a Norwegian aluminium company established in 1905. Hydro was involved in several different industries throughout the 20th century, including the petroleum industry and production of fertilizer. The aluminium industry was expanded gradually together with the oil and gas industry in the 1980s and 1990s. After the conglomerate was split into an oil and gas(now part of Equinor), fertilizer(YARA) and aluminium division, Hydro was left as a specialized aluminium company.[4] The company is now a global supplier of aluminium and a fully integrated company with 36 000 employees in 40 countries worldwide.[5] Hydro produces a total of about 2 million metric tons primary aluminium annually.[6] Almost 53% of this is produced at five different locations in Norway with Norwegian hydropower as the main energy source for the energy-demanding industry.

According to their annual report, Hydro recycled over 1.2 million metric tons aluminium in 2019. About 86% of this was «pre-consumer scrap», which is waste from the production process that never ended up as a product. Only 175 000 metric tons of the recycled aluminium came from scrap that has been outside the aluminium plants (post-consumer scrap).[6]

Raw Materials and Material Flow

Hydro's bauxite mines are located in the northern part of Brazil, in the state of Pará. The bauxite is transported through pipelines to the refinery at the coast. Hydro Alunorte is the world's largest alumina refinery outside China and is located in the city of Barcarena, state of Pará. The alumina is the raw material for aluminum and is produced from bauxite, through the Bayer process.[7] Primary aluminium is produced by electrolysis in the Hall-Héroult process, and the melted aluminium is passed on to the casthouse. Figure 3 shows a simplified process flow chart of the production process, from bauxite to primary aluminium.

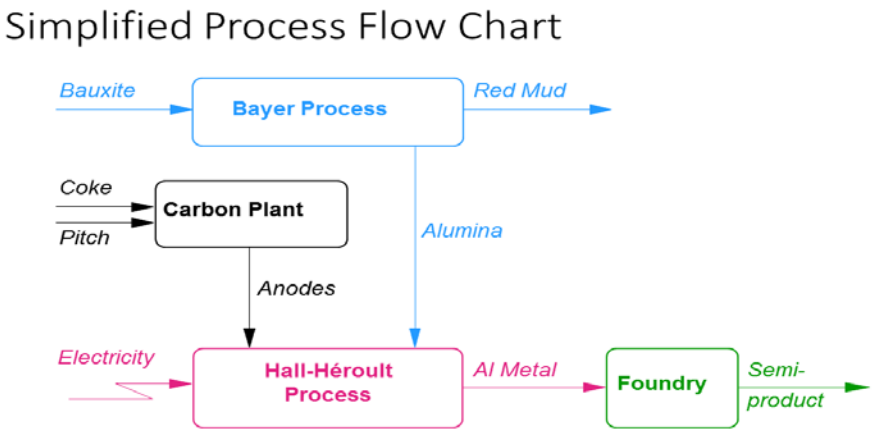

Figure 3: Simplified process flow chart for production of aluminium.

Hydro Sunndal

Sunndal municipality is located in Møre og Romsdal county. Hydro Sunndal aluminium plant, with a number of 681 employees as of December 31, 2019, has a significant role in the municipality with 7036 inhabitants.[8] The aluminium production started in 1954 and the plant is the largest and most modern plant for production of primary aluminium in Europe.[9] Hydro Sunndal produced 421 000 metric tons of primary aluminium in 2019.[6] There is an anode factory which produces 80 000 metric tons of pre-baked carbon anodes for the electrolysis process annually. One of Hydro's metallurgical research centres (RDS), Hydro Accounting Competence Center (ACC), and the equipment company Hycast AS are all located adjacent to the aluminium plant.[9]

Figure 4: Hydro Sunndal.[10]

Hydro Karmøy

Karmøy is a municipality with 42 186 inhabitants, located close to Haugesund in Rogaland county.[8] Hydro established at Karmøy in 1967 and has an aluminium plant, a rolling mill, and a research and development facility located here. The metal plant and the rolling mill have about 650 employees.[11] The plant produced 271 000 metric tons of primary aluminium in 2019. Products are extrusion ingots, wire rods for high-voltage cables, and plates for the rolling mill. The capacity at the rolling mill is 90 000 metric tons of rolled aluminium products annually.[6]

Figure 5: Hydro Karmøy.[12]

Hydro Årdal

Årdal municipality in Vestland county has a population of 5193 people.[8] Hydro's plant is located in Øvre Årdal. The construction was started by the German company A/S Nordag during the Second World War and completed by AS Årdal Verk. The production of aluminium started in 1948. The plant was taken over by Hydro in 1986. Today, they are operating one of the industry's leading research centres here, in addition to primary aluminium production, production of casthouse products, and a plant for production of carbon anodes.[13] 201 000 metric tons of primary aluminium and 172 000 metric tons of anodes were produced in 2019.[6]

Figure 6: Hydro Årdal.[14]

Hydro Høyanger

Høyanger municipality, located in Vestland county, has about 4101 inhabitants.[8] Hydro's aluminium plant in Høyanger is the smallest of its kind in Norway, but it is still a dominant factor for employment and settlement in the local community, with 161 employees. The

production started in 1917 as one of the first primary aluminium plants in Norway.[15] The production quantity in 2019 were 66 000 metric tons. The plant is delivering sheet ingots.[6]

Figure 7: Hydro Høyanger[16].

Hydro Husnes (fka. Sør-Norge Aluminium AS)

Husnes is located in Kvinnherad municipality in Vestland. The municipality has about 13 071 inhabitants.[8] The aluminium plant was established in 1965 and is formerly known as Sør-Norge Aluminium(SørAl), before it became a fully owned Hydro company in 2014.[17] Hydro Husnes has 322 employees, produces primary aluminium and casthouse products, and had a production quantity of 96 000 metric tons primary aluminium in 2019.[6]

Due to low aluminium prices in the world market, the production were cut by 50% in 2009. In 2017, 1.3 billion NOK was invested to upgrade and restart the closed production line. The goal is to achieve a total production of 190 000 metric tons per year by 2020.[18]

Figure 8: Hydro Husnes.[19]

Hydro Holmestrand (Rolled Products)

Hydro Holmestrand is located in Holmestrand municipality in Vestfold og Telemark county, with a population of 24 699 inhabitants.[8] The rolling mill has 400 employees and manufactures rolled products, with an annual production capacity of 90 000 metric tons.[6] In addition to that, Hydro Holmestrand is operating advanced lacquering of aluminium and is the major recycler of aluminium in Norway.[20] Unlike the other plants mentioned in this report, the plant in Holmestrand is not producing primary aluminium.

Figure 9: Hydro Holmestrand.[21]

Alcoa Norway ANS

Alcoa (Aluminium Company of America) is an American aluminium company established in 1888 as «The Pittsburgh Reduction Company» by Charles Martin Hall, one of the inventors of the famous Hall-Héroult process. The company has been a part of the development of aluminium production from the beginning.[22] Alcoa established itself in Norway in 1962 through a cooperation with Elkem ASA, and together they operated a plant in Lista and in Mosjøen. Today, the plants are are owned by Alcoa alone.[23] Alcoa is, like Hydro, a fully integrated aluminium company and among the world's 10 largest aluminium producers with about 13 800 employees and business worldwide. Alcoa had a global production of 2.1 million metric tons primary aluminium in 2019. [24] 290 000 metric tons were produced at the two aluminium plants in Norway, which is equivalent to 13.8% of the total production.[25]

In May 2018, Alcoa and Rio Tinto Aluminium announced that they have further developed the production process of aluminium using inert anodes instead of traditional carbon anodes in the electrolysis process. With inert anodes, no CO_2 is produced during electrolysis. This has been under development for over 50 years. It will be considered as a revolution in the aluminium industry if they succeed to commercialize the technology.[26]

Raw Materials and Material Flow

Alcoa operates bauxite extractions in Australia, Brazil, Guinea and Saudi Arabia. The material flow at Alcoa is similar to Hydro's. The extracted bauxite is sent to an alumina refinery before the alumina is transported to the smelters. While Hydro receives most of its bauxite from Brazil, Alcoa has large parts of its bauxite mines in Australia.[24]

Alcoa Lista

Lista is located in Farsund municipality in Agder county, with a population of 9691 people.[8] Alcoa Lista was established here in 1971. In 2019, the plant had 270 employees and produced 94 000 metric tons of electrolysis metal. Alcoa Lista differs from other aluminium plants in Norway, as it uses Søderberg electrodes.[23] This is continuously self-baking carbon electrodes, which is used in the electrolysis process instead of pre-baked anodes that has to be replaced. The use of Søderberg electrodes have been associated to lower power efficiency because they generally have lower quality than pre-baked anodes. They are also associated to higher emissions of greenhouse gasses to the furnace house while the electrodes are built continuously, and the process gets more open. Alcoa Lista has developed and made the plant efficient enough to be competitive.

Figure 10: Alcoa Lista.[27]

Alcoa Mosjøen

Mosjøen is located in Vefsn municipality in Nordland, with a population of 13 278 inhabitants.[8] The aluminium plant in Mosjøen was established in 1958 by Elektrokemisk (today known as Elkem) and AIAG (Aluminium-Industrie-Aktien-Gesellschaft, today known as Alusuisse). Alcoa took over for AIAG as early as 1963. The production was originally at 23 000 metric tons. Today, the plant has 450 employees and a production capacity of 188 000 metric tons of primary aluminium. In addition to aluminium production, Alcoa operates an anode plant in

Mosjøen. They deliver anodes to the aluminium production in Mosjøen, as well as to Alcoa Fjardaal in Iceland.[23]

Figure 11: Alcoa Mosjøen.[28]

Silicon

Silicon is the second most abundant in the Earth's crust, occupying approximately 25.7wt%. It is found as silicon oxides, e.g. as silica and quartz. Silicon is a semiconductor and is important within, among other things, electronics and solar energy, as well as in the metal industry. It is used as deoxidizer and alloying element in the steel industry, as an alloying element in the aluminium industry and in the production of the countless varieties of silicone materials. The different applications of silicon require different degrees of purity. Metallurgical silicon contains at least 96% silicon. Here there usually are trace elements such as iron, calcium, aluminium and titanium. Silicon for solar cells or electronics requires higher purity[29]. The silicon production process is sketched in Figure 12.

Silicon (Si) and ferrosilicon (FeSi) are two products with different properties and applications. When the FeSi contains more than 65% silicon, which is the case for the production in Norway, the two production methods are similar.[29] Norway accounted for about 5.3% of the world's production of silicon and ferrosilicon in 2019, making it the third largest producer worldwide.[30]

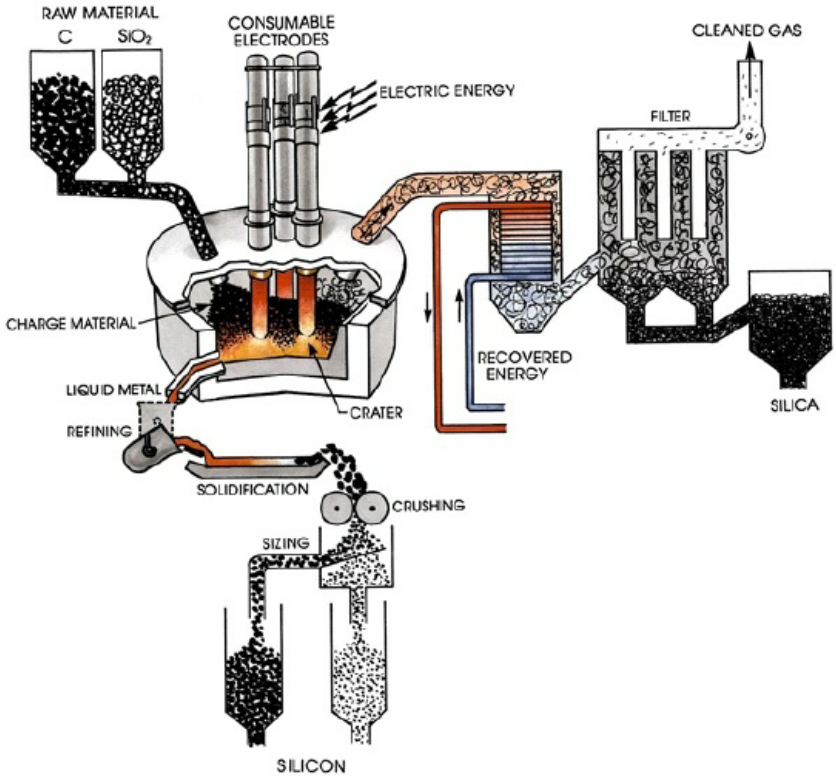

Figure 12: Sketch of the standard production process of silicon and ferrosilicon (more than 65% Si).[31]

Finnfjord AS

Finnfjord's plant is located in Finnfjordbotn in Senja municipality, five kilometres from the town Finnsnes. The municipality has 14 851 inhabitants.[8] The plant started the production in 1962 and was owned by Fesil. Finnfjord metal plant was established to continue the production when Fesil went bankrupt in 1982. The company changed its name to Finnfjord AS in 2007 and has 130 employees today. The plant produces ferrosilicon and microsilica, as well as operating a thermal energy recovery plant.[32] Finnfjord produced 104 239 metric tons of silicon products in 2019, of which 86 994 metric tons were ferrosilicon and 17 245 metric tons were microsilica.[33]

Figure 13: Finnfjord smelteverk.[34]

Raw Materials and Material Flow

Finnfjord gets the raw materials for the production form different parts of the world. Iron pellets are sourced from Russia, and Elkem Tana in Norway produces the quartz needed. Finnfjord gets coal and coke from South America, Great Britain and Poland, and wood chips from Norway.[33] The supply of raw materials is not a big problem at the moment, but it could potentially be a problem in the future and companies that buy all of their raw materials from just a few suppliers may be particularly vulnerable. The supply of raw materials tends to deteriorate as the world is moving away from fossil energy sources, including coal and coke. There are already fewer suppliers and closure of mines, and there is a need for new, large and serious providers of bio-based carbon raw materials.[33] Finnfjord produces FeSi in 3 furnaces through a standard production process. The flue gas goes through steam boilers for energy recovery (production of electricity) before the dust, i.e. the microsilica, is filtered out in a plant for purification of smoke.

Elkem ASA

Elkem was established by Sam Eyde as an industrial company based on Norwegian natural resources. In 1917, the company developed the Søderberg electrode and produced ferroalloys. In the 1960s, Elkem expanded its operations with production of aluminium and extraction of raw materials. Throughout the latter half of the 1900s, Elkem merged with several companies and became an international giant in metal production.[35]

Elkem was acquired by the Orkla group and sold its aluminium production in 2005. The Orkla group sold Elkem to China International Bluestar Group in 2011. This agreement included Elkem's silicon, casting, carbon and solar cell manufacturing operations.[35] Elkem is headquartered in Oslo with 6 370 employees worldwide. The company currently has 1100 employees in Norway and is mainly engaged in the production of silicon and ferrosilicon.[36]

Elkem Thamshavn

Elkem Thamshavn is located in Orkland municipality, about 40 kilometres southwest of Trondheim. The plant was established by Orkla Grube Aktiebolag in 1930, originally for the production of sulphur and copper from copper mines nearby. The production of ferrosilicon started in 1964 and the plant became a part of Elkem in 1984. Elkem Thamshavn today produces metallurgical silicon and microsilica.[37] The production quantity in 2019 was 81 889 metric tons of silicon products.[38]

Figure 14: Elkem Thamshavn.[39]

Elkem Salten

Elkem Salten is located in Straumen in Sørfold municipality, 50 kilometres from Bodø. The first smelting furnace started production in 1967. Today, the plant produces high purity silicon (96-99% purity), microsilica and Sidistar, which is a polymer additive developed by Elkem.[40] Elkem Salten produced 79 952 metric tons of silicon and 27 396 metric tons of microsilica and Sidistar in 2019.[41]

Figure 15: Elkem Salten.[42]

Elkem Bjølvefossen

Elkem Bjølvefossen is located in Ålvik in Kvam municipality in Vestland county. The plant was established in 1905. Today, it has 155 employees and operates 2 reduction furnaces. Elkem Bjølvefossen specializes in the production of ferrosilicon and magnesium-ferrosilicon and is one of the world's largest producers of magnesium-ferrosilicon.[43] The plant produced 45 043 metric tons of ferrosilicon and 55 814 metric tons of magnesium-ferrosilicon in 2019.[44]

Figure 16: Elkem Bjølvefossen.[45]

Elkem Rana (fka. Fesil Rana Metall AS)

Elkem acquired Fesil Rana Metall in December 2016. The plant was established in 1989 and is located in Mo Industrial Park in Rana municipality in the county of Nordland, sharing a lot of infrastructure with partners in the industrial park. Elkem Rana has 109 employees and produces ferrosilicon in two furnaces, as well as microsilica.[46] The plant produced 74 542 metric tons of ferrosilicon in 2019.[47]

Figure 17: Elkem Rana[48].

Elkem Bremanger

Elkem Bremanger is located in Svelgen in the municipality of Bremanger in Vestland county. The plant was started in 1928 and has today 195 employees. Elkem Bremanger produces ferrosilicon, microsilica and Silgrain - a silicon powder containing minimum 99% Si.[49] In 2019, the plant had a production quantity of 56 409 metric tons of ferrosilicon.[50]

Figure 18: Elkem Bremanger.[51]

Raw Materials and Material Flow

Elkem receives the quartz for the production from their own mines in Spain and in Norway. Coke is supplied from varies countries[52].

REC Solar Norway AS (fka. Elkem Solar AS)

Starting during the nineties, Elkem developed a process for the production solar grade silicon through refining of metallurgical silicon. Silicon acts as a semiconductor in solar cells, and the purity of the material is significant for the efficiency in the solar cell. There are very specific requirements set for the quality of silicon for solar cells and the production process is expensive.[53] In 2009, a factory was built in Kristiansand for producing solar grade silicon. In 2016, it was taken over by REC and the name was changed to REC Solar Norway. REC has headquarters in Norway and operational headquarters in Singapore.[54] The company has over 2000 employees worldwide and produces 1.8 GW of solar panels annually.[55] REC Solar Norway produces silicon for solar cells at its plant in Kristiansand in the county of Agder. The production quantity in 2019 was 2 718 metric tons.[56]

Raw Materials and Material Flow

REC Solar Norway produces silicon for solar cells by a metallurgical refining process based on metallurgical silicon (96% purity), using a unique production process with 70% lower energy consumption and 90% lower carbon footprint than the Siemens process. Recently, they have also started to use kerf as raw material. Si-kerf is the waste (dust) from the silicon used in the solar industry and using this is making the solar industry more circular. REC is using a new plant for kerf processing. After slag treatment, leaching, solidification and post treatment, the kerf is refined to solar grade silicon which can be further processed to, among other things, solar cells.[57]

Figure 19: REC Solar Norway in Kristiansand.[58]

Wacker Chemicals Norway AS

Wacker Chemicals Norway is located at Kyrksæterøra in Heim municipality, approximately 70 kilometres southwest of Trondheim. The municipality has 5 963 inhabitants.[8] The plant was originally established by the Fesil group in 1964 and sold to Wacker in 2010.[59] Wacker is a German chemical company working with, among other things, silicon, polymers and biotechnology. The acquisition of the plant in Heim was a strategic decision to secure access to silicon metal and thus get a fully integrated silicon business. The plant, which has about 200 employees, produces silicon and microsilica.[60] In 2019, the world largest silicon furnace was started which has a capacity of 30 000 metric tons per year. Wacker Chemicals Norway produced 61 204 metric tons of silicon in 2019.[61]

Figure 20: Wacker Chemicals Holla[62].

Raw Materials and Material Flow

Wacker Chemicals Norway produces silicon in arc furnaces with three electrodes, see Figure 12. Quartz and carbon sources as coal, charcoal or wood chips are used in the process. Wacker Chemicals Norway import quartz from different countries. After the reduction, the silicon is tapped from the furnace, cast, crushed and sold.[61]

Manganese alloys

Manganese is a grey-white transition metal which exists as oxides in nature. The metal is hard and brittle in its pure form. Almost all commercially produced manganese is used in the steel industry as ferromanganese. This is produced by reducing iron oxide and manganese dioxide containing ore with carbon in an electric furnaces.[63]

There are two main groups of ferromanganese alloys. The first one is called ferromanganese (FeMn). It contains about 80% manganese. The second group is called silicomanganese (SiMn) which, in addition to minimum 65% manganese contains at least 17% silicon.[63]

Eramet Norway AS

Eramet Norway is a part of the French multinational industrial group Eramet which is a world leader in the production of metal alloys. The group is producing nickel and manganese, as well as high quality special alloys. Eramet is a fully integrated mineral and metal company with operations in 20 countries worldwide. It was founded in 1985 as a unifying organization for several companies, among others, the nickel company Société Le Nickel (founded in 1880), the metal c336ompany AUBERT & DUVAL (founded in 1907) and the mining company COMILOG (founded in 1953). After the merger, the company has expanded the diversity of investment arenas. Eramet currently has three plants in Norway.[64] The three plants produced a total of 530 000 metric tons of ferromanganese and silicomanganese in 2019. Details about the production capacity of each plant are not given.[65]

Eramet Sauda

Sauda municipality is located in the northeast part of Rogaland county and has around 4595 inhabitants.[8] In the beginning of the 20th century, the watercourse in Sauda were harnessed for hydroelectric power generation, which laid the foundation for further industry in the area. The plant, shown in Figure 21, was created by the American industrial group Union Carbide Corporation and produced carbide until the First World War. After this, the plant was converted producing ferro alloys, and Eramet has owned the plant since 1999. Eramet Sauda produces ferromanganese alloys and it is the largest producer of ferromanganese in Northern Europe, with two 40 MW furnaces and refining plants.[66] Figure 22 shows the material flow in the production process at the plant in Sauda.

Figure 21: Eramet Sauda.[67]

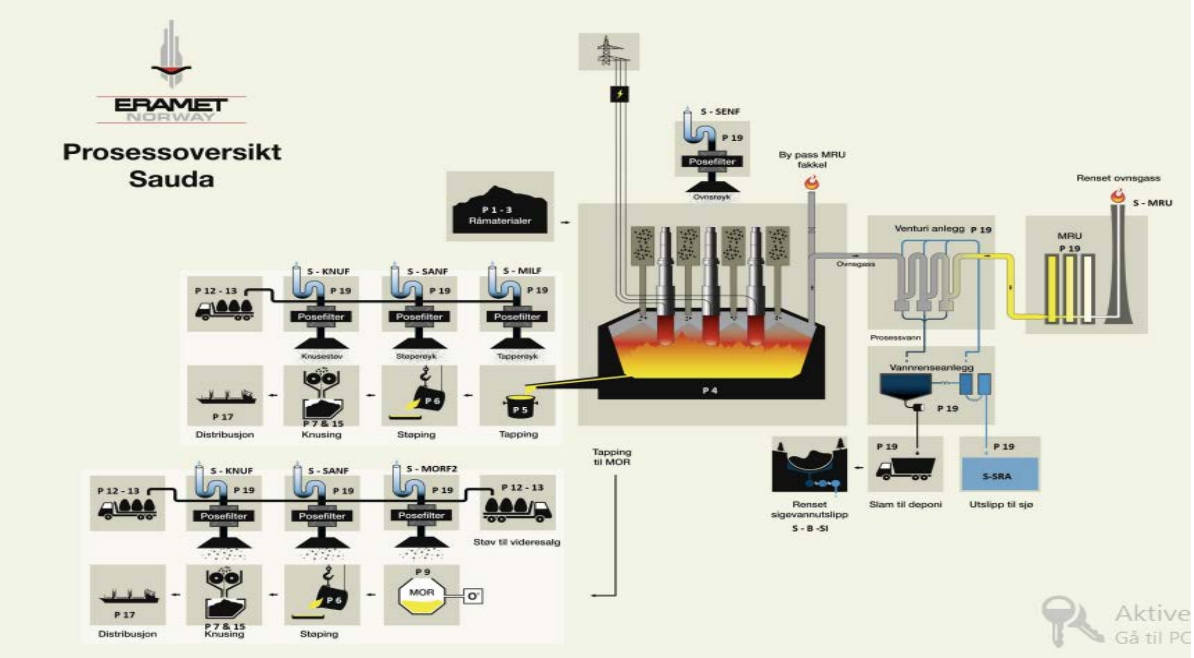

Figure 22: Flow chart of the production process at Eramet Sauda.[68]

Eramet Kvinesdal

Eramet Kvinesdal is located in Kvinesdal municipality in Agder with about 5 987 inhabitants.[8] The plant, shown in Figure 23, producing silicomanganese has a significant role in the municipality, employing 200 people. The supply of power and proximity to the port area was crucial for the location of the smelter when it was established by Tinfos in 1974. The plant was acquired by Eramet in 2008, which took over both business and employees. Eramet Kvinesdal produces silicomanganese and is primarily selling to manufacturers of stainless steel in Europe and North America.[69] The slag which is formed in the process is considered

as a by-product and is mostly used as a filler, e.g. in road construction. Figure 24 shows the material flow in the production process at the plant in Kvinesdal.

Figure 23: Eramet Kvinesdal.[70]

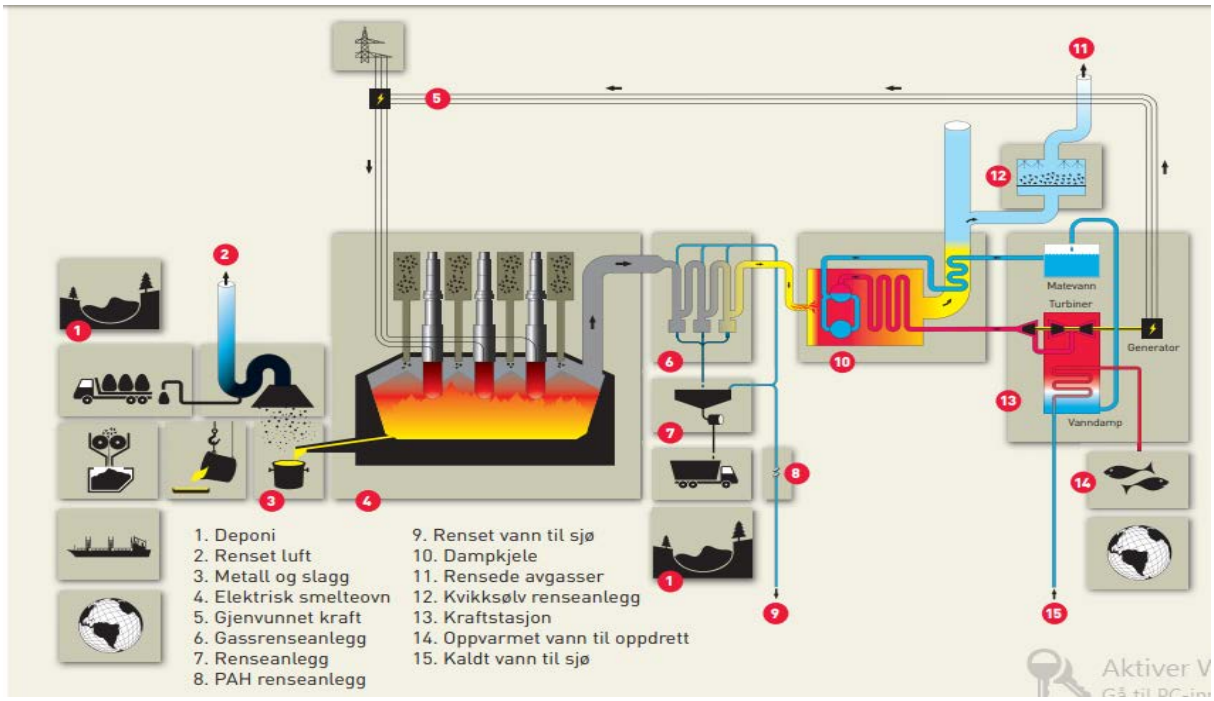

Figure 24: Flow chart of the production process at Eramet Kvinesdal.[68]

Eramet Porsgrunn

Eramet Porsgrunn is located at Herøya industrial park, shown in Figure 25, in Vestfold og Telemark in the south of Norway and has 160 employees. Porsgrunn municipality has 36 397

inhabitants.[8] Eramet's smelter here was established in 1913 by METEOR, a Swiss company that was attracted to the region because of the supply of cheap hydropower. Eramet Norway acquired the plant in 1999 and today it produces refined ferromanganese and silicomanganese alloys in two furnaces.[71] The co-location at Herøya industrial park offers great benefits for the operation. Among other things, furnace gas (CO gas) is sold to Yara, which contributes to a reduction in the total emissions of greenhouse gas. This furnace gas is a by-product of metal production, which becomes a more environmentally friendly alternative for Yara than fossil fuels would have been. Other benefits of the industrial park include access to a staffing agency, a shared, online apprentice recruiting platform and consulting companies and engineering firms with valuable expertise close to the plant.[71] Figure 26 shows the material flow in the production process at the plant in Porsgrunn.

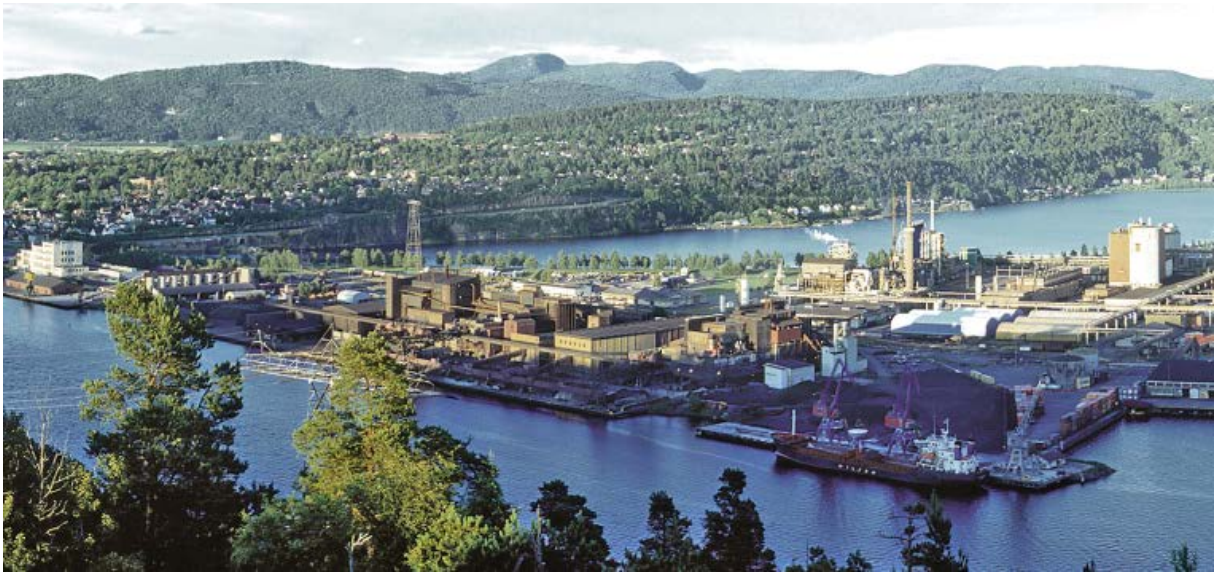

Figure 25: Eramet Porsgrunn.[72]

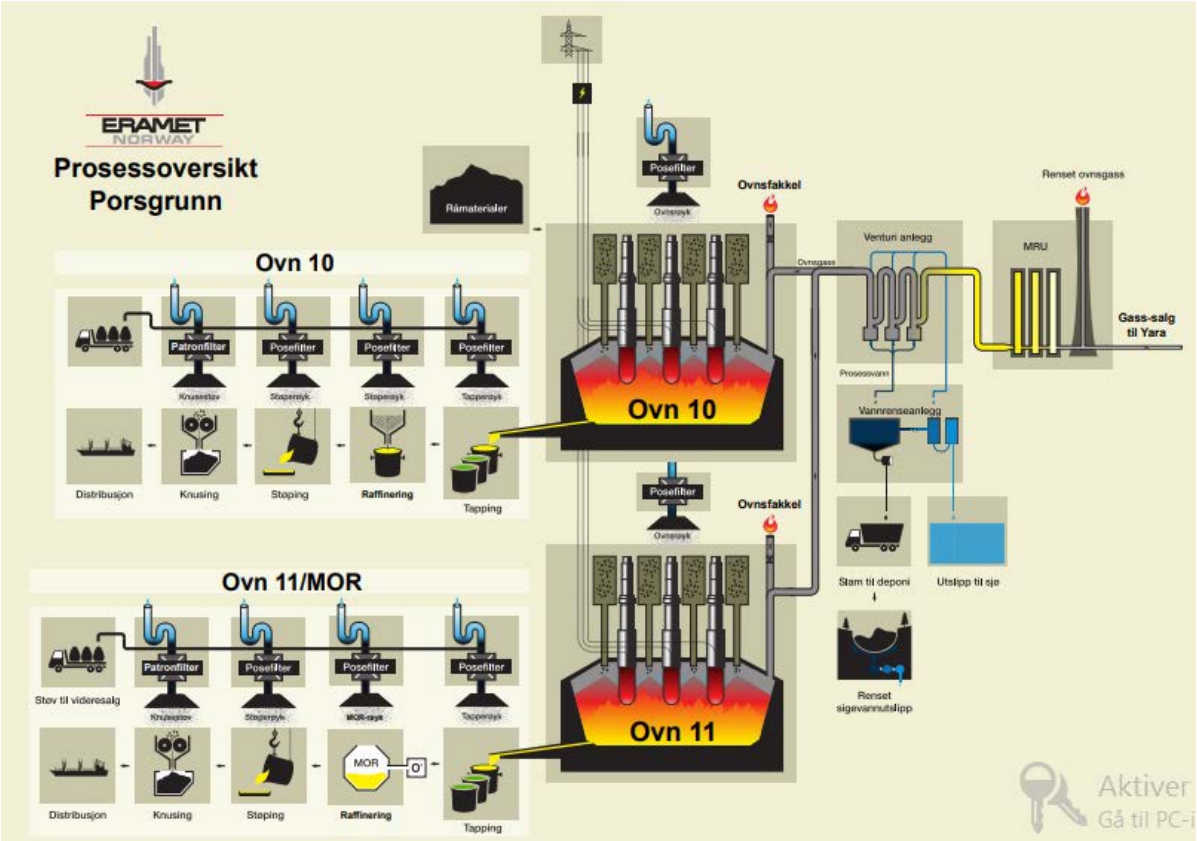

Figure 26: Flow chart of the production process at Eramet Porsgrunn.[68]

Raw Materials and Material Flow

Eramet Norway have the advantage of access to manganese ore from the parent company's own mine in Moanda in Gabon, West Africa. Eramet is the second largest producer of manganese ore through its subsidiary COMILOG.[73] Quartz is obtained from Eramet's own quartz quarries in Snekkevik, Norway.[65] Eramet

Ferroglobe Mangan Norge AS (fka. Glencore Manganese Norway AS)

In November 2017, it was announced that Ferroglobe PLC had purchased all the shares in Glencore Manganese's smelters in Mo i Rana and in Dunkirk, France. The acquisition was completed in February 2018 and the new name of the plant in Mo i Rana was «Ferroglobe Mangan Norge AS». The production with the new owners continued as before. The acquisition of the smelters in Norway and France made Ferroglobe to one of the world's largest producers of ferromanganese and silicomanganese.[74]

Figure 27: Ferroglobe Mangan.[75]

Ferroglobe Mangan Norge produces ferromanganese and silicomanganese as primary products. The production quantity varies, depending on the market. In 2019, the plant produced 5 692 metric tons of ferromanganese and 89 571 metric tons of silicomanganese.[76]

Raw Materials and Material Flow

Table 1 shows the consumption of the different raw materials in the production process at Ferroglobe Mangan Norge. There is variation in consumption numbers, depending on the production rate.[77]

Table 1: The amount of consumption of various raw materials in the production process of ferromanganese and silicomanganese at Ferroglobe Mangan Norge in 2019.

Raw material	Quantity [metric tons]	Comment
Coke	44 117	
Coke powder	12 450	
Dolomite	8 105	
Electrode mass	1 873	
FeSi skoller (off-grade)	4 230	
Quartz	36 000	
High carbon slag	71 031	
Iron pellets	2 765	
Lime	0	Same function as dolomite
Ore	21 376	
Quartz	36 000	
Sinter	112 794	Intermediate product

Note: Data for consumption of raw materials at Ferroglobe from Ferroglobe Mangan Norge (2020).[77]

Sinter is an intermediate product used to convert the ore to a metallurgically stable product that can be used in the furnaces. The production of ferromanganese requires more sinter than the production of silicomanganese.

Ferroglobe Mangan Norge gets its raw materials at the open market and there is a limited number of suppliers. The ore is mainly produced in Brazil and South-Africa, while coke is largely sourced from Poland, Ukraine and Russia. Electrode mass is obtained from Norway or Poland, and the high-carbon slag from a sister company in France. They get quartz from one of Elkem's quarries, in Mårnes, and dolomite from a local quarry. Ferroglobe Mangan Norge considers the supply of raw materials as fairly stable and secure, but it can be challenging to obtain raw materials with sufficiently good quality in the future.[77]

The production processes of FeMn and SiMn leave two different types of slag. Both types are classified as by-products and not as waste. The slag from the production of ferromanganese is recovered in their own furnaces because it contains enough manganese to be raw material for SiMn production. The slag from the SiMn is sold to another company, which crushes it down to different fractions for further use in different projects, e.g. construction of roads and stabilization masses for house construction.[77] Figure 28 shows a flow chart of the production process at Ferroglobe in Norge.

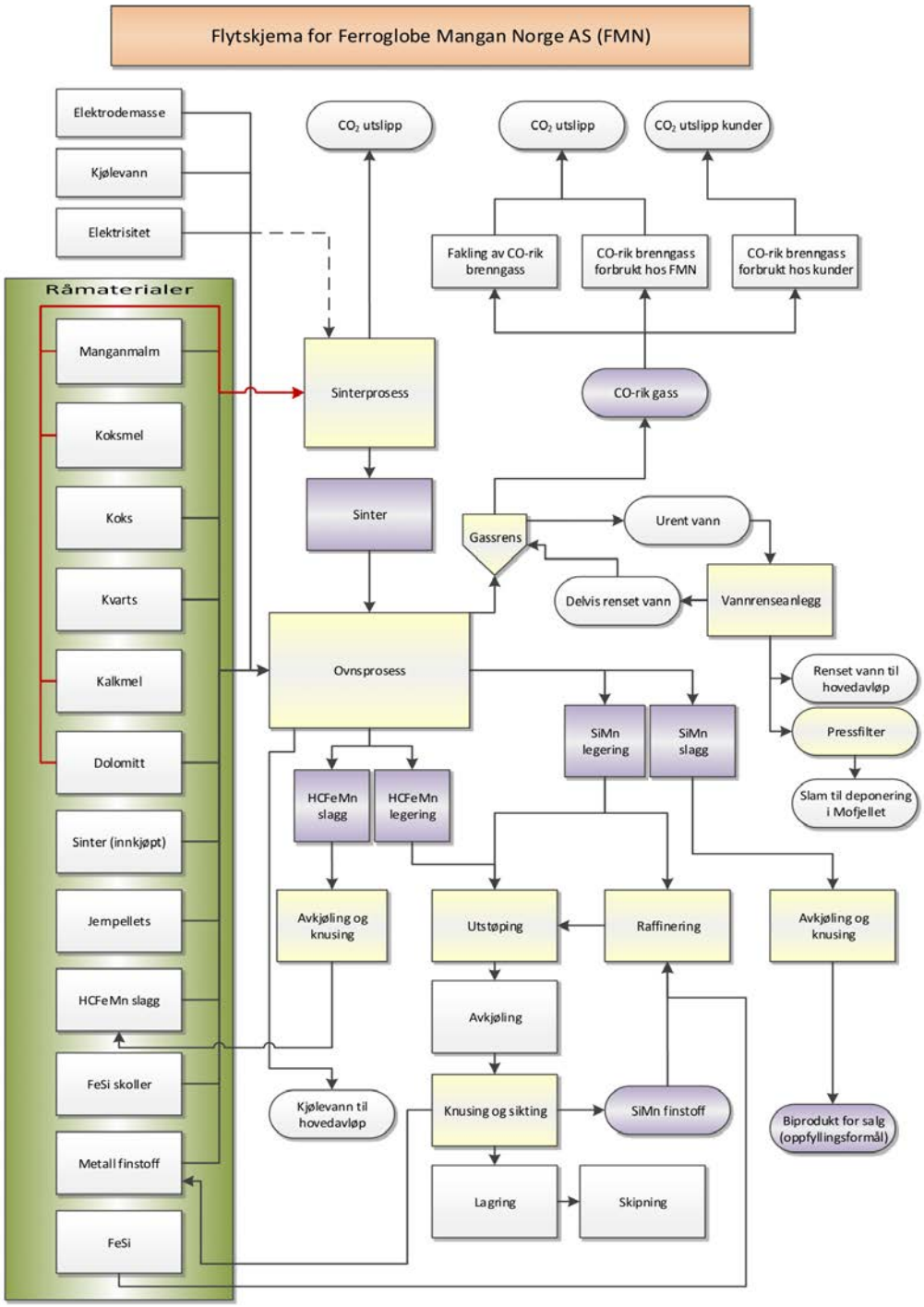

Figure 28: Flow chart of the production process at Ferroglobe Mangan Norge.[78]

Silicon Carbide

Pure silicon carbide (SiC) is a colourless, refractory and hard material. It is widely used as abrasive. In addition, it is used in electronics as it also has semiconductor properties. Silicon carbide is produced with the Acheson process, shown in Figure 29. In the Acheson process, pure silica sand and finely divided carbon (coke) are reacted in an electric furnace at temperatures in the range of 2 200°C–2 480°C. The material is found in several modifications and purities, including a cubic low temperature structure and a hexagonal high temperature structure. The latter is technically manufactured and is usually contaminated with aluminium

(which gives a black colour) or iron and nitrogen (which gives a green colour). Silicon carbide has low thermal conductivity and is also used as linings in holding furnaces in iron foundries and steel plants. In Norway, two companies are operating silicon carbide production.[79]

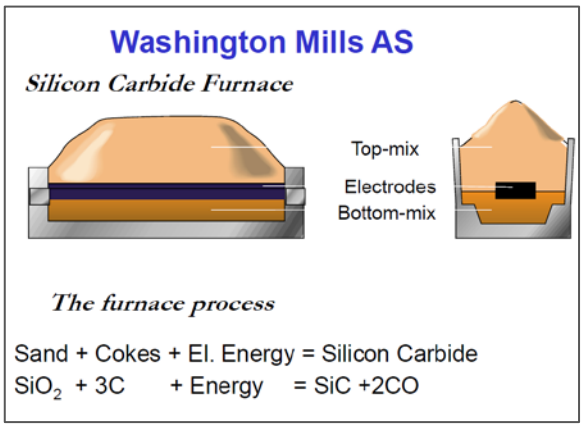

Figure 29: Production of silicon carbide.[80]

Washington Mills AS

Washington Mills is a manufacturer of abrasives and molten mineral products. The company was founded in 1868 and has large businesses, i.a. in USA, Canada and Great Britain. The company engaged in the production of silicon carbide in Orkanger and secured 100% ownership in 2005. The plant, located in Orkanger in the municipality of Orkland, about 40 kilometres southwest of Trondheim, has 120 employees. It no longer produces raw silicon carbides. The plant in Orkanger is buying coarse silicon carbide and granules from its owner in the United States, processing it to fine powder. In 2019, Washington Mills processed 1 696 metric tons of raw silicon carbide in Orkanger.[81]

Figure 30: Washington Mills.[82]

Raw Materials and Material Flow

The raw materials used in the production process at Washington Mills Orkanger is imported from other plants. At the plant in Orkanger, the silicon carbide is crushed into fine particles and further refining, as shown in 31.

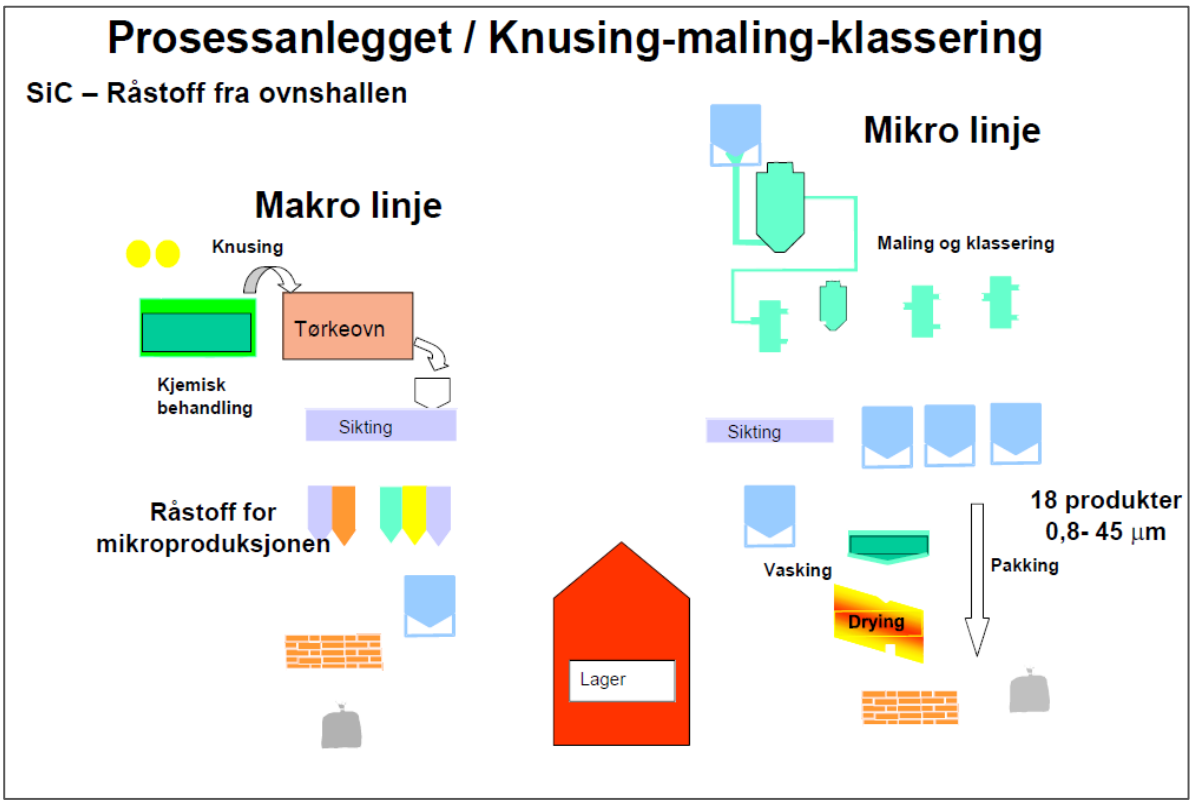

Figure 31: Material flow at the plant in Orkanger [80]

Fiven Norge AS (fka. Saint-Gobain Ceramic Materials AS)

Fiven is a new company headquartered in Oslo, Norway. It is the result of a recent corporate carve-out from the Saint-Gobain Group in 2019. Fiven is a global leader in the silicon carbide industry mainly in Europe and South America, where the company has 6 production sites, two of them in Norway.[83] The two plants in Norway is located in Lillesand and Arendal in Agder. They are focused on specialty products and abrasive applications, and their products are sold worldwide. The plant in Lillesand produces primary silicon carbide and had a production quantity of 16 750 metric tons in 2019.[84] The further processing of the silicon carbide is done In Arendal. The plant here refined 7845 metric tons of silicon carbide in 2019.[85]

Figure 32: Fiven Norge Lillesand.[86]

Raw Materials and Material Flow

Figure 33 shows a simplified flow chart of the production process of silicon carbide, most commonly produced in electrical resistance furnaces. Raw materials in the process are carbon materials and silica or quartz sand, which reacts chemically at relatively high temperatures (1700-2500°C). After this, the silicon carbide is sorted and further processed for different applications.[83]

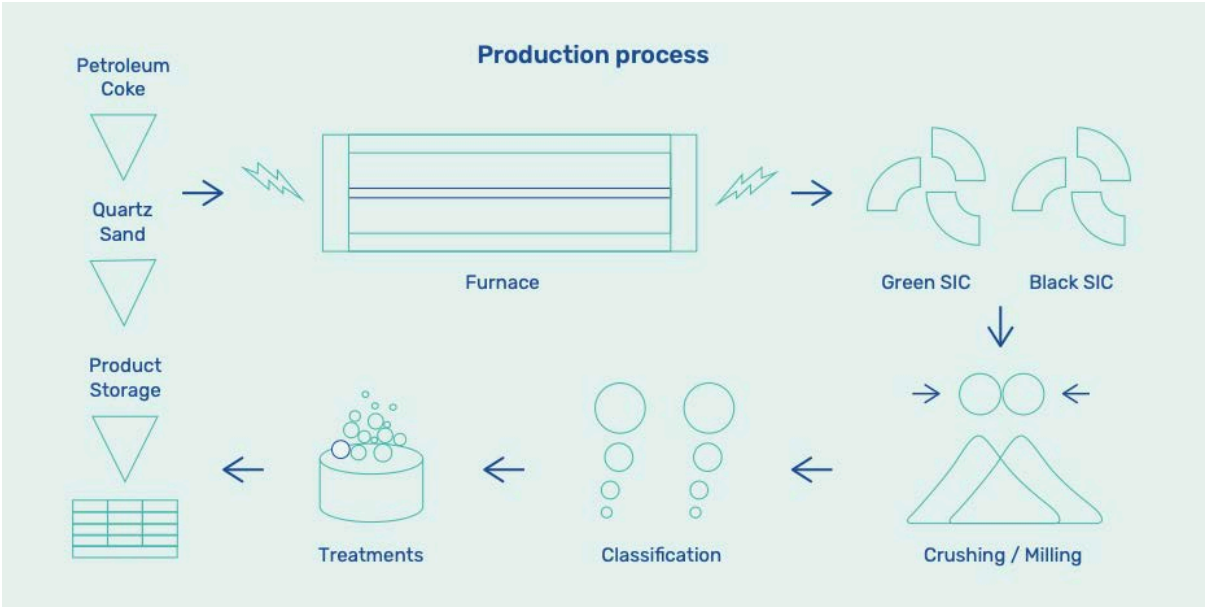

Figure 33: Flow chart of the production process of silicon carbide.[87]

Titanium dioxide

Titanium dioxide is used as a pigment, called titanium white, Pigment White 6 (PW6), or CI 77891. Generally, it is sourced from ilmenite, rutile, and anatase. Ilmenite ($FeTiO_3$) is by far the most important raw material for the production of titanium. Titanium is a light metal that has high specific strength. There is one company in Norway that produces titanium dioxide slag from ilmenite.[88]

TiZir Titanium & Iron AS

TiZir Titanium & Iron, shown in Figure 34, is located in Tyssedal in the municipality of Ullensvang in Hordaland. The municipality has 11 048 inhabitants and has long traditions with primary productions of metal.[8] The plant started production in 1986 as KSI and has operated under the name «TiZir Titanium and Iron» since 2011. The plant was owned by ERAMET and Mineral Deposits Limited (MDL) and the two companies also own Grande Côte mineral sand operation (GCO) in Senegal, West Africa.[88] Tronox, a worldwide chemical company, acquired the titanium smelting facility in May 2020. As a part of the transaction, they have a supply agreement with GCO to provide GCO's ilmenite to TTI. The plant is upgrading ilmenite to produce high-grade titanium slag mainly supplied to the pigment industry and high-purity pig iron for iron foundries.[89] The production quantity in 2019 was 188 700 metric tons of TIO_2-slag and 74 200 metric tons of pig iron.[90]

Figure 34: TiZir Titanium & Iron.[91]

Raw Materials and Material Flow

Tronox has not officially taken over the plant yet, because the acquisition process is still awaiting approval by the US Competition Authority. Since part of the terms of sale was that the plant will continue to obtain raw materials from the mine in Senegal, there is no indications that there will be major changes immediately.[92] Figure 35 shows a simplified flow chart for the process at the plant in Tyssedal. It is a two-stage process. The first stage is a pre-reduction stage and the second one is a smelting stage.

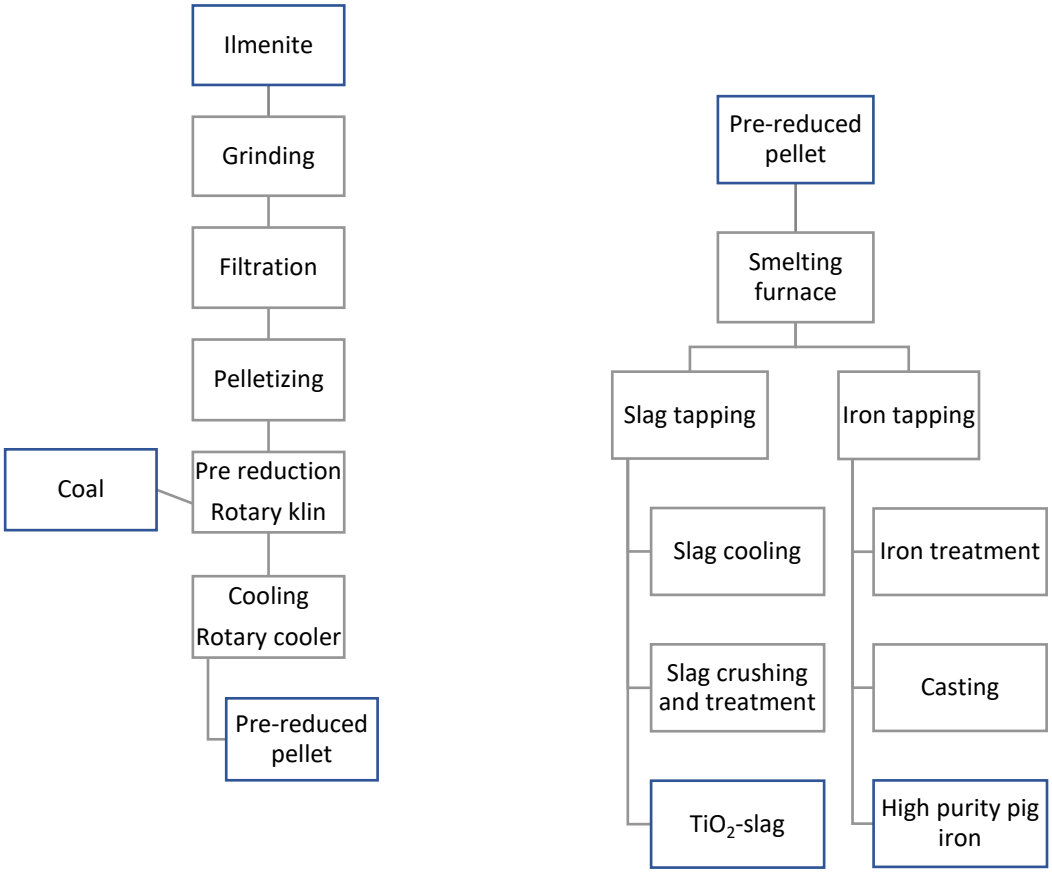

Figure 35: Simplified flow chart of the production process at TiZir Titanium & Iron.[93]

Steel

Steel is a term for iron alloys with an intermediate carbon content. Steel has a high strength and toughness. Steel is a cheap material compared to many other metals and this is one of the reasons for its wide applications and use, e.g. in the transport industry, buildings and constructions. Today, there are two different processes of steel production; ore-based primary production in blast furnace and scrap-based production of crude steel in arc furnaces.[94] In Norway, there is one company operating the latter process.

Celsa Armeringsstål AS

Celsa Armeringsstål is located in Mo industrial park, shown in Figure 36, in the municipality of Rana in Nordland. The plant was established in 1955 under the name A/S Norsk Jernverk but has been part of the Spanish steel company CELSA GROUP since 2007. Celsa Armeringsstål currently has 320 employees and bases all their steel production on recycled scrap.[95] In 2019, the plant produced 618 709 metric tons of reinforcing bar from recycled steel.[96]

Figure 36: Mo Industrial Parc with Celsa Armeringsstål.[97]

Raw Materials and Material Flow

Annually, between 660 000 and 667 000 metric tons of scrap are used in the production. About 60% of this comes from Norway and the remaining 40% mainly comes from the Nordic countries. In addition to that, coke, lime, and dolomite are used in the process. The lime is obtained from Verdal and the dolomite is to be found locally. Celsa uses coke coming from SSAB in Finland and ferro alloys that mainly come from Elkem and Ferroglobe at Mo industrial park. Oxygen and electrical energy are also produced in the park.[98] Figure 37 shows a simplified process of the material flow.

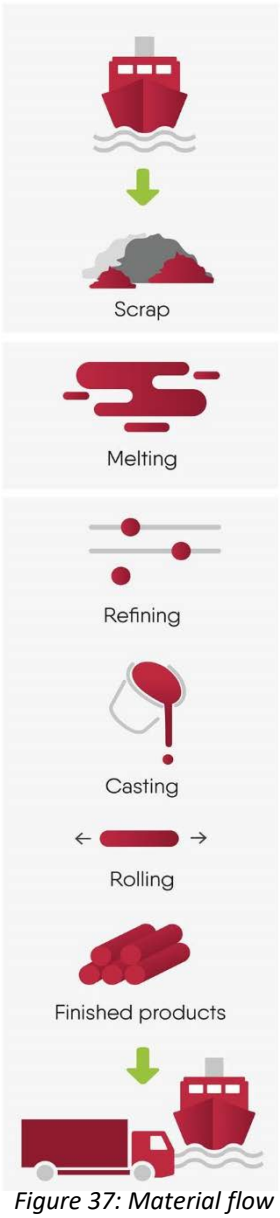

Figure 37: Material flow at Celsa Armeringsstål.[99]

Nickel

Nickel is a group 8 metal in the periodic system with atomic number 28. In its pure form, nickel has a silver shimmering colour. In nature, it appears as sulphides, arsenides and antimonides, often together with copper and iron. The most important application of nickel is as an alloying additive for iron, steel, copper, zinc and aluminium, and as a base metal for super alloys for use at high temperatures. The alloys are generally characterized by corrosion resistance and heat resistance and have many applications in, among other things, machines, motors, constructions, magnets and coins. There is one producer of nickel in Norway.[100]

Glencore Nikkelverk AS

Glencore Nikkelverk is located in Kristiansand in Agder. The plant was established as «Kristiansand Nikkeraffineringsverk» in 1910 by a small group of businesspeople and

engineers, including Jacob Børresen, Sam Eyde, Anton Grønningsøter and Viktor Hybinette. The plant has had several different owners after that. Since 2013, it has been a part of the Glencore Group.[101] Glencore is an international industrial group with companies in metals, minerals, energy and agricultural products. The company has 146 000 employees worldwide and is headquartered in Switzerland.[102]

The nickel production in Kristiansand is based on «matte», an intermediate product rich in several valuable elements, which is, in short, mechanically and chemically processed raw materials. As a result, the plant in Kristiansand has developed the production process to manufacture many other products in combination with the production of nickel. This includes cobalt, copper and sulphuric acid.[103] Glencore Nikkelverk produced 92 132 metric tons of nickel in 2019.[104] Moreover, 4 354 tons of cobalt and 21 962 tons of copper as by-products were produced.

Figure 38: Glencore Nikkelverk.[105]

Raw Materials and Material Flow

Glencore Nikkelverk obtains most of the matte for the production from is sister factory Sudbury INO in Canada, which is the main supplier of raw materials to Kristiansand. In addition, Glencore has a raw material business that works internationally outside Canada and provides additional raw material for Glencore Nikkelverk. For many years, this raw material business had an agreement with a mining company in Botswana for the supply of raw materials to the Glencore Nikkelverk. However, the company in Botswana ceased operations in 2016 and since then no raw material has arrived in accordance with this agreement to Kristiansand.[104]

The process at the plant in Kristiansand starts with the raw material being crushed to a fine powder and transported to a chlorine leach plant. The metals of the raw material are separated from each other by means of chlorine in hydrochloric acid and distributed to different process areas for purification and refining. These different process areas treat solid materials, gaseous and liquids. After this, the products are sent for finishing treatment, cutting and packaging before being shipped to the world market.[103] Figure 39 shows a flow chart of the production process at Glencore Nikkelverk.

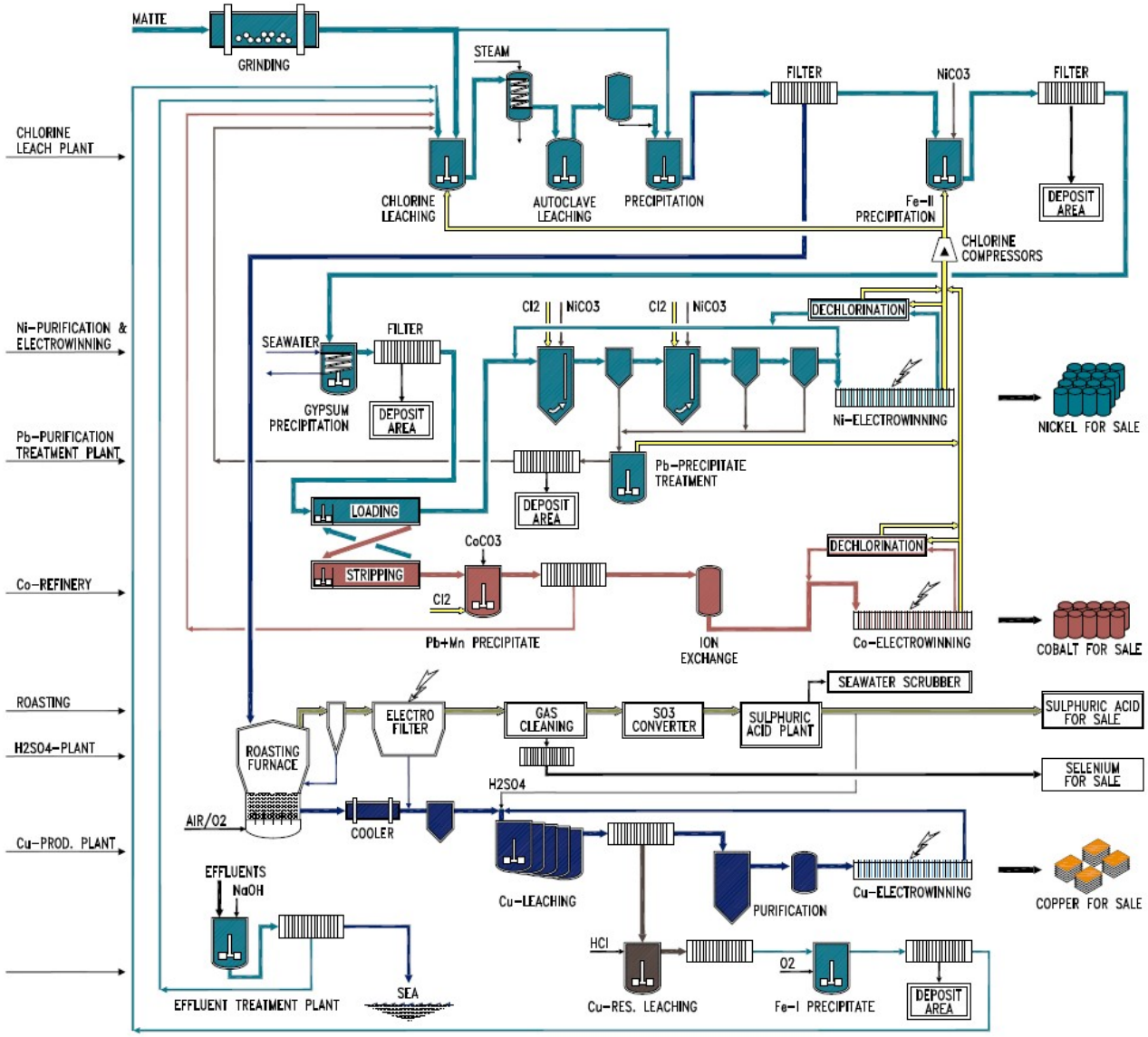

Figure 39: Flow chart of the production process at Glencore Nikkelverk.[106]

Zinc

Zinc has atomic number 30 and is a group 12 element in the periodic system. It is a base metal and does not occur in its pure form in nature. The chief ore of zinc is the mineral (Zn,Fe)S, which is called sphalerite or zinc blende.

About 40% of all zinc produced is used for corrosion protection. This is done by galvanizing iron and steel. Zinc is applied by dipping objects in molten zinc, by electrolysis, spraying or using zinc-rich paint. Another wide application of zinc is in various alloys, especially in brass. It is also used in batteries, as reductant, in the production of paint pigments and in catalysts. Whether it is used in construction materials or in coatings, it is highly recyclable. There is one manufacturer of zinc in Norway.[107]

Boliden Odda AS

New Boliden is a Swedish company founded in the village of Boliden during the gold rush in Skellefteå in the 1920s. The company has about 5 800 employees with mining and smelting operations in Sweden, Norway, Finland and Ireland. Boliden is one of the world's leading zinc manufacturers and a leading company in the production of copper and nickel in Europe.[108]

Boliden's operations in Norway consists of a zinc plant in Odda, shown in Figure 40. The municipality of Ullensvang in Hordaland. Odda is known as an industrial municipality with both Boliden and TiZir Titanium and Iron located there. The zinc plant has 290 employees and produced about 195 000 metric tons of zinc in 2019.[109] In addition to that, sulphuric acid is produced at Boliden Odda. The plant was first established in 1924 as Det Norske Zinkkompani A/S by the French Belgian mining company Compagnie Royale Asturienne des Mines but has been part of Boliden since 2004.[110]

Figure 40: Boliden Odda.[111]

Raw Materials and Material Flow

About 60% of the raw material for the production at Boliden Odda comes from Boliden's own mines in Europe. The rest are purchased internationally. The supply varies cyclically, and the price variation follows the same pattern, according to where the bottleneck in the cycle is. Boliden has always had access to raw materials.[112]

Boliden uses two different types of raw material; sulphidic and oxidic zinc. Sulphidic zinc is zinc concentrate extracted from mines. The mines grind and concentrate the zinc minerals by flotation and filtration. Typical concentration of zinc is the range of 50-55%. Boliden Odda consumes about 300 000 metric tons of this annually. Oxidic zinc is recycled zinc and a lot of this comes from steel plants that melt recycled, galvanized steel. Here, the concentration of zinc is typically 65-70% and Boliden Odda consumes approximately 65 000 metric tons annually.[112] See Figure 41 for a rough sketch of the material flow at Boliden Odda.

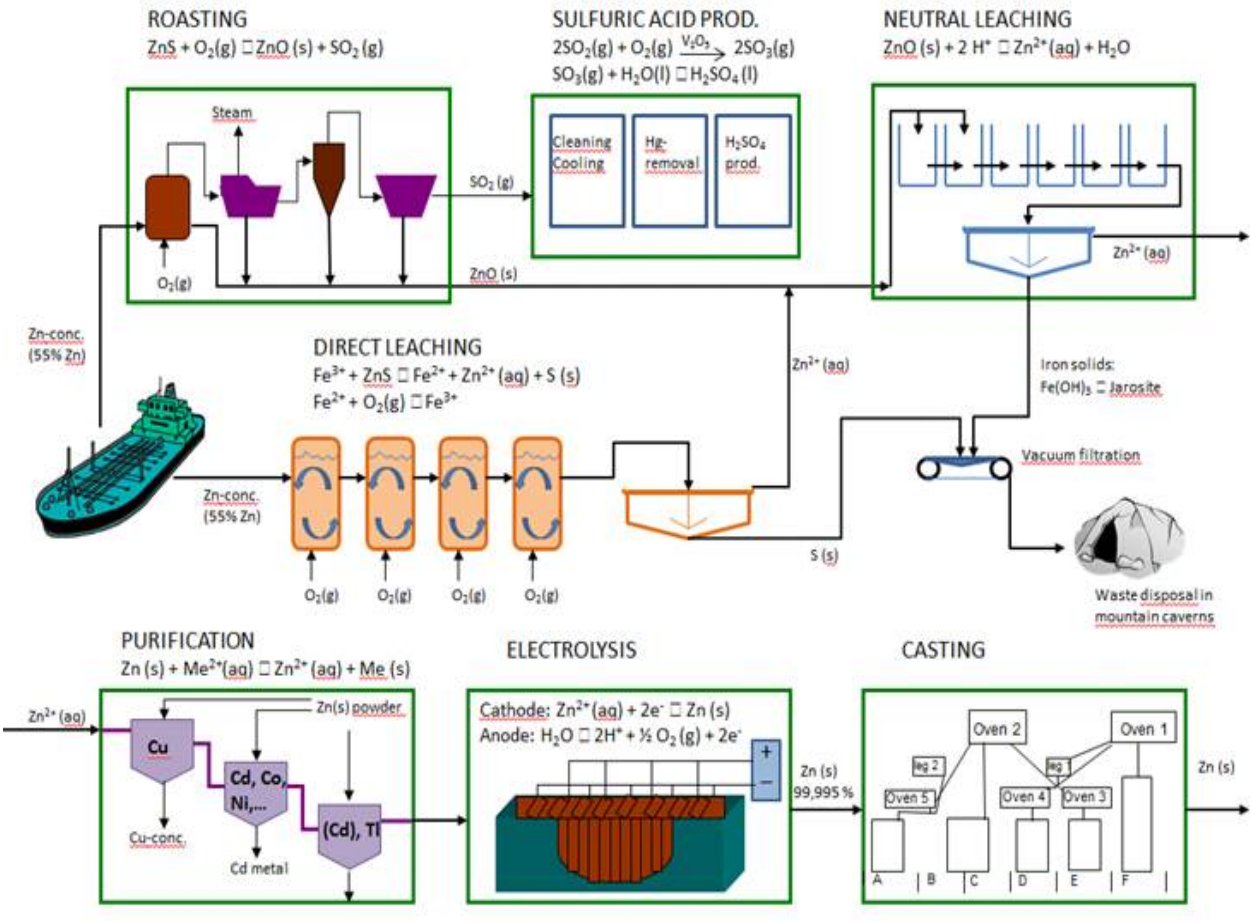

Figure 41: Material flow at Boliden Odda.[113]

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