Horizon 2020 Programme

SCRREEN2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211.

Start date: 2020-11-01 Duration: 36 Months

SCRREEN

Solutions for CRitical Raw materials - a European Expert Network

FACTSHEETS UPDATES **BASED ON THE EU FACTSHEETS 2020**

NICKEL

AUTHOR(S):

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NICKEL

OVERVIEW

Nickel (chemical symbol Ni) is a shiny white metal with typical metallic properties. In nature, it mostly occurs in combined form, and mainly as isotopes of mass number 58 (68%) and 60 (26%). It has a relatively high melting point of 1,455°C and a density of 8.908 g/cm^3. The presence of nickel in the earth's crust is middling, with 47 ppm upper crustal abundance (Rudnick & Gao, 2003). Most nickel deposits of economic importance occur in geological environments of magmatic sulphides and in laterites. Nickel concentrations of sulphide ores, which are the primary source of mined nickel at present, range from 0.15% to around 8% nickel, but 93% of known deposits are in the range 0.2-2% nickel.

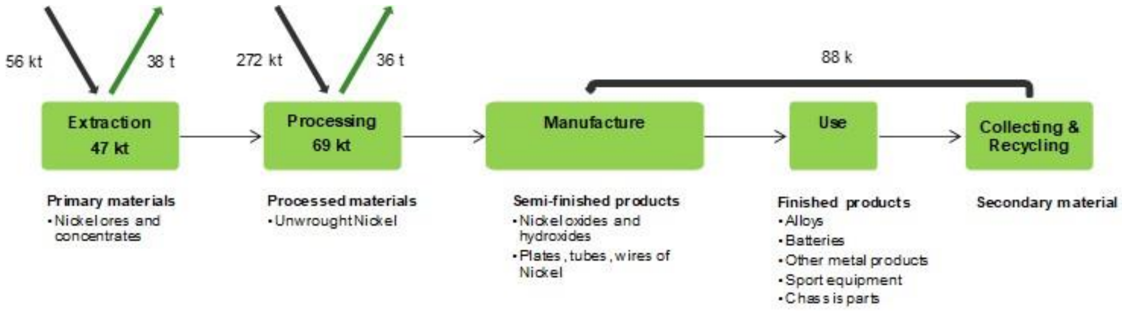

Figure 1. Simplified value chain for nickel in the EU[1]

Table 1. Nickel supply and demand at extraction stage in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
2,331,612	Indonesia 26% Philippines 14% Russia 10% New Caledonia 9% Canada 8% Australia 8%	78,084	3%	Canada 59% South Africa 19% USA 9% Guatemala 6% Norway 3%	31%

Table 2. Nickel supply and demand at processing stage in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
2,143,025	China 33% Indonesia 12% Japan 9% Russia 7% Canada 6% Australia 5%	257,147	12%	Russia 38% Norway 14% Canada 9% Australia 9% Brazil 6% United Kingdom 6%	75%

[1] JRC elaboration on multiple sources (see next sections)

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Prices: The nickel-price dynamics of the 2000s and early 2010s seem quite well explainable by two major factors (cf. Szurlies et al., 2021, INSG, 2021): First, nickel-price growth in the 2000s was driven by the raw-materials boom in China, which was reflected by massive growth in nickel consumption over this period (see the section on global markets). Second, effects of the global financial crisis started materializing in 2007 already, as indicated by stock-market dynamics at that time. The crisis caused a contraction of nickel demand and a phase of over-supply, which was reflected by nickel-price dynamics after 2007.

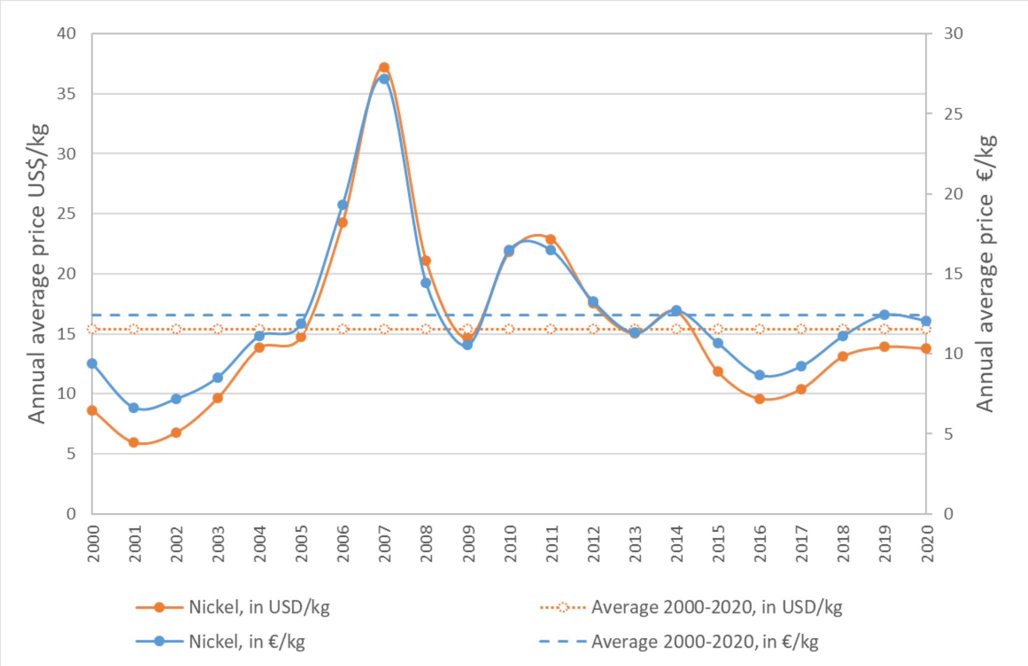

Figure 2. Annual average price of nickel between 2000 and 2020 (USGS, 2021)[2].

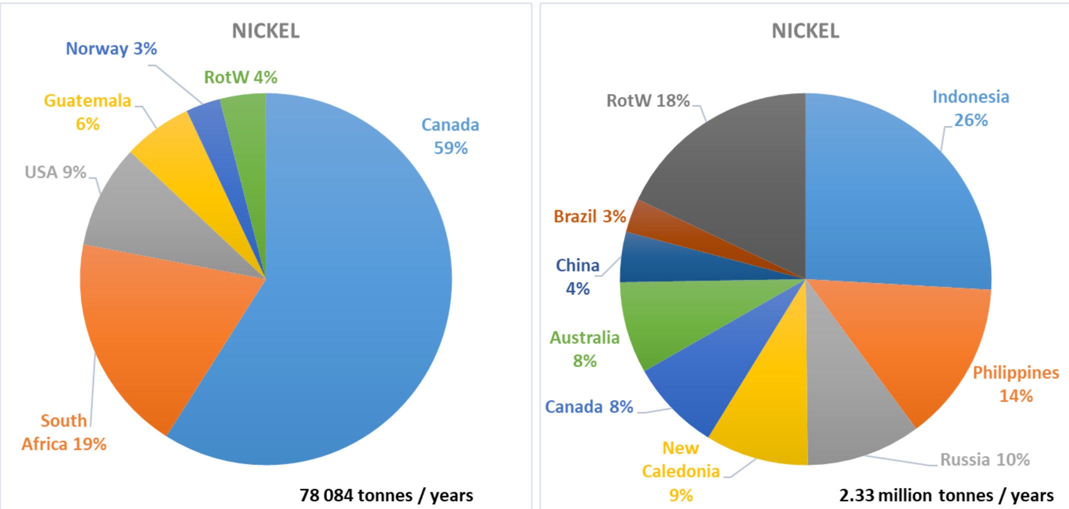

Figure 3. EU sourcing of nickel (Eurostat 2022) and global mine production (WMD 2022), at extraction stage, average 2016-2020

[2] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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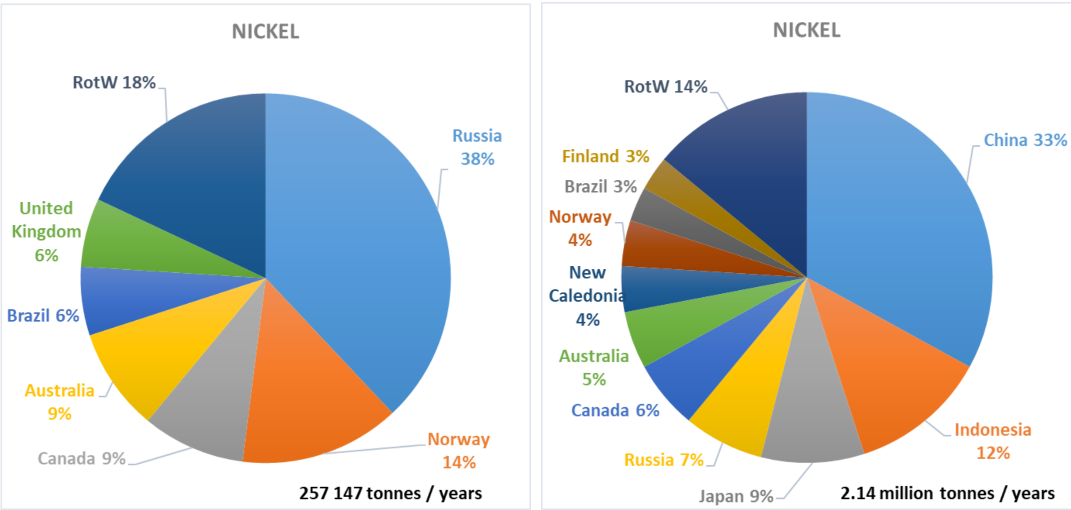

Figure 4. EU sourcing of nickel (Eurostat 2022) and global production (combined references USGS, INSG 2022), at processing stage, average 2016-2020

Primary supply: The global production of nickel ores between 2016 and 2020 was annually 2,332 kt on average. Indonesia and Philippines are the leading producers of nickel ores between 2016 and 2020, (respectively 26% and 14%, which means 613 kt and 327 kt average annual production). They are followed by Russia (10%; 231 kt), New Caledonia (9%, 209 kt), Canada (8%; 198 kt) and Australia (8%; 175 kt).

Secondary supply: Nickel can be recycled without loss of quality and sourced as secondary raw material to be used in many of its applications; large tonnages of secondary or "scrap" nickel are currently used to supplement newly mined ores (INSG, 2018; Nickel Institute, 2018). In 2016, from the total amount leaving the use phase more than 186kt of nickel were collected and sorted for recycling. Functional recycling recovers 81 kt Ni to the internal EU market (Matos et al, 2020)

Uses: Nickel is mainly used to produce different stainless and alloy steels. Furthermore, it is used for superalloys and plating for the protection of metal goods. Additionally, the battery sector gets a more and more important sector for nickel demand, as nickel is used in some cathode materials for lithium-ion-batteries.

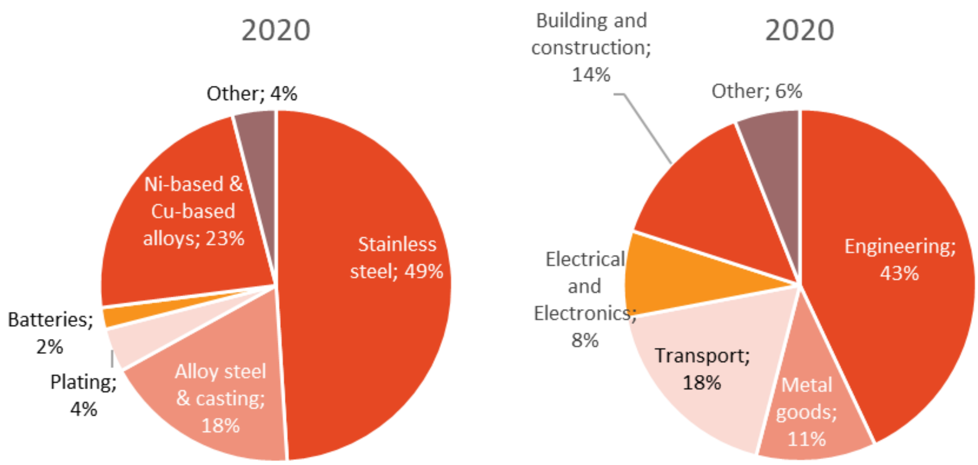

Figure 5: EU first uses (left) and end-uses (right) of nickel

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Substitution: Substitution of nickel is possible in both metal products and batteries.

Table 3. Uses and possible substitutes

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Engineering (industrial)	20%	Ferritic stainless steel (Cr, Mn, Mo)	20%	Similar or lower	Reduced
Engineering (machinery & equipment)	20%	Ferritic stainless steel (Cr, Mn, Mo)	20%	Similar or lower	Reduced
Transportation (motor vehicles)	8%	Ferritic stainless steel (Cr, Mn, Mo)	33%	Similar or lower	Reduced
	8%	Ni free plating solutions (Co, Zn, Cd, Cr)	19%	Slightly higher (up to 2 times)	Reduced
	8%	Other alloys (Ti, W, V)	32%	Very high (more than 2 times)	Reduced
Transportation (other transport equipment)	10%	Ferritic stainless steel (Cr, Mn, Mo)	33%	Similar or lower	Reduced
	10%	Ni free plating solutions (Co, Zn, Cd, Cr)	19%	Slightly higher (up to 2 times)	Reduced
	10%	Other alloys (Ti, W, V)	32%	Very high (more than 2 times)	Reduced
Building and construction	10%	Ferritic stainless steel (Cr, Mn, Mo)	61%	Similar or lower	Reduced
	10%	**Aluminium**	**31%**	**Similar or lower**	**Similar**
Electro and electronics (electronic)	6%	Ferritic stainless steel (Cr, Mn, Mo)	56%	Similar or lower	Reduced
	6%	**Aluminium**	**28%**	**Similar or lower**	**Similar**
	6%	Ni free plating solutions (Co, Zn, Cd, Cr)	16%	Similar or lower	Reduced
Electro and electronics (electrical)	6%	Ferritic stainless steel (Cr, Mn, Mo)	56%	Similar or lower	Reduced
	6%	**Aluminium**	**28%**	**Similar or lower**	**Similar**
	6%	Ni free plating solutions (Co, Zn, Cd, Cr)	16%	Similar or lower	Reduced
Metal goods	21%	Ferritic stainless steel (Cr, Mn, Mo)	86%	Similar or lower	Reduced
	21%	**Titanium (medical devices)**	**5%**	**Slightly higher (up to 2 times)**	**Similar**
Batteries (portable, mobility, e-bikes, industrial)	1%	Ni free Li battery technologies (Li, Fe, P, Al, Mn, Co)	50%	Similar or lower	Reduced
	1%	Ni free batteries (Zn, Pb)	50%	Similar or lower	Reduced

* Percentage for Europe in 2016 = Estimated end use shares of nickel (outputs of SCRREEN Experts Validation Workshop 2022)

Other issues: The impacts of nickel and nickel compounds on human health depend on the physical-chemical structure, amount, duration, and route of exposure to the substance. Humans are exposed to this metal very often since it is present in foodstuff, water and air. The riskiest route of exposure is inhalation (Ronchi et al.,

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2020). An increase in nickel demand and limited reserves of nickel sulphide ore is fostering the sourcing from laterite, arising environmental concerns given that this process requires higher temperatures and thus is more energy intensive. Hydrometallurgy is a promising alternative which would reduce energy consumption and GHG emissions. While this method is not yet common in industrial applications this could change in the following years since laterite also contains cobalt, whose demand is increasing and may incentivise hydrometallurgical methods (Stankovic, S. 2020). There are several responsible sourcing programs developed by the Nickel Institute (NI) member companies – many of these programs are based on the OECD Due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas (OECD DDG). (NI 2023). Moreover, the NI has joined a few associations (eg. ILA, IMOA, IZA etc.) in publishing a Joint Due Diligence Standard for copper, lead, molybdenum, nickel and zinc. It builds on existing standards and looks to provide flexibility for multi-metal producers to include any associated metal products of their site(s) as needed.

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

Table 4 Nickel supply and demand at extraction stage, in metric tonnes nickel content, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
2,331,612	Indonesia 26% Philippines 14% Russia 10% New Caledonia 9% Canada 8% Australia 8%	78,084	3%	Canada 59% South Africa 19% USA 9% Guatemala 6% Norway 3%	31%

Table 5 Nickel supply and demand at processing stage, in metric tonnes nickel content, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
2,143,025	China 33% Indonesia 12% Japan 9% Russia 7% Canada 6% Australia 5%	257,147	12%	Russia 38% Norway 14% Canada 9% Australia 9% Brazil 6% United Kingdom 6%	75%

Since the 1990s, nickel supply (at extraction stage) has grown at an annual rate of 5.7% on average, but growth has slowed down to 3.1% in the last decade (Szurlies et al., 2021). In the present, the global primary nickel production is ca. 2.3 million tonnes (see Table 1).

While in the early 1990s, Russia and Canada were the largest nickel suppliers globally (USGS, 1996), Indonesia and Philippines are major suppliers today accounting for 606291 tonnes, and 326438 tonnes, respectively. Key company-level actors at the nickel (metal) market include Norilsk Nickel, Jinchuan Group, Glencore and Vale (Szurlies et al., 2021).

The strong nickel-supply growth over the last decades has been driven by strong nickel-*demand* growth in China. In the 1990s, China's share in global consumption was rather marginal. Today, China and Asia in general are by far the largest nickel consumers (INSG, 2021; Szurlies et al., 2021). The major fields of application of nickel are stainless steel (71%), non-ferrous alloys (10%), plating (6%), batteries (5%) and other (8%) – the numbers in parentheses indicate the demand shares in 2019 (Szurlies et al., 2021; cf. INSG, 2021, Nickel Institute, 2021, NORNICKEL, 2021).

There is 'free-market' trade for nickel in form of, e.g., cathodes, pellets, briquettes. Nickel in these forms is traded at London Metal Exchange. Corresponding price indices are published. Nickel market has been affected significantly by the Covid and Ukraine crises (see the discussion in the section on price and price volatility).

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OUTLOOK FOR SUPPLY AND DEMAND

In the longer run, nickel demand and nickel supply are expected to grow, driven by applications in stainless steel, batteries and energy transition (European Commission, 2020; SCRREEN, 2022). Since the effects of the Covid and Ukraine crises have had significant impacts on nickel-market dynamics in the past, the uncertainty about future development of these crises poses corresponding limits to the outlook (cf. SCRREEN, 2022).

EU TRADE

Table 6 Relevant Eurostat CN trade codes for nickel

		Processing/refining	
CN trade code	**title**	**CN trade code**	**Title**
2604 00 00	Nickel ores and concentrates	**2825 40 00**	Nickel oxides and hydroxides
		2827 35 00	Nickel chloride
		2833 24 00	Nickel sulphate
		7202 60 00	Ferro-nickel
		7501 10 00	Nickel mattes
		7502 10 00	Unwrought nickel: Nickel, not alloyed
		7502 20 00	Unwrought nickel: Nickel, alloyed
		7504 00 00	Nickel powders and flakes

Figure 6 Figure 7 Figure 8 Figure 9 Figure 10 Figure 11 Figure 12 Figure 13 Figure 14 show the EU trade flows of nickel compounds between 2000 and 2020. The EU was a net importer of nickel compounds, except for nickel chloride and sulphate.

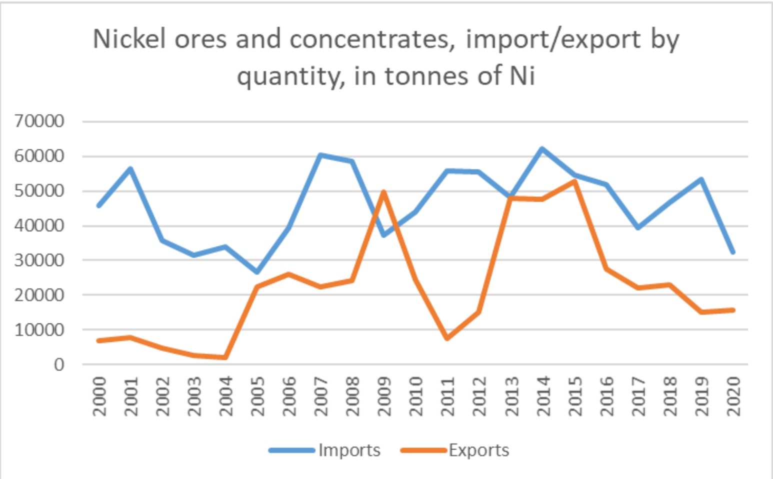

Figure 6 EU trade flows of nickel in tonnes (Nickel ores and concentrates - CN 2604 00 00 – Nickel content 20 %) from 2000 to 2020 (Eurostat, 2022)

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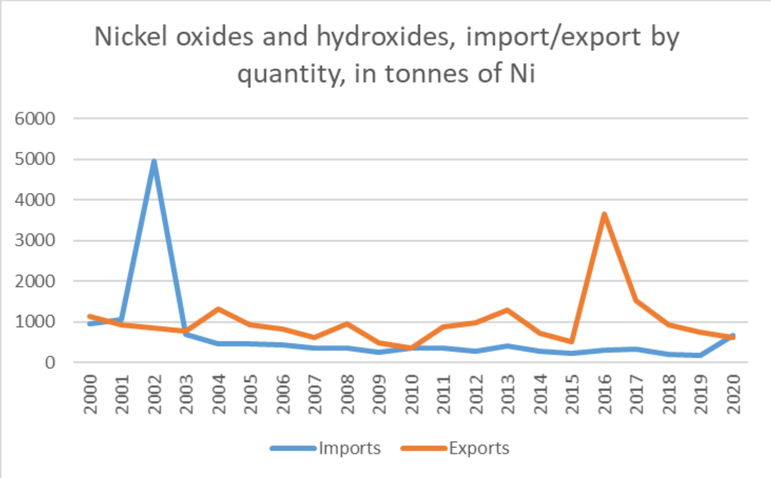

Figure 7 EU trade flows of nickel in tonnes (Nickel oxides and hydroxides - CN 2825 40 00 – Nickel content 67 %) from 2000 to 2020 (Eurostat, 2022)

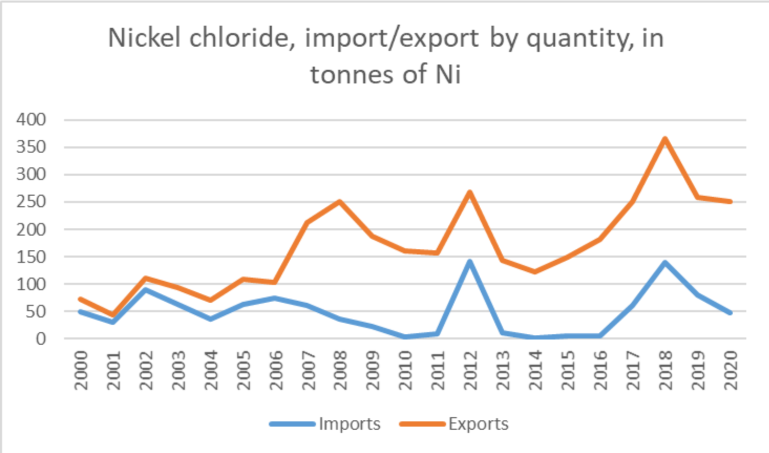

Figure 8 EU trade flows of nickel in tonnes (Nickel chlorides - CN 2827 35 00– Nickel content 25 %) from 2000 to 2020 (Eurostat, 2022)

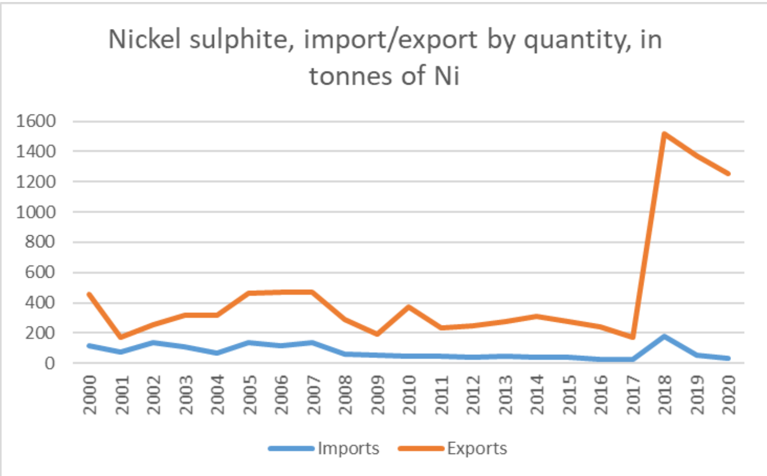

Figure 9 EU trade flows of nickel in tonnes (Nickel sulphites - CN 2833 24 00 -– Nickel content 5 %) from 2000 to 2020 (Eurostat, 2022)

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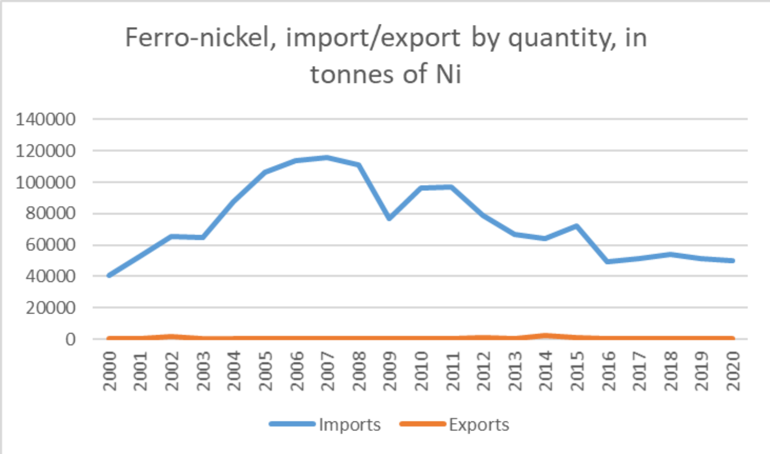

Figure 10 EU trade flows of nickel in tonnes (Ferro-nickel - CN 7202 60 00 – Nickel content 25 %) from 2000 to 2020 (Eurostat, 2022)

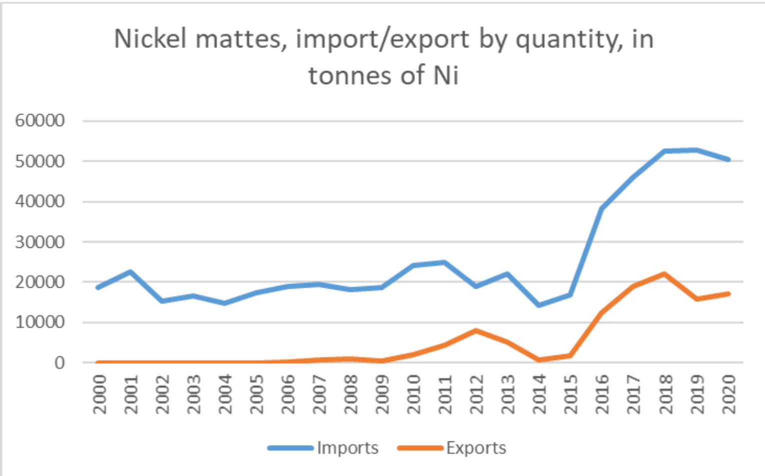

Figure 11 EU trade flows of nickel in tonnes (Nickel mattes - CN 7501 10 00 – Nickel content 45 %) from 2000 to 2020 (Eurostat, 2022)

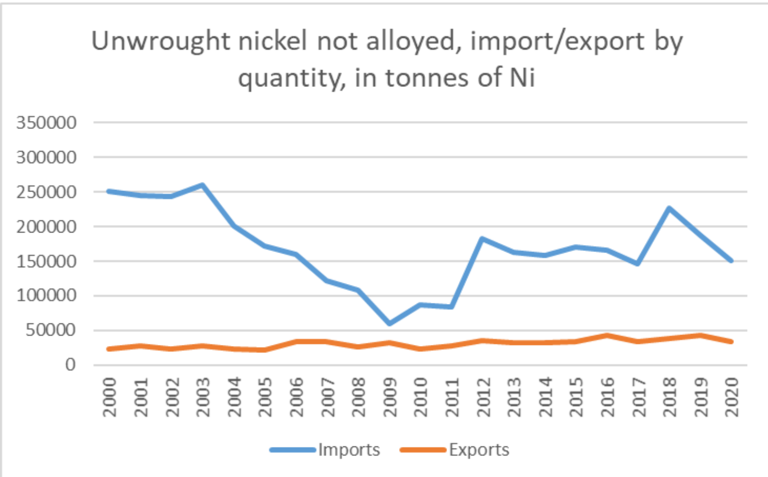

Figure 12 EU trade flows of nickel in tonnes (Unwrought nickel, not alloyed - CN 7502 10 00 – Nickel content 100 %) from 2000 to 2020 (Eurostat, 2022)

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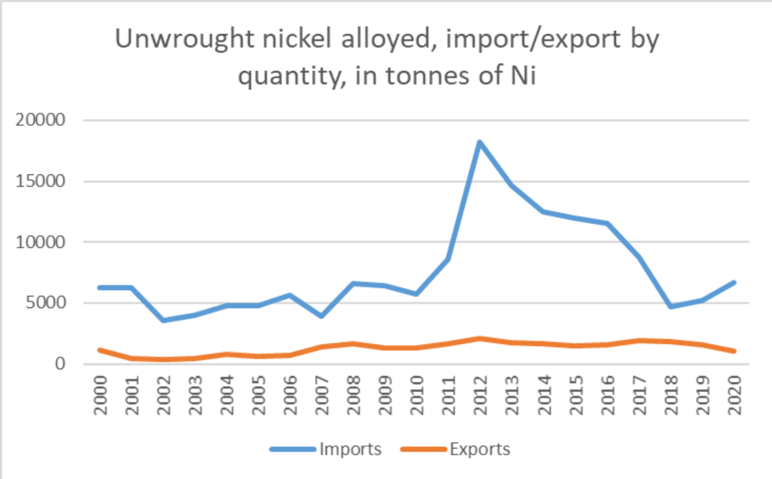

Figure 13 EU trade flows of nickel in tonnes (Unwrought nickel, alloyed - CN 7502 20 00 – Nickel content 50 %) from 2000 to 2020 (Eurostat, 2022)

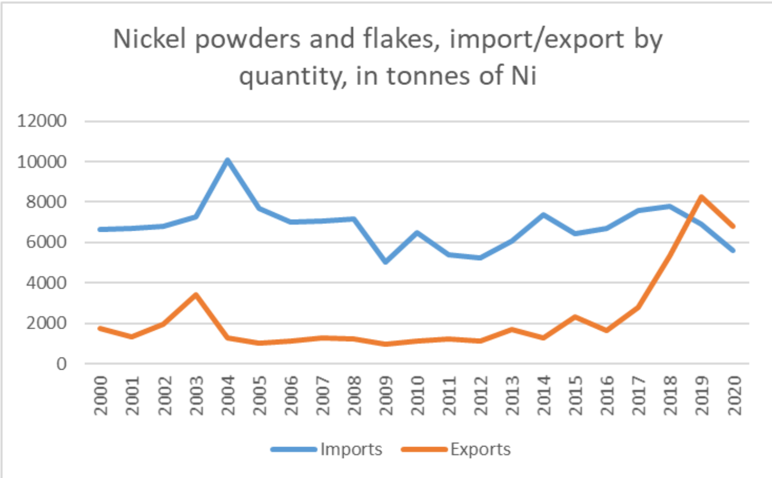

Figure 14 EU trade flows of nickel in tonnes (Nickel powders and flakes - CN 7504 00 00 – Nickel content 100 %) from 2000 to 2020 (Eurostat, 2022)

Figure 15 Figure 16 Figure 17 Figure 18 Figure 19 Figure 20 Figure 21 Figure 22 Figure 23 indicate the EU imports of nickel compounds by country between 2000 and 2021. In this period, the EU main suppliers of nickel compounds were China, Russia, US, UK, Canada, and Japan. Between 2018 and 2021, there were significant changes in the shares of the EU nickel imports, in which Taiwan, Brazil, South Africa, and the Philippines were the main suppliers of nickel oxide and hydroxide, ferro-nickel, nickel sulphite, nickel chloride, respectively.

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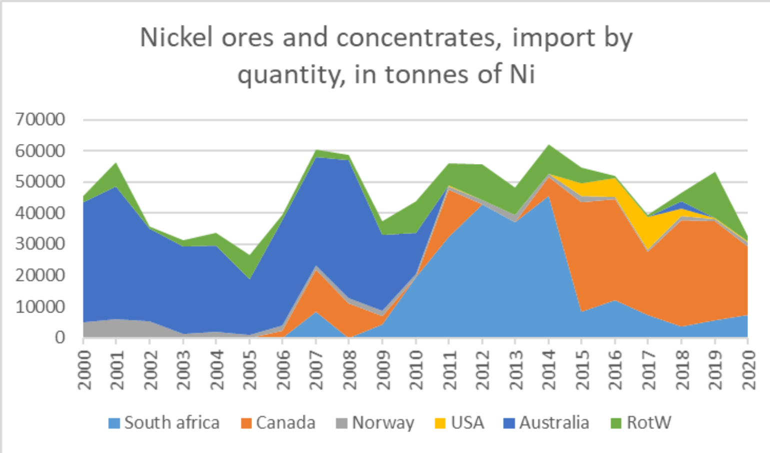

Figure 15 EU imports of nickel in tonnes (Nickel ores and concentrates - CN 2604 00 00 – Nickel content 20 %) by country from 2000 to 2020 (Eurostat, 2022)

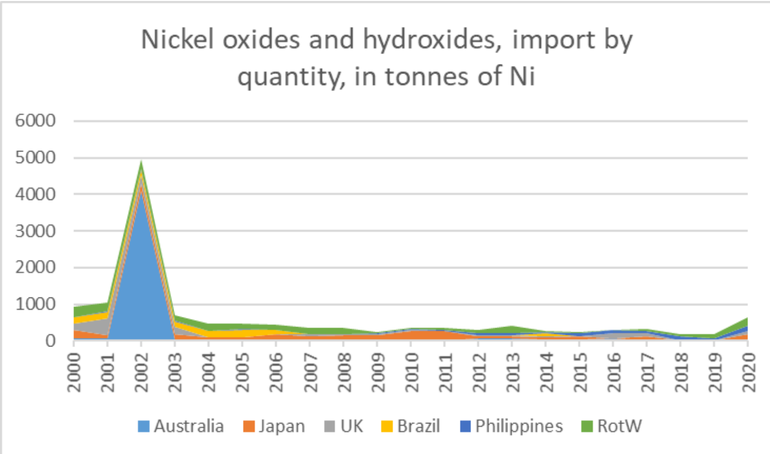

Figure 16 EU imports of nickel in tonnes (Nickel oxides and hydroxides - CN 2825 40 00 – Nickel content 67 %) by country from 2000 to 2020 (Eurostat, 2022)

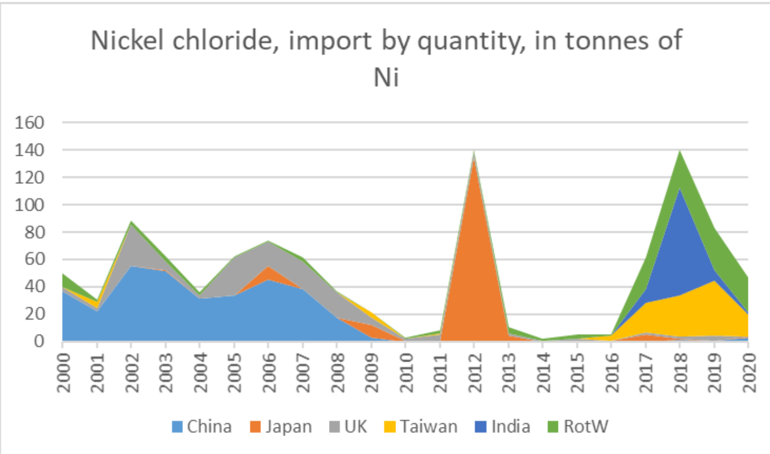

Figure 17 EU imports of nickel in tonnes (Nickel chlorides - CN 2827 35 00 – Nickel content 25 %) by country from 2000 to 2020 (Eurostat, 2022)

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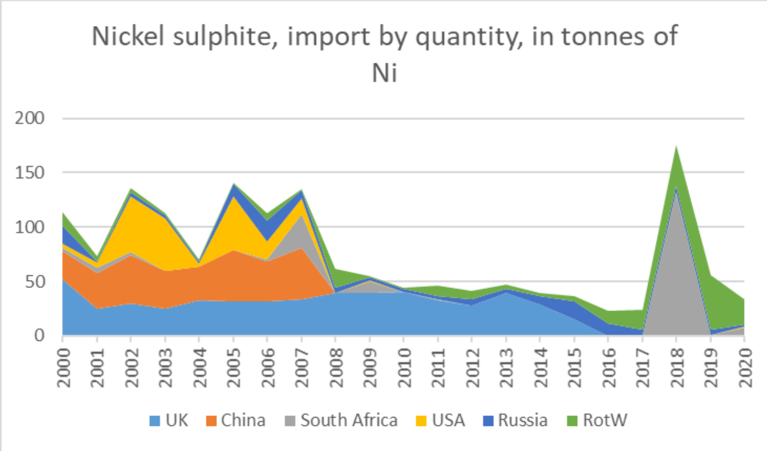

Figure 18 EU imports of nickel in tonnes (Nickel sulphites - CN 2833 24 00 – Nickel content 5 %) by country from 2000 to 2020 (Eurostat, 2022)

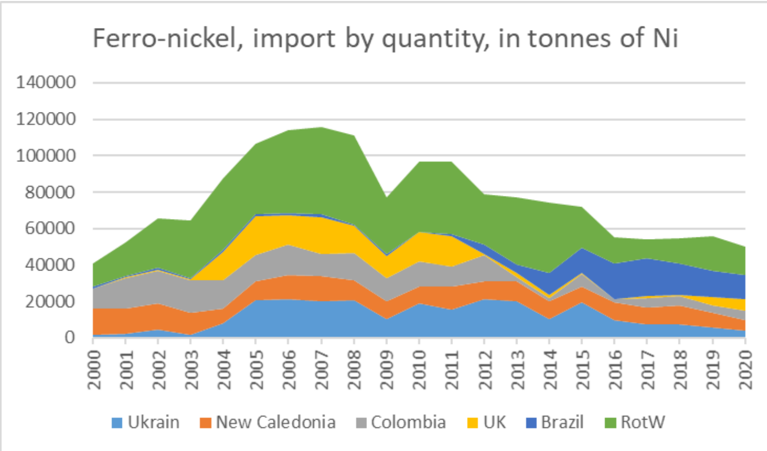

Figure 19 EU imports of nickel in tonnes (Ferro-nickel - CN 7202 60 00 – Nickel content 25 %) by country from 2000 to 2020 (Eurostat, 2022)

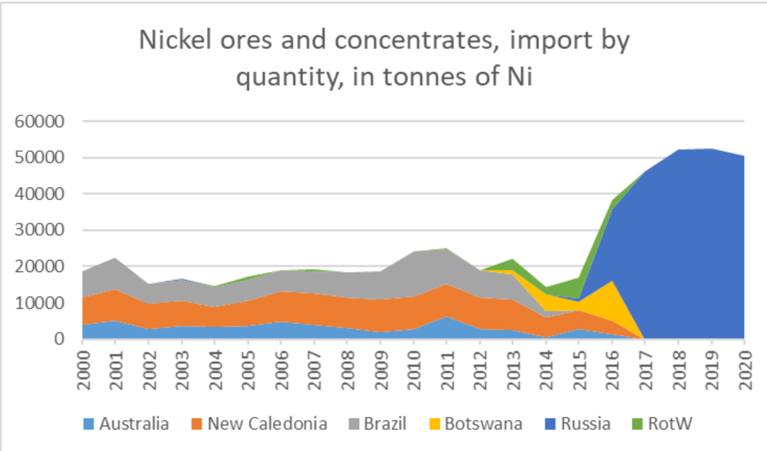

Figure 20 EU imports of nickel in tonnes (Nickel mattes - CN 7501 10 00 – Nickel content 45 %) by country from 2000 to 2020 (Eurostat, 2022)

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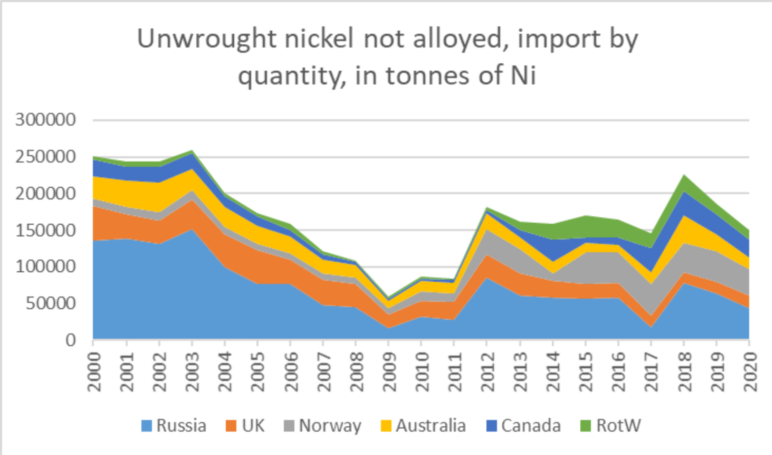

Figure 21 EU imports of nickel in tonnes (Unwrought nickel, not alloyed - CN 7502 10 00 – Nickel content 100 %) by country from 2000 to 2020 (Eurostat, 2022)

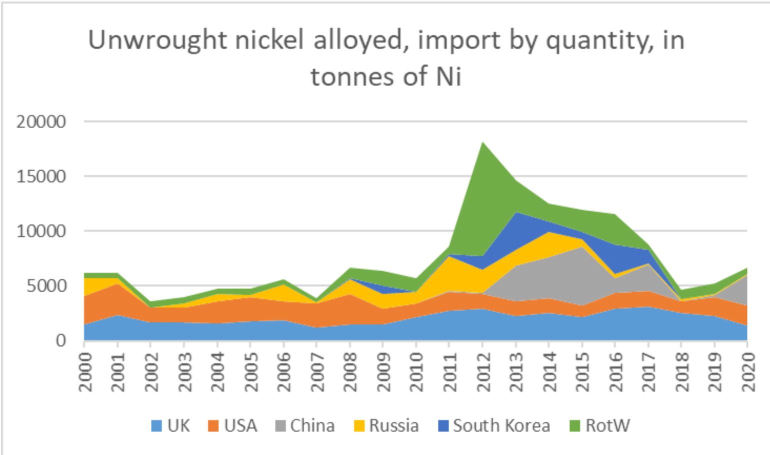

Figure 22 EU imports of nickel in tonnes (Unwrought nickel, alloyed - CN 7502 20 00 – Nickel content 50 %) by country from 2000 to 2020 (Eurostat, 2022)

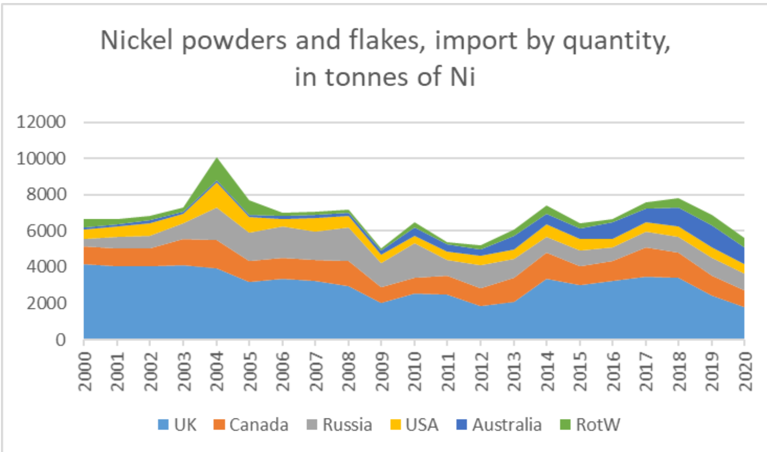

Figure 23 EU imports of nickel in tonnes (Nickel powders and flakes - CN 7504 00 00 – Nickel content 100 %) by country from 2000 to 2020 (Eurostat, 2022)

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PRICE AND PRICE VOLATILITY

The nickel-price dynamics of the 2000s and early 2010s seem quite well explainable by two major factors (cf. Szurlies et al., 2021, INSG, 2021): First, nickel-price growth in the 2000s was driven by the raw-materials boom in China, which was reflected by massive growth in nickel consumption over this period (see the section on global markets). Second, effects of the global financial crisis started materializing in 2007 already, as indicated by stock-market dynamics at that time. The crisis caused a contraction of nickel demand and a phase of over-supply, which was reflected by nickel-price dynamics after 2007.

Events that caused price fluctuations over the 2010s up to now include nickel-export bans (and their ease) in Indonesia, nickel supply disruptions in Philippines due to mine suspensions for environmental reasons, expectations of increased nickel demand for electro mobility, Covid crisis and Ukraine crisis (DERA, 2022a; Reuters, 2016; Szurlies et al., 2021; USGS, 2022). While the Covid crisis caused nickel-demand contractions (INSG, 2021; USGS, 2022), the Ukraine crisis was associated with a massive jump in nickel price and even a nickel-trade cancelling at London Metal Exchange (cf. DERA, 2022a).

In the period 2017-2021, the volatility of the nickel cash price at London Metal Exchange was 22%, as indicated by the measure of standard deviation of logarithmic return calculated by DERA (2022b).

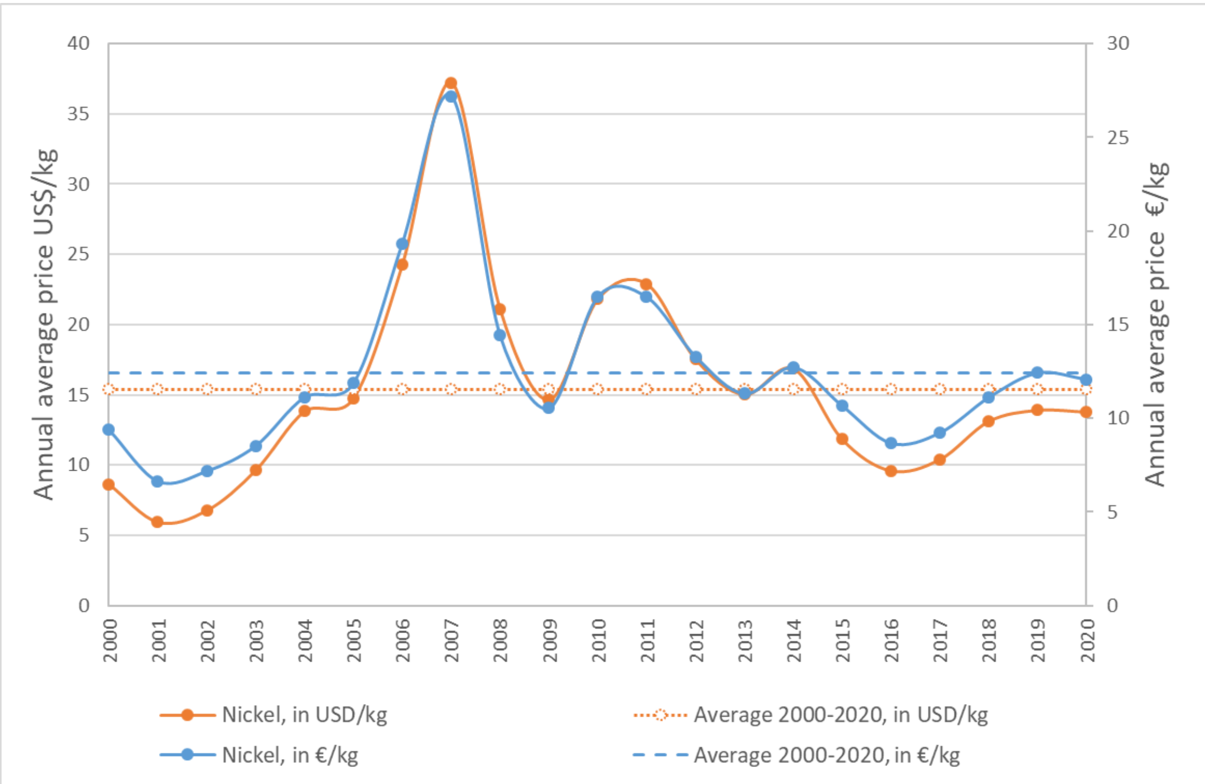

Figure 24 Annual average cash price of nickel at London Metal Exchange (LME), between 2000 and 2020, in US$/kg and €/kg.[3] Source: USGS, 2004, 2007, 2010, 2013, 2016, 2019, 2022.

[3] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html).

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DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

Following the global financial crisis, world nickel consumption accelerated from 2010 to exceed 2,200 kt in 2017 (INSG, 2018).

The annual average EU consumption of nickel metal between 2015 and 2018 was stable, around 300 kt (INSG, 2018; Glencore, 2018) (329 kt based on Statista, 2018).

Nickel extraction stage EU consumption is presented by HS code CN 2604 Nickel ores and concentrates. Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from Eurostat Prodcom (2022a) using PRCCODE 7291200.

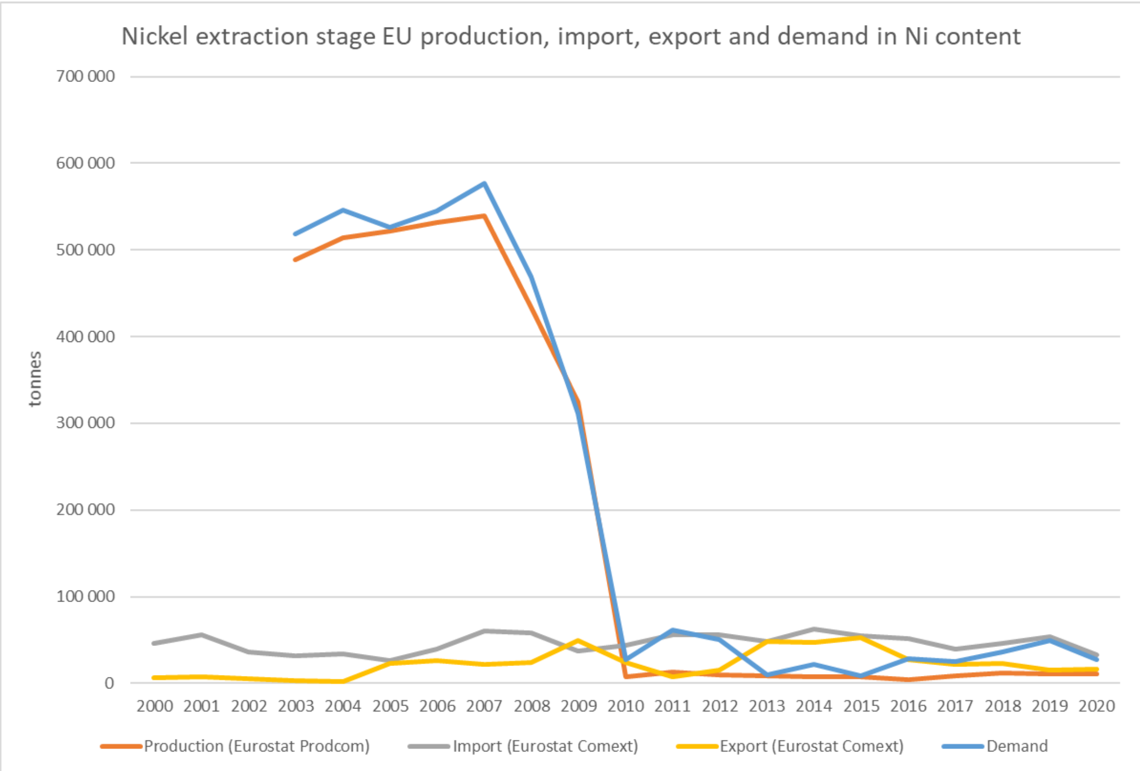

Figure 25. Nickel (CN 2604 Nickel ores and concentrates) extraction stage apparent EU consumption. Production data is available from Eurostat Prodcom (2021a) for 2003-2020. Consumption is calculated in nickel content (EU production+import-export).

Based on Eurostat comext (2022) and Eurostat Prodcom (2022a) average import reliance of nickel at extraction stage is 39.2 % for 2003-2020. However, the average import reliance for 2016-2020 is 71.3 %.

Nickel processing stage EU consumption is presented by HS codes CN 75011000 Nickel mattes, CN 75021000 Nickel unwrought, not alloyed, CN 75022000 Unwrought nickel, alloyed, CN 75040000 Nickel powders and flakes, CN 28254000 Nickel oxides and hydroxides, CN 28273500 Nickel chloride, CN 28332400 Nickel sulphate

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and CN 72026000 Ferro-nickel. Import and export data are extracted from Eurostat Comext (2022). Production data is extracted from Eurostat Prodcom (2022b) using PRCCODE 24451110 Nickel unwrought, not alloyed, 24451120 Unwrought Nickel, alloyed, 24452100 Nickel powders and flakes, 20121965 Nickel oxides and hydroxides, 20133132 Nickel chloride, 20134161 Nickel sulphate and 24101240 Ferro-nickel.

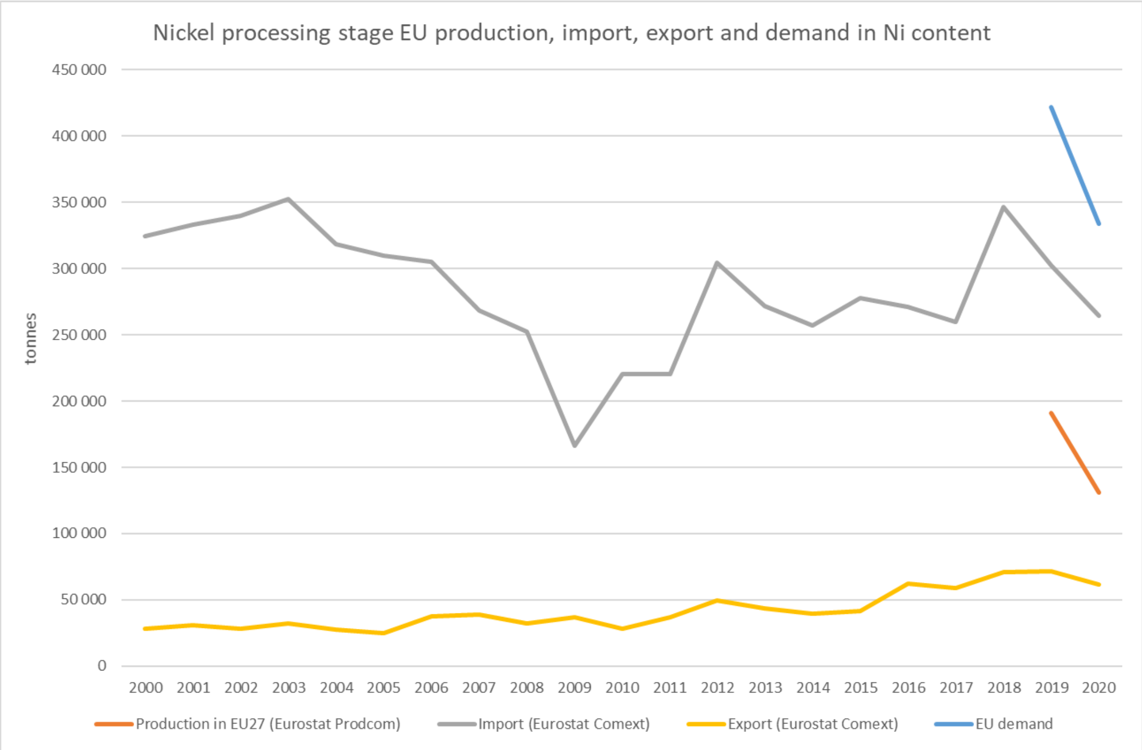

Figure 26. Limestone (CN 75011000, CN 75021000, CN 75022000, CN 75040000, CN 28254000, CN 28273500, CN 28332400and CN 72026000) processing stage apparent EU consumption. Production data from Eurostat Prodcom (2022b) is available for 2003-2020. Production data is represented by sold production (Eurostat Prodcom 2022b). Production data for nickel unwrought, not alloyed, unwrought nickel, alloyed, nickel oxides and hydroxides, nickel chloride, nickel sulphate and ferro-nickel only available for 2019-2020 from Eurostat Prodcom (2022b). Production data for nickel powders and flakes is available for 2008-2020 from Eurostat Prodcom (2022b), however the production averages only 3 000 tonnes annually for 2008-2020. Consumption is calculated in nickel content (EU production+import-export).

Based on Eurostat comext (2022) and Eurostat Prodcom (2022a and 2022b) average import reliance of nickel at processing stage is 53.8 % for 2019-2020.

GLOBAL AND EU USES AND END-USES

Nickel is mainly used to produce different stainless and alloy steels. Furthermore, it is used for superalloys and plating for the protection of metal goods. Additionally, the battery sector has a growing impact on nickel demand, as nickel is used in some cathode materials for lithium-ion-batteries.

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The distribution of nickel used for these first uses is shown in Figure 27 for the world and in Figure 28 for Europe.

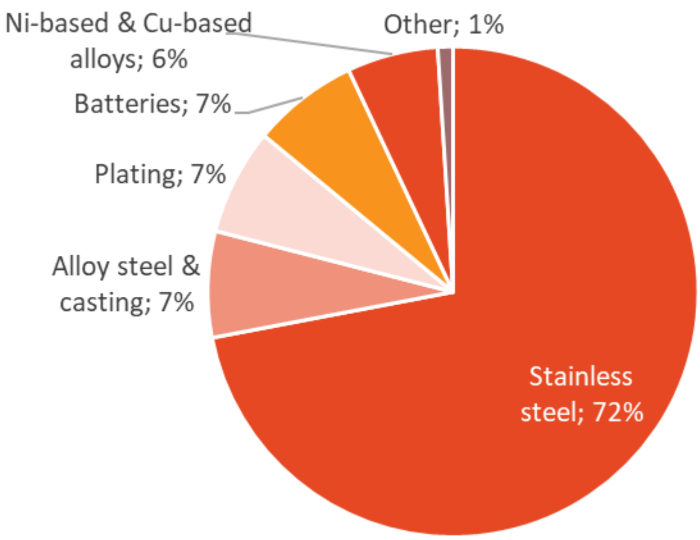

Figure 27 Global first uses of nickel in 2020 (Nickel Institute (2022) based on data by Roskill)

Figure 28 shows the development of the first-use production in Europe from 2010 to 2020. The use of nickel for batteries appears to have come up within this timeframe and lies with 2 % below the global share of 7 % (Nickel Institute, 2022).

The share of nickel used for all kinds of alloys increased within this decade, while stainless steel and plating applications decreased in proportion.

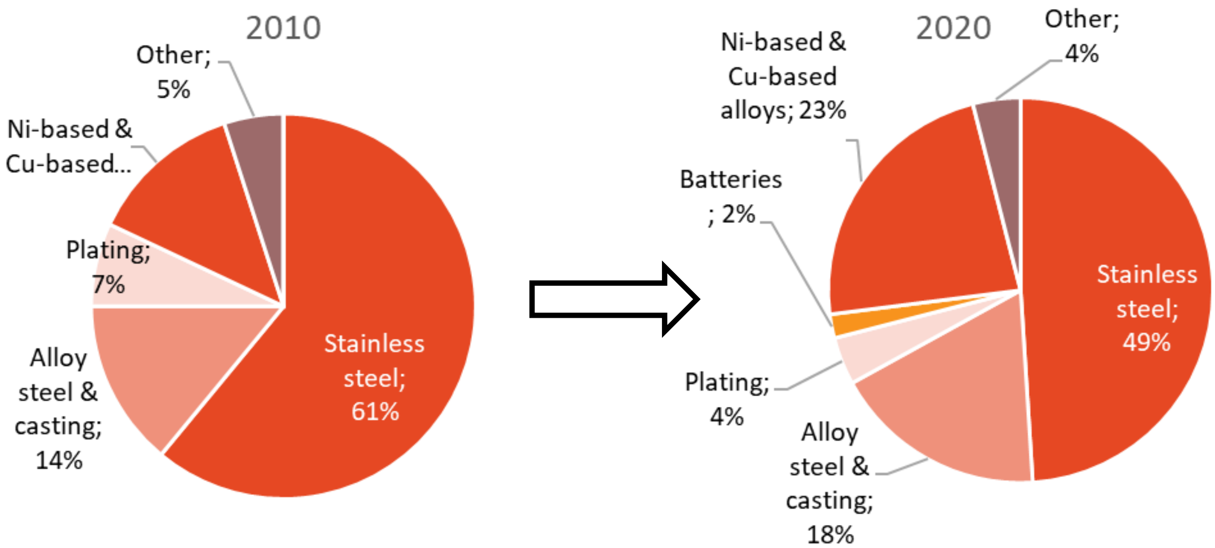

Figure 28 European first uses of nickel in 2010 on the left side (Nickel Institute (2012)) and in 2020 on the right side (Nickel Institute (2022) based on data by Roskill).

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The first uses of nickel are applied in different end use sectors as shown in Figure 28 for the world and Figure 30 for Europe.

The steel products are mainly used as building and construction material, tubes, machinery and metal goods, transportation, electrical and electronic, engineering, and consumer and other products.

Nickel-based alloys and nickel–containing stainless steels have a key role in renewable energy technologies, e.g. thermal solar plants.

It is used in hydropower, geothermal energy plants and wave energy technologies. Nickel is needed to prevent degradation especially in systems with high operating temperatures (Nickel Institute, 2018).

Nickel-containing batteries are used for electric vehicles (transportation), electronic goods like mobile phones but also for stationary power storage.

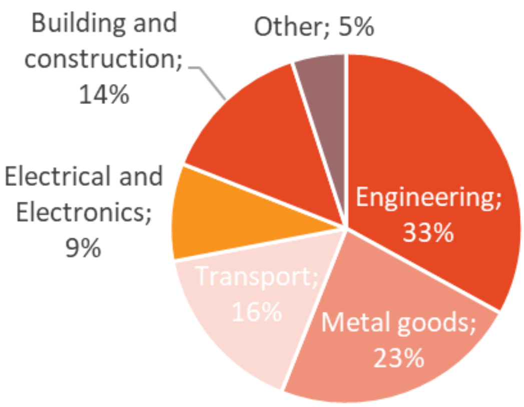

Figure 29 Global end uses of nickel in 2020 (Nickel Institute (2022) based on data by Roskill)

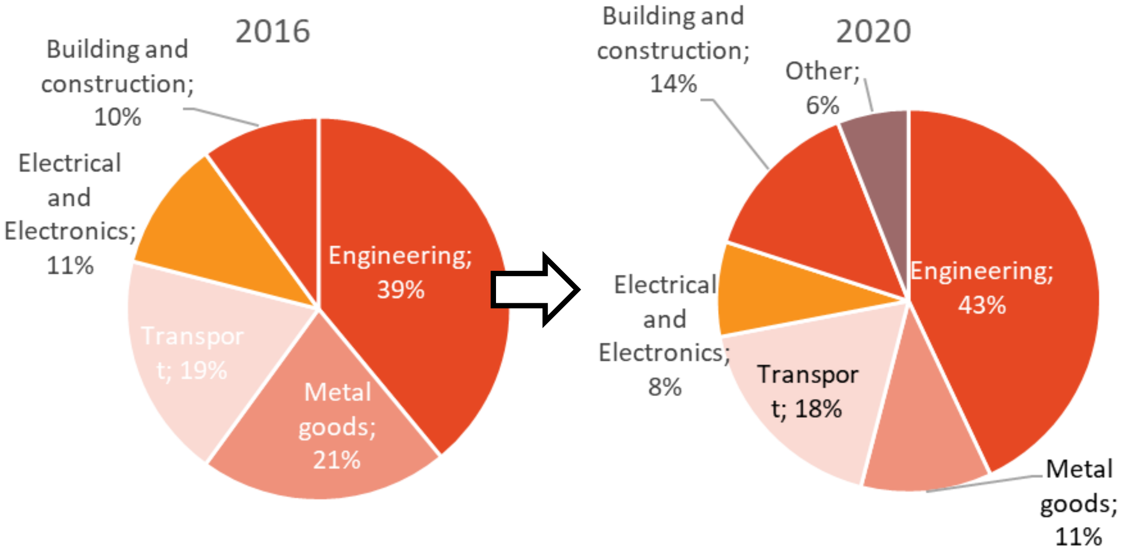

Figure 30 European end uses of nickel in 2016 (European Commission 2020, based on data by Nickel Institute and Eurometaux) and in 2020 (Nickel Institute (2022) based on data by Roskill)

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Table 7 Nickel applications, 2-digit and examples of associated 4-digit NACE sectors, and value-added per sector for 2018 (* for 2014) (Eurostat, 2021).

Applications	2-digit NACE sector	Value added of NACE 2 sector (M€)	4-digit CPA
Transport (Steel)	C30 - Manufacture of other transport equipment	49,098*	C30.1.1 - Building of ships and floating structures; C30.2.0 - Manufacture of railway locomotives and rolling stock; C30.3.0 - Manufacture of air and spacecraft and related machinery; C30.9 - Manufacture of transport equipment n.e.c.
Electrical and Electronics (Steel)	C27 - Manufacture of electrical equipment	98,417	C27.2.0 - Manufacture of batteries and accumulators; C27.5.1 - Manufacture of electric domestic appliances; C26.1.1 - Manufacture of electronic components
Engineering (Steel)	C28 - Manufacture of machinery and equipment n.e.c.	200,030*	C28.1 - Manufacture of general-purpose machinery; C28.2 - Manufacture of other general-purpose machinery; C28.9.3 - Manufacture of machinery for food, beverage and tobacco processing ; C28.9.5 - Manufacture of machinery for paper and paperboard production; C25.9.2 - Manufacture of light metal packaging
Building and construction (Steel)	C25 - Manufacture of fabricated metal products, except machinery and equipment	183,016	C25.1.1 - Manufacture of metal structures and parts of structures; C25.1.2 - Manufacture of doors and windows of metal; C25.2.1 - Manufacture of central heating radiators and boilers; C25.2.9 - Manufacture of other tanks, reservoirs and containers of metal
Metal goods (Steel)	C24 - Manufacture of basic metals	71,391	

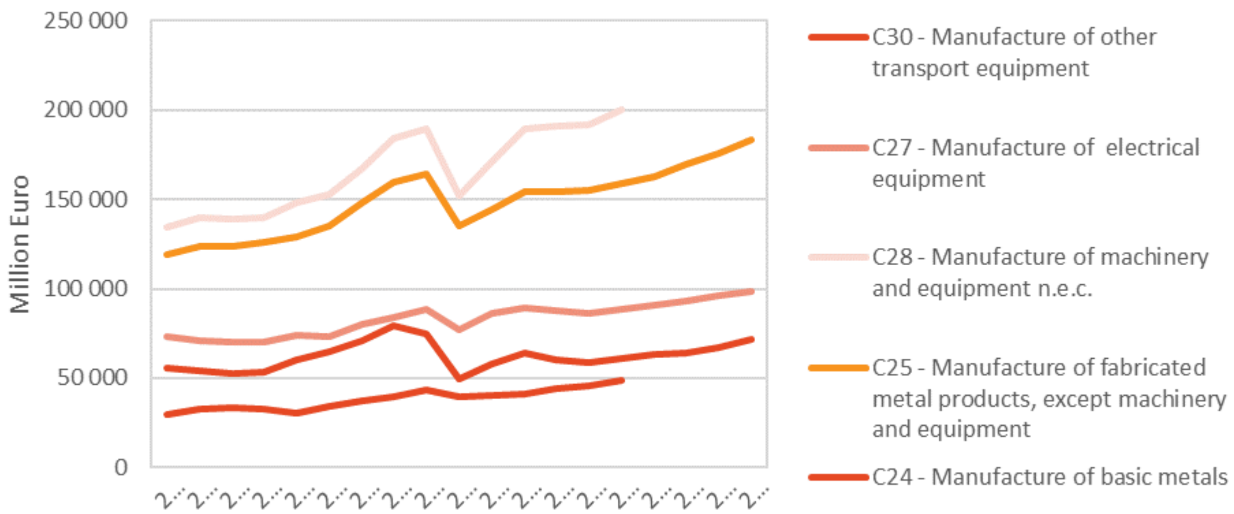

Figure 31 Value added per 2-digit NACE sector over time (Eurostat, 2021).

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APPLICATIONS OF NICKEL

STAINLESS STEEL

Nickel increases stainless steel's formability and weldability, ensures resistance against acids, and enhances corrosion resistance.

The addition of nickel (8-10%) results in the most important class of corrosion- and heat-resistant steels (Nickel Institute, 2018). Stainless steel is used for kitchen sinks, laundry equipment, furniture, and tableware.

In the construction and machinery sector, nickel-containing stainless steel is used (for example) in railway cars and road tank trailers (Kerfoot 2012).

The resistance against corrosion and acids makes stainless steel a widely used material in the chemical industry.

ALLOY STEEL

Nickel is used in other steel alloys to improve the hardness, malleability, and closeness of grain. Nickel based alloys also have very useful low expansion characteristics which make them well suited for applications where extreme temperatures are required (Nickel Institute, 2018).

NON-FERROUS ALLOYS

Nickel is used in non-ferrous alloys like nickel or copper-based alloys. The most common, cupronickel, is used extensively in coins to improve corrosion resistance.

Its adjustable electrode potential enables seawater resistance, most important in the marine industry and for desalination plants.

Other non-ferrous alloys are nickel-titanium memory alloys, which can revertto their original shape without undergoing plastic deformation under stress and super-alloys for power generation, aerospace and military applications (Nickel Institute, 2018).

PLATING

Thin layers of nickel are used in plating to increase corrosion and wear resistance, especially in medical equipment, construction materials and cosmetic applications such as cutlery and domestic fittings.

Nickel plating is used in the manufacture of computer hard discs and optical storage media (Nickel Institute, 2018).

Nickel-plated parts are used for bicycles, motorcycles, jewellery, eyeglass frames, and musical instruments (Kerfoot 2012).

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BATTERIES

Nickel use in the battery sector is increasing and is expected to increase more rapidly in coming years (CRM experts, 2022), mainly related to the fast development of Li-ion batteries for the automotive sector and the improvement in electrical energy storage systems (Nickel Institute, 2018).

Nickel is used for the cathode materials Lithium Nickel Manganese Cobalt Oxide (NMC) as well as Lithium Nickel Cobalt Aluminium Oxide (NCA), while the cathode materials Lithium Manganese Oxide (LMO) and Lithium Iron Phosphate (LFP) do not use Nickel (Marscheider-Weidemann 2021).

Li-ion based battery technologies contain up to 0,725 kg/kWh nickel (Marscheider-Weidemann 2021). These have several applications like electric vehicles, electronic goods and stationary power storage. Beside Li-ion batteries, nickel is used for low-cost rechargeable Nickel Metal Hydride Batteries (NiMH), which become less important over time due to their lower performance and operational capability compared to Li-ion batteries.

FOUNDRY

Foundry products include nickel castings for pumps, valves and fittings.

OTHER

Nickel is used in a wide range of chemical processes, including hydrogenation of vegetable oils, reforming hydrocarbons and production of fertilizers, pesticides and fungicides.

SUBSTITUTION

Substitution of nickel is possible in both metal products and batteries. The options are summed up in Table 8 and described within this chapter.

Table 8 Substitution options for nickel by application.

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Engineering (industrial)	20%	Ferritic stainless steel (Cr, Mn, Mo)	20%	Similar or lower	Reduced
Engineering (machinery & equipment)	20%	Ferritic stainless steel (Cr, Mn, Mo)	20%	Similar or lower	Reduced
Transportation (motor vehicles)	8%	Ferritic stainless steel (Cr, Mn, Mo)	33%	Similar or lower	Reduced
	8%	Ni free plating solutions (Co, Zn, Cd, Cr)	19%	Slightly higher (up to 2 times)	Reduced
	8%	Other alloys (Ti, W, V)	32%	Very high (more than 2 times)	Reduced
Transportation	10%	Ferritic stainless steel (Cr, Mn, Mo)	33%	Similar or lower	Reduced

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(other transport equipment)	10%	Ni free plating solutions (Co, Zn, Cd, Cr)	19%	Slightly higher (up to 2 times)	Reduced
	10%	Other alloys (Ti, W, V)	32%	Very high (more than 2 times)	Reduced
Building and construction	10%	Ferritic stainless steel (Cr, Mn, Mo)	61%	Similar or lower	Reduced
	10%	**Aluminium**	**31%**	**Similar or lower**	**Similar**
Electro and electronics (electronic)	6%	Ferritic stainless steel (Cr, Mn, Mo)	56%	Similar or lower	Reduced
	6%	**Aluminium**	**28%**	**Similar or lower**	**Similar**
	6%	Ni free plating solutions (Co, Zn, Cd, Cr)	16%	Similar or lower	Reduced
Electro and electronics (electrical)	6%	Ferritic stainless steel (Cr, Mn, Mo)	56%	Similar or lower	Reduced
	6%	**Aluminium**	**28%**	**Similar or lower**	**Similar**
	6%	Ni free plating solutions (Co, Zn, Cd, Cr)	16%	Similar or lower	Reduced
Metal goods	21%	Ferritic stainless steel (Cr, Mn, Mo)	86%	Similar or lower	Reduced
	21%	**Titanium (medical devices)**	**5%**	**Slightly higher (up to 2 times)**	**Similar**
Batteries (portable, mobility, e-bikes, industrial)	1%	Ni free Li battery technologies (Li, Fe, P, Al, Mn, Co)	50%	Similar or lower	Reduced
	1%	Ni free batteries (Zn, Pb)	50%	Similar or lower	Reduced

* Percentage for Europe in 2016 = Estimated end use shares of nickel (EU MSA 2020 ; outputs of SCRREEN Experts Validation Workshop 2022)

METAL PRODUCTS

Substitutes are possible for nickel used in metal products such as plates, tubes, beams etc.. Titanium, chromium, manganese and cobalt are mentioned as substitutes for nickel as alloying element (Karhu et al., 2016).

This also holds true for applications processing these materials such as machinery, leisure goods, medical equipment and specific building materials (doors, windows etc.). However, those alternatives usually have a higher cost or occur with adverse impacts on performance.

BATTERIES

Li-ion batteries drive the main demand for nickel in battery sector.

Several Li-ion technologies contain nickel such as NMC (Lithium Nickel Manganese Cobalt Oxide) which is growing in automotive and energy storage applications, or the NCA (Lithium Nickel Cobalt Aluminium Oxide).

In batteries for electric vehicles, these types of batteries use respectively 33% and 80% of nickel, and in NMC chemistries, higher percentages are expected in the near future (Nickel Institute. 2019). Within these cell chemistries, cobalt can be a substitution for nickel. The true market tendency is reversing due to prices, so that the trend is to decrease the amounts of cobalt and substitute it by nickel. There are increasing concerns regarding cobalt prices and availability, which in turn leads to the production and development of low cobalt batteries and, as a result, high-nickel content. Future chemistries are envisaged with even higher nickel content than the existing ones e.g. the newly proposed NMC 9.5.5 battery (with 9 parts of nickel, and 0.5 of cobalt and manganese) (Azevedo et al., 2018) (Zubi et al., 2018).

Non-nickel containing cell chemistries such as LMO (Lithium Manganese Oxide) and LFP (Lithium Iron Phosphate) could be used instead of NMC and NCA but display lower energy densities (Marscheider-Weidemann 2021).

The use of fuel cell electric vehicles could make the application of nickel containing batteries in electric vehicles obsolete.

Further technology by technology substitutions are conceivable for stationary energy storages like redox-flow batteries or similar technologies. The material-for-material substitution for nickel in Nickel Metal Hydride (NiMH) batteries are typically not performed mainly due to performance and costs (Tercero et al., 2013).

SUPPLY

EU SUPPLY CHAIN

Within the EU 2016-2020, nickel was mined on average 54 kt per year corresponding approximately 2% of world's nickel mine production (2,332kt). Finland accounted for 66% (36 kt) of the EU nickel mine production followed by Greece (33%; 18 kt) and with minor share Poland (1%; 723 t) (WMD, 2021). The EU was dependent on nickel oreimports, with an average import reliance for 2016-2020 of 71% (the ratio of net imports (imports minus exports) divided by domestic material consumption (Eurostat, 2022).

From 2016 to 2020, EU production of refined nickel amounted on average to 161 kt (in Ni content) per year (Eurostat, 2021). Between 2016 and 2020, the world smelter/refinery production of nickel was 2,298 kt per year, mainly supplied by China (30%; 701 kt). The leading supplier in the EU is Finland (89 kt), followed by Greece (14 kt) and France (5 kt) (British Geological Survey, 2022).

Table 9 Relevant Eurostat production codes for nickel

Mining		Processing/refining	
HS code	**title**	**HS code**	**title**
CN2604	Nickel ores and concentrates	CN75021000	Nickel unwrought, not alloyed
		CN75022000	Unwrought nickel, alloyed
		CN75040000	Nickel powders and flakes
		CN28254000	Nickel oxides and hydroxid4es
		CN28273500	Nickel chloride
		CN28332400	Nickel sulphate
		CN72026000	Ferro-nickel
		Prodcom code	**title**

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	24451110	Nickel unwrought, not alloyed
	24451120	Unwrought nickel, alloyed
	24452100	Nickel powders and flakes
	20121965	Nickel oxides and hydroxides
	20133132	Nickel chloride
	20134161	Nickel sulphate
	24101240	Ferro-nickel

Nickel can be recycled without loss of quality and sourced as secondary raw material. In 2016, the collection rate for nickel was 73%, the end-of-life recycling rate (EoL-RR) was 42% and end-of-life recycling input rate (EoL-RIR) was 16%. A considerable fraction of secondary nickel collected for recycling isexported from the EU. (Matos et al, 2020)

SUPPLY FROM PRIMARY MATERIALS

GEOLOGY, RESOURCES AND RESERVES OF NICKEL

GEOLOGY

The presence of nickel in the earth's crust is middling, with 47 ppm upper crustal abundance (Rudnick & Gao, 2003). Most nickel deposits of economic importance occur in geological environments of magmatic sulphides and in laterites. Nickel concentrations of sulphide ores, which are the primary source of mined nickel at present, range from 0.15% to around 8% nickel, but 93% of known deposits are in the range 0.2-2% nickel. The most important nickel sulphide mineral is pentlandite [$(Fe,Ni)_9S_8$], which occurs mainly in iron- and magnesium-rich igneous rocks in Russia, South Africa, Canada and Australia.

Lateritic ores, with an average nickel content of 1-1.6%, are formed by (sub)tropical surface weathering of ultramafic rocks. Their main nickel-bearing minerals are garnierite (general name for Ni-Mg hydrosilicates) and nickeliferous limonite [(Fe,Ni)O(OH)], occurring in New Caledonia (France), Indonesia, Columbia and Greece (Bide et al., 2008). There are 3 types of lateritic deposits: limonite type, silicate type and oxide type, corresponding to the different horizons (layers) of the deposits; the silicate one showing the highest Ni content (around 1.8-2.5%). Despite accounting for around 70% of global Ni deposits, lateritic ores constitute only 40% of the current world production (Jébrak and Marcoux, 2008).

According to the Minerals4EU website, some exploration for nickel was carried out in Greenland, the UK, Sweden, Sapin, Portugal, Poland, Ukraine and Kosovo (Minerals4EU, 2019). Currently, an extensive exploration of nickel is taking place in Finland (GTK, 2019).

GLOBAL RESOURCES AND RESERVES

According to USGS, identified land-based resources averaging 1% nickel or greater contain at least 130 million tonnes of nickel, with about 60% in laterites and 40% in sulphide deposits (USGS, 2019). Extensive nickel resources are found in manganese crusts and nodules on the ocean floor. The decline in discovery of new sulphide deposits in traditional mining districts has led to exploration in more challenging locations such as

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east-central Africa and the Subarctic. The USGS reports over 95 million tonnes of world known nickel reserves (USGS, 2022). The global reserves are largely reported in Indonesia, Brazil, and Australia.

Table 10. Global reserves of nickel in 2020 (USGS, 2022)

Country	Nickel reserves (million tonnes)
Finland	NA
New Caledonia	---
United States	340,000
Indonesia	21,000,000
Australia	21,000,000
Brazil	16,000,000
Russian Federation	7,500,000
Other Countries	6,500,000
Cuba	5,500,000
Philippines	4,800,000
South Africa	3,700,000
China	2,800,000
Canada	2,000,000
Guatemala	1,800,000
Madagascar	1,600,000
Colombia	440,000
World total (rounded)	*>95,000,000*

EU RESOURCES AND RESERVES

Resource data for some Countries in Europe are available in the Minerals4EU website (Minerals4EU, 2019) but cannot be summed as they are partial and they do not use the same reporting code.

Table 11. Reserve data for the EU compiled in the European Minerals Yearbook of the Minerals4EU website (Minerals4EU, 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Resource Type
Spain	NI43-101	1.132	kt	0.6%	Proven
Finland	NI43-101 JORC	0.1 1.5	Mt Mt	0.59% 0.32%	Proven Proved
Ukraine	Russian Classification	15.007	kt	-	RUS(A)
Macedonia	Ex-Yugoslavian	5,600	kt	0.96%	(RUS)B
Kosovo	Nat. rep. code	8,812.5	kt	1.22%	(RUS)A
Turkey	JORC	29.7	Mt	1.13%	Proved

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GLOBAL AND EU MINE PRODUCTION

The global production of nickel ores between 2016 and 2020 was annually 2,332 kt on average. Indonesia and Philippines are the leading producers of nickel ores between 2016 and 2020, (respectively 26% and 14%, which means 613 kt and 327 kt average annual production). They are followed by Russia (10%; 231 kt), Canada (9%; 198 kt) and Australia (8%; 175 kt).

With an annual production of 54 kt (2016-2020), the EU accounted for 2% of the world's nickel mine production. Finland attributed over 66% of the EU production (38 kt), followed by Greece (33%; 18 kt), and Poland (1%; 723 t). There was no nickel production reported anymore from Spain for years 2016-2020.

Figure 32 displays mine production of nickel for the period 1984-2020 according to WMD (2022)

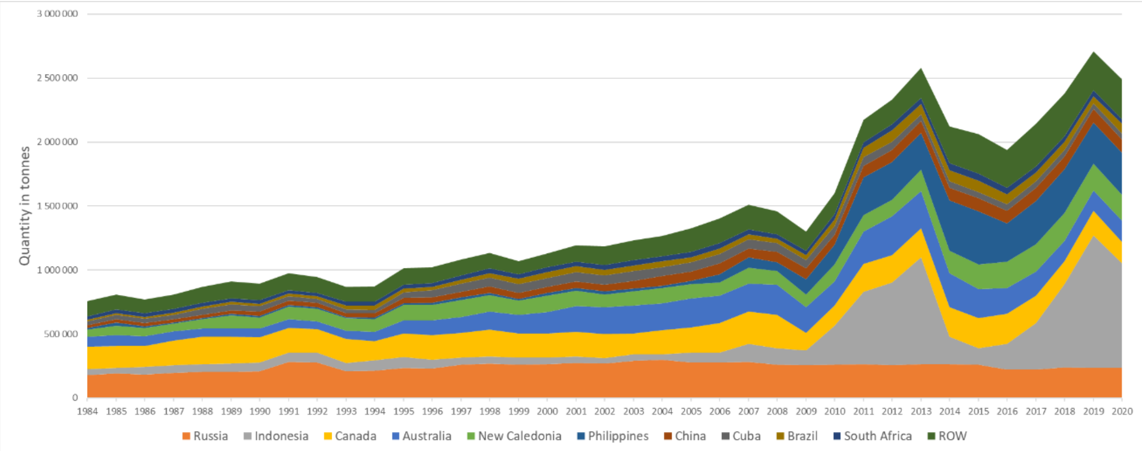

Figure 32 Top ten global nickel producers and the rest of the world (ROW) for the period 1984-2020 (WMD, 2022)

OUTLOOK FOR SUPPLY

Following Russia's military aggression of Ukraine, the uncertainty in international commodity markets of non-food, non-energy (NFNE) raw materials has ramped up with significant and immediate implications in the EU and worldwide. The list of NFNE raw materials identified as having high import value and share in total EU imports comprises products required for strategic EU value chains (e.g., PGM for the automotive industry, titanium metal for aerospace applications, electrical steel for electric motors, nickel metal for superalloys in turbines and batteries) (European Commission, 2022).

PROCESSING

Ore beneficiation comprises the metal concentration and refining of the nickel ores, to ultimately obtain nickel matte. The specific processes depend on whether the ore is a sulphide or a laterite.

- Sulphide ores processing: After ore crushing, sulphide ores which typically contain several sulphur-bearing minerals such as chalcopyrite and pyrrhotite undergo magnetic separation in order to remove pyrrhotite-bearing particles. A two-step flotation is then performed on the non-magnetic concentrate.

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The first stage is designed to remove copper concentrate, and the second stage produces a Ni concentrate of approximately 10-20% Ni after dewatering and thickening processes. The magnetic concentrate is further grinded to liberate Ni-bearing particles and goes through another flotation process.

Refining process is subsequently applied to the final Ni concentrate (containing up to 25% Ni), using a pyrometallurgical or hydrometallurgical route. Nickel hydrometallurgy is commonly performed using ammonia leach process. Other leaching processes use chlorine or acid leaching. The metal is then recovered in the solution by applying electrowinning. For the pyrometallurgical stages, the reaction of oxygen with iron and sulphur in the ore supplies a portion of the heat required for smelting (Brittanica, 2009). The choice of the refining route is dependent on several factors such as the maximum amount of impurities allowed in the matte, the energy efficiency ratio, etc.

- Lateritic ores processing: Lateritic (oxide) ores have fewer options for treatment and are mostly dried and smelted in furnaces. Hydrometallurgy can also be applied to the limonitic lateritic oresusing the Caron Process (selective reduction combined with ammonia leaching) or the Pressure Acid Leaching (heating of slurried ore)

Various processes are used to refine nickel matte, depending on the type of the ore the matte came from. These processes include hydrogen reduction (ammonia pressure leach), roasting to produce high-grade nickel oxides that are then pressure leached before electrowinning or refining through the carbonyl process. The carbonyl process can be used to produce high-purity nickel pellets. In this process, copper and precious metals remain as a pyrophoric residue that requires separate treatment. Electro-winning, in which nickel is removed from solution in cells equipped with inert anodes, is the more common refining process. Sulphuric acid solutions or, less commonly, chloride electrolytes are used (WBG, 1998).

Primary nickel is produced and used in the form of ferronickel, nickel oxides and other chemicals, and as nickel metal with a concentration of over 90% (Class I if Ni content higher than 99%. This is used in batteries). Ferronickel (15-45% of nickel content) predominantly originates from lateritic ores which is converted into an impure product. In the recent years, production of a low grade ferronickel called Nickel Pig Iron (NPI) has boomed almost exclusively in China (2-17% of nickel content). NPI is made of low-grade lateritic nickel ore, coking coal, and a mixture of gravel and sand as an aggregate (Eurofer, 2016).

Between 2016 and 2020, the world smelter/refinery production of nickel was 2,298 kt per year, mainly supplied by China (30%; 701 kt), Indonesia (14%; 330 kt), Japan (8%; 184kt) and Russia (8%; 179 kt). The EU produced less than 4% of the world production. The leading supplier in the EU is Finland (89 kt), followed by Greece (14 kt) and France (5 kt) (British Geological Survey, 2022).

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

POST-CONSUMER RECYCLING (OLD SCRAP)

Nickel can be recycled without loss of quality and sourced as secondary raw material to be used in many of its applications; large tonnages of secondary or "scrap" nickel are currently used to supplement newly mined ores (INSG, 2018; Nickel Institute, 2018). In 2016, from the total amount leaving the use phase more than 186kt of

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nickel were collected and sorted for recycling. Functional recycling recovers 81 kt Ni to the internal EU market (Matos et al, 2020)

There are several enterprises in the EU for recycling of nickel. Major recycling activities of nickel, take place further downstream in the value chain, namely in the stainless steel mills, given that more than 80% of nickel first uses are related to the use as alloying element in stainless steel and other nickel containing alloys. The dominant use of nickel as alloying element in stainless steels and other non-ferrous alloys facilitates collection and recycling. The economic value of nickel metal provides a significant incentive for this. The recycling efficiencies are estimated to be around 68% (Nickel Institute, 2018). Production of stainless steel considers the use of recycled material, including stainless steels and other nickel alloys, mixed turnings, waste from primary nickel producers and re-melted ingot from processing nickel-containing slags, dusts, batteries etc. Although special alloys are recycled as mono-material wherever possible, in practice different alloys and products may get mixed and blending processes are used to maintain quality. For the US and EU, a share of 43% and 45% in the total nickel consumption is reported for recovered nickel (Nickel Institute, 2016).

In 2016, the collection rate for nickel was 73%, and the end-of-life recycling rate was 42%. The ration of recycling from old scrap to the EU demand for nickel, end-of-life recycling input rate, EOL-RIR was 16%. A considerable fraction of secondary nickel collected for recycling is exported from the EU. (Matos et al, 2020)

OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES RELATED TO THE NICKEL OR SPECIFIC/RELEVANT COMPOUDS AT ANY STAGE OF THE LIFE CYCLE

The impacts of nickel and nickel compounds on human health depend on the physical-chemical structure, amount, duration, and route of exposure to the substance. Humans are exposed to this metal very often since it is present in foodstuff, water and air. The riskiest route of exposure is inhalation (Ronchi et al., 2020).

Nickel “damages organs through prolonged or repeated exposure, may cause cancer by inhalation, is toxic to aquatic life with long-lasting effects, may damage fertility, is suspected of causing genetic defects, is suspected of causing cancer, may cause an allergic skin reaction and may cause allergy or asthma symptoms or breathing difficulties if inhaled” (ECHA, 2022). Soluble and insoluble nickel compounds are classified as carcinogenic to humans (group 1) while nickel alloys are classified as possibly carcinogenic (group 2) (IARC, 2012).

According to (WHO, 1991), the most toxic nickel compound is nickel carbonyl. Poisoning by this substance causes headache, vertigo, nausea, vomiting, insomnia, irritability, and pulmonary symptoms like viral pneumonia. Chronic exposure leads to rhinitis, sinusitis, nasal septal perforation, and asthma. 10 % of the female and 1 % of the male global population are sensitive to nickel and, among them, almost one-half have hand eczema or dermatitis caused by contact with the metal.

(WHO, 2022) has set a guideline value for nickel concentration in water for human consumption at 0.07 mg/L. The (Drinking water EU directive, 2020) sets a limit of 20 µg/l for nickel concentration in water for human consumption. A 2022 amendment to the EU carcinogens and mutagens Directive 2004/37/EC sets a new limit

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to occupational exposure to nickel compounds: from year 2025 the 8-hour limit value will be 0.1 mg/m3 for respirable dust and 0.05 mg/m3 for inhalable dust. Until then, a limit value of 0.1 mg/m3 shall apply. No short-term exposure limit is set for nickel compounds (Carcinogens and mutagens EU Directive, 2004).

ENVIRONMENTAL ISSUES

An increase in nickel demand and limited reserves of nickel sulphide ore is fostering the sourcing from laterite, arising environmental concerns given that this process requires higher temperatures and thus is more energy intensive. Hydrometallurgy is a promising alternative which would reduce energy consumption and GHG emissions. While this method is not yet common in industrial applications this could change in the following years since laterite also contains cobalt, whose demand is increasing and may incentivise hydrometallurgical methods (Stankovic, S. 2020).

(Wei et al., 2020) used a model based on the law of conservation of mass and energy to investigate the energy utilization and the related greenhouse gas emissions (GHG) of several nickel smelting products containing different percentages of nickel: nickel metal (Ni), nickel oxide (NiO), ferronickel (NiFe) and nickel pig iron (NPI). The results show that the required primary energy is 174 GJ/t alloy, 369 GJ/t alloy, 110 GJ/t, and 60 GJ/t alloy, respectively. Furthermore, the associated GHG emissions are 14 tCO2eq/t alloy, 30 tCO2eq/t alloy, 6 tCO2eq/t alloy, and 7 tCO2eq/t alloy.

NORMATIVE REQUIREMENTS RELATED TO MINING/NICKEL PRODUCTION, USE AND PROCESSING OF THE MATERIAL

There are several responsible sourcing programs developed by the Nickel Institute (NI) member companies – many of these programs are based on the OECD Due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas (OECD DDG). (NI 2023).

Moreover, the NI has joined a few associations (eg. ILA, IMOA, IZA etc.) in publishing a Joint Due Diligence Standard for copper, lead, molybdenum, nickel and zinc. It builds on existing standards and looks to provide flexibility for multi-metal producers to include any associated metal products of their site(s) as needed.

SOCIO-ECONOMIC AND ETHICAL ISSUES

ECONOMIC IMPORTANCE OF NICKEL FOR EXPORTING COUNTRIES

Table 12 lists the countries for which the economic value of exports of nickel represents more than 0.1 % in relation to the total value of their exports.

Table 12: Countries with the highest economic shares of nickel exports in relation to their total exports.

Country	Export value (USD)	Share in total exports (%)
Zimbabwe	1,597,066,830	36.3
Madagascar	147,006,980	7.5
Philippines	1,480,171,199	2.3

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Finland	1,193,879,435	1.8
Norway	1,253,612,048	1.5
Aruba	921,787	1.4
Russian Federation	3,106,624,379	0.9
Canada	2,938,895,174	0.8
Zambia	45,140,955	0.6
Indonesia	808,441,447	0.5
Guatemala	56,562,133	0.5
South Africa	328,662,169	0.4
United Kingdom	1,300,620,171	0.3
Costa Rica	34,283,120	0.3
Austria	401,977,957	0.2
United Arab Emirates	651,863,956	0.2
USA	2,443,749,472	0.2
Australia	401,097,967	0.2
Japan	980,862,274	0.2

Source: COMTRADE (2022), based on data for 2020.

The data show that Zimbabwe and Madagascar rely strongly on nickel exports. In the first case, exported products are both ores (13.9 % of overall exports) and articles and matte (22.4 % of overall exports). Secondly, Madagascar mainly exports nickel in the form of article and matte. Almost all exporting countries generally sell nickel as one type of product: ores or articles and matte. Only one country, South Africa, exports nickel in the form of oxide.

SOCIAL AND ETHICAL ASPECTS

Several mining activities have been developed on Inuit and Innu land in Canada, provoking the loss of vegetation and the reduction of hunting and fishing opportunities for the community (EJAtlas, 2019a, EJAtlas, 2019b). Moreover, since 2019 the company Twin Metals Minnesota has been running exploration activities for mining copper and nickel along the shores of Birch Lake and the South Kawishiwi River, in Minnesota, USA. The local population has fought against the projects on the grounds of potential negative impacts on the environment and on human health (Kraker, D., 2021). In January 2023, the US Interior Department blocked any mining or geothermal activity within the area of northeast Minnesota until 2043, with the purpose of protecting the state's vast network of interconnected waterways.

In 1975 the Rio Tuba Nickel Mining Corporation (RTNMC) started nickel open pit mining activities in the Island of Palawan, the Philippines, and are currently still ongoing. Nickel ore extraction and processes is releasing different hazardous subproducts to the environment. After the operation began, the Palawan indigenous people reported health issues, such as cough, headaches, and skin diseases. Palawan island is known for its diverse and endemic flora and fauna, with some of the species being considered rare, threatened or endangered. Mining operations are destructing old-growth forests and polluting water, pushing local people to protest and request for protection and support from the central government and from international NGOs. The NGO Friends of the Earth Japan has been working to help the local communities to be provided of

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environmental and health protection. Since 2009 their experts collected and analysed water samples from different water streams nearby the nickel mine, aiming to understand the extent of water contamination in the extraction area. The main pollutant found in the rivers was hexavalent chromium (chromium(VI)). This substance exceeded the drinking water standards of the World Health Organization for at least 11 years, from 2009 to 2019, posing a significant threat to the local population and the ecosystem. As of April 2022, the people from the island of Palawan were still jeopardized by polluted water, and the RTNMC was in dialogue with the Philippine government to expand the nickel mining area (Electronics Watch, 2022; Electronics Watch, 2021, Environmental Justice Atlas, 2018).

RESEARCH AND DEVELOPMENT TRENDS

RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

No data available.

OTHER RESEARCH AND DEVELOPMENT TRENDS

- ElectroNick - The Combination of Electrochemistry and Nickel Catalysis: New Bond-Forming Reactions on a Sustainable Platform (2018 – 2021)[4]

Sustainable routes towards the formation of key synthetic carbon–carbon bonds by cross-coupling remains a challenge in organic chemistry. Realization of this goal will enable the combination of simple building blocks to rapidly assimilate synthetic complexity with only a minimum level of stoichiometric waste. Electrochemistry provides a new platform to conduct reactions through in situ generation of reactive intermediates under mild conditions, with broad applications to industrial synthesis. Herein, we seek to combine the fields of electrochemistry and cross-coupling reactions, using an electric current to catalytically generate alkylzinc reagents and reactive alkyl radicals. These intermediates will then undergo coupling, facilitated by nickel catalysis, to generate key carbon–carbon bonds, including challenging C(sp3)–C(sp3) bonds. Furthermore, the powerful combination of electrochemistry and nickel catalysis will enable the simplest feedstock chemicals – alkanes – to be utilized for the first time in cross-coupling through a nickel chain-walking process, providing facile access to fatty acids and alternative coupled products. These projects will enable the emergence of new reaction strategies for exploitation in a sustainable manner. Additionally, this ambitious and innovative proposal will succeed through considerable two-way transfer of knowledge between the participating organizations and the ER, developing the fellow into a leading international researcher.

- DEstiNi - Investigation of the Dynamic Estuarine and Marine cycling of Nickel (2019 – 2023, EU)[5]

Nickel plays an important role in the marine carbon cycle but its effects on the ocean ecosystem are still not well understood. The EU-funded DEstiNi project will shed further light on nitrogen cycling as it is directly related to climate dynamics. A record of the temporal evolution of nickel stable isotopes from marine

[4] https://cordis.europa.eu/project/id/789399
[5] https://cordis.europa.eu/project/id/844529

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sedimentary archives has the potential to elucidate the forces controlling the Earth's climate on glacial-interglacial timescales. Their multifaceted approach will include archived sample analysis and sample collection of nickel through field campaigns, and high-precision isotope analysis. Project results will enable nickel isotopes to become a tool for tracing the feedbacks between past climatic variability and production and preservation of organic carbon.

- Association of urinary nickel levels with diabetes and fasting blood glucose levels: A nationwide Chinese population-based study (Qu et al 2023)

Some epidemiological studies support a relationship between nickel exposure and diabetes in the general population. To address this, it was tested the association of nickel exposure with diabetes in 10,890 adults aged ≥ 18 years old from the China National Human Biomonitoring study conducted in 2017–2018. Urinary nickel concentrations and fasting blood glucose (FBG) were measured, and lifestyle and demographic data were collected. Weighted logistic and linear regressions were used to estimate the associations of urinary nickel levels with diabetes prevalence and FBG.

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