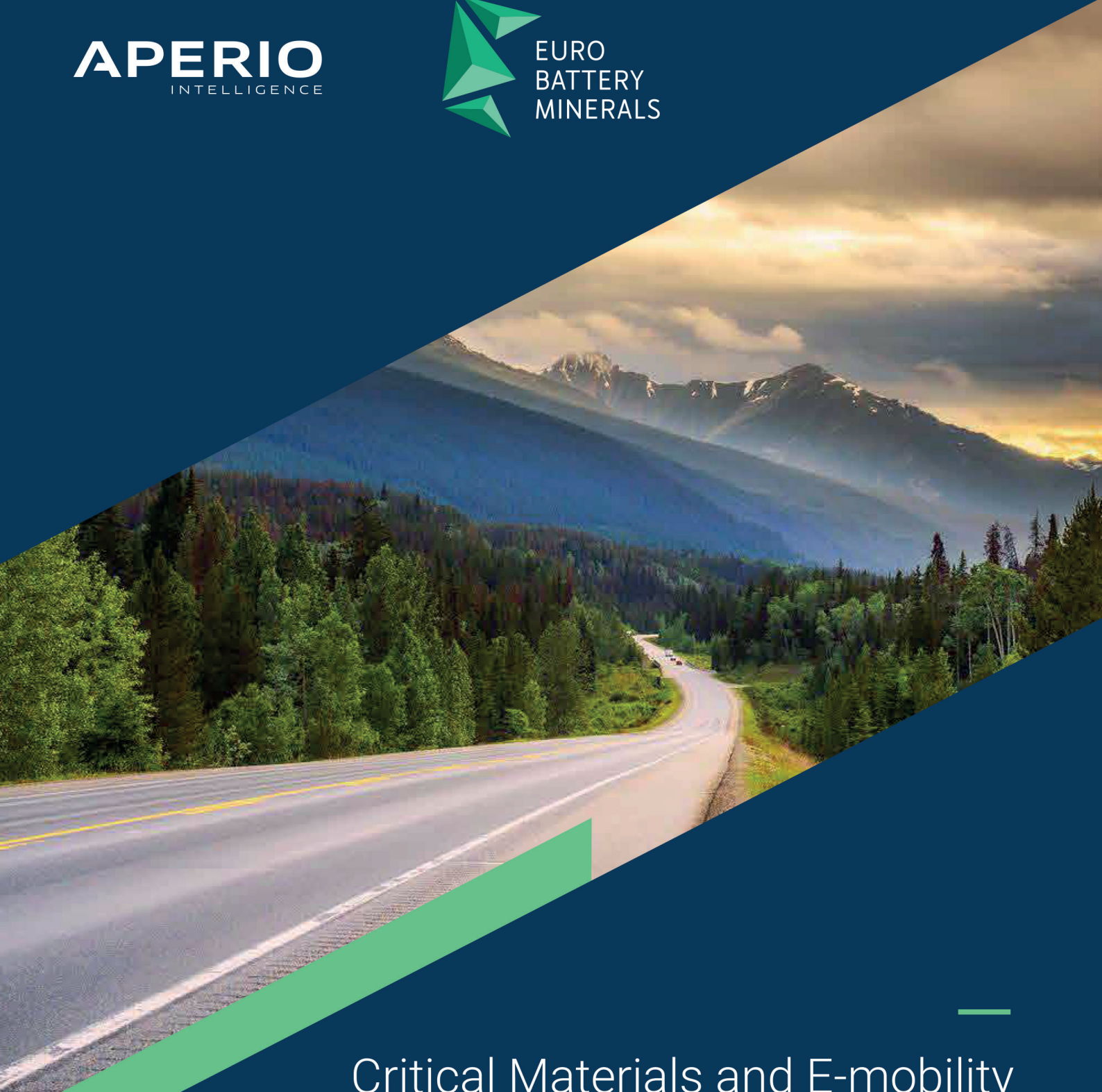


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Critical Materials and E-mobility

March 2021

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1 Introduction

1.1 Introduction and terms of reference

This report provides an overview of principal sources of certain critical materials deemed pivotal to the production of electric and plug-in hybrid vehicles. The report also analyses current and future market volumes of electric and plug-in hybrid vehicles as well as e-bikes – with a focus on Europe and China – and their associated demands on copper, nickel and cobalt.

Should you wish to discuss any findings in this report, please contact the London office of Aperio Intelligence at +44 (0) 20 3146 8900.

2 Executive summary

The materials copper, nickel and cobalt are all considered crucial for the global energy transition and the world's demand for each of them is set to increase as e-mobility is adopted at a faster scale over the next five to ten years. This report provides an overview of production volumes of all three materials, within Europe and globally, and also outlines aspects of the future growth in demand from the electric vehicle and e-bike industries.

In 2020, global copper mine production amounted approximately to 20 million tonnes, a slight decline from approximately 20.4/20.5 million tonnes in 2019. In 2018 the EU 27 countries produced 911,703 tonnes of mined copper, which amounted to 4.3% of total global production of 21 million tonnes. The largest producers of copper in the EU are Poland, Spain, Bulgaria and Sweden. In 2019 Europe's mined production rose to 13% of total world production, a large portion of which (399,000 tonnes) was produced in Poland. Global annual copper demand was around 28 million tonnes in 2020 and consumption is expected to grow by approximately 38% by 2030, to approximately 38 million tonnes annually.

Global nickel mine production amounted to approximately 2.5 million tonnes in 2020. The EU's mined nickel ore production is a fraction of global production and has been mainly focused in Finland (approximately 39,000 tonnes in 2019) and Greece (approximately 14,000 tonnes in 2019). In 2018 global production was 2.26 million tonnes, with the EU contributing just 64,212 tonnes (<0.5%) to that figure from mines in Finland (43,572 tonnes), Greece (19,980 tonnes) and Poland (660 tonnes). European Nickel production has been mainly carried out by state-owned Terrafame Oy and Swedish Boliden AB as well as Greek partially state-owned General Mining and Metallurgical Company SA which is currently under liquidation measures.

Global mine production of cobalt amounted to 140,000 tonnes in 2020, dominated by the Democratic Republic of Congo (98,000 tonnes). European cobalt production was mainly a by-product of the mining operations of state-owned Terrafame and Swedish Boliden. In 2018 global production was 156,483 tonnes, with the EU – through Finland – contributing just 1,377 tonnes (0.9%) to that figure. The European Commission's latest list of critical materials (September 2020) records that the EU imports 86% of the cobalt it needs and that its demands will require five times more cobalt by 2030 and over 15 times more by 2050 compared to current supply levels.

In 2020, sales volumes of electric cars in Europe surpassed China for the first time. Europe's market increased by 137% on 2019 levels compared to growth in China of just 12%. This followed growth of 44% in Europe during 2019 and Q1 2020. In 2019 sales increased by more than 10% in almost every European country with The Netherlands and Germany contributing to almost half of that growth.

In terms of production, Europe produced around 750,000 EVs in 2019, a total which is set to rise to more than 4 million in 2025. This equates to an increase from 4% of market share in 2019 to 22% market share in 2025. Production growth can be broadly split between Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) with BEV increasing the share of overall production over the next decade.

According to a 2019 report by the European Federation of Transport and Environment, by 2025, Germany, France, Spain, Italy and the UK will produce about 85% of Europe's EVs, however, Europe's leading manufacturers will split operations between Europe and Asia.

China's sales and production of EVs was badly hit by the Covid-19 pandemic in 2020 however it is forecast that it will return to double-digit growth during 2021. Specifically, around 3.5 million EVs are forecast to be sold in 2021, with China set to produce an estimated 6.4 million EVs in 2025.

Based on current battery usage in EVs, the report estimated that copper demand solely from battery electric and plug-in hybrid cars and vans would grow from approximately 52,000 tonnes in 2019 to around 317,000 tonnes in 2025. Demand for nickel would increase from 22,500 tonnes in 2019 to 129,000 tonnes in 2025 while 51,600 tonnes cobalt will be needed in 2025 compared to 9,000 tonnes in 2019.

Car manufacturers and the makers of components are looking to localize production in key target markets. According to the consultancy McKinsey, by 2040, based on a range of scenarios, European EV production could require EU-based battery manufacturing of 0.7–1.5 TWh a year, the equivalent of 45–95 gigafactories. Growth in battery-cell manufacturing in Europe means the continent could be self-sufficient and no longer have to rely on imported batteries by 2025. In Europe there are currently 15 large-scale battery cell factories under construction on top of existing facilities which include projects led by Northvolt, CATL, SK Innovation, Tesla, Automotive Cells Company (ACC) and LG Chem.

3 Mines and production

3.1 Copper

Pure copper metal is generally produced from a multistage process, beginning with the mining, and concentrating of low-grade ores containing copper sulphide minerals. This is followed by smelting and electrolytic refining to produce a pure copper cathode¹. Copper is also one of the most recycled materials globally. Recycling accounts for over 30% of annual copper use over the past decade.

According to the International Copper Association (“ICA”), global copper reserves are estimated at 870 million tonnes and annual copper demand was around 28 million tonnes in 2020². According to recent estimates by the UK-based research consultancy Roskill, global copper consumption (including refined demand and direct use scrap) is expected to grow by approximately 38% by 2030, to approximately 38 million tonnes annually.³⁴

Global copper production

According to the International Copper Study Group (“ICSG”) and the US Geological Survey (“USGS”), in 2020, global copper mine production declined slightly to 20 million tonnes, from approximately 20.4/20.5 million tonnes in 2019⁵⁶. In 2018 the EU 27 produced 911,703 tonnes of mined copper, which amounted to 4.3% of total global production of 21 million tonnes⁷. The largest EU producers were Poland, Spain, Bulgaria and Sweden (see Table 3 below).

In recent years, global copper mine production has been dominated by Latin America (43%), with Chile (5.8 million tonnes in 2019) and Peru (2.46 million tonnes in 2019) the other largest producers. Asia accounted for 15% of the global output in 2019, closely followed by North America and Europe. In 2019, China (1.6 million tonnes) was the third largest producing country behind Chile and Peru, followed by the US (1.3 million tonnes) and the Democratic Republic of Congo (“DRC” 1.3 million tonnes).

¹ [Copper Statistics and Information](#), USGS, accessed on 12 February 2021

² [Copper meets out future needs](#), ICA, 2020

³ [Copper Demand to 2030, 2nd Edition](#), Roskill, 14 December 2020

⁴ [Global copper demand forecast to grow 28% in a decade](#), BNamericas, 15 December 2020

⁵ [Copper](#), USGS: Mineral Commodity Summaries 2021, 29 January 2021

⁶ [2020 World Copper Factbook](#), ICSG, 2020

⁷ [World Mining Data](#), accessed 14 February 2021

Table 1: Global copper mine production (metric tonnes) - United States Geological Survey

	2019 (tonnes)	2020 (tonnes)
US	1,260,000	1,200,000
Australia	934,000	870,000
Canada	573,000	570,000
Chile	5,790,000	5,700,000
China	1,680,000	1,700,000
DRC	1,290,000	1,300,000
Kazakhstan	562,000	580,000
Mexico	714,000	690,000
Peru	2,460,000	2,200,000
Poland	399,000	400,000
Russia	801,000	850,000
Zambia	797,000	830,000
Other countries	3,100,000	3,300,000
Total (rounded)	20,400,000	20,000,000

Largest copper producers

The largest copper-producing company by output is the Chilean state-owned copper mining company Corporación Nacional del Cobre (“CODELCO”) which produced 1.7 million tonnes of copper mined through its seven mining divisions in the country in 2019⁸⁹. CODELCO is followed by Glencore with 1.37 million tonnes of copper produced by its various copper assets located in South America, Africa, Asia, Australia and North America.¹⁰ The third largest copper producer in 2019 was global resources company BHP Billiton with 1.25 million tonnes of attributable copper output through its mines in Chile and South Australia.¹¹

According to the ICSG *Directory of Copper Mines and Plants* (September 2020 edition), the Chilean Escondida and Collahuasi mines remained the largest copper producers globally in 2019, with 1.4 million and 0.61 million metric tonnes capacities, respectively. According to Escondida’s 57.5% operator BHP Billiton, the mine’s copper production in the financial year ending 30 June 2020 totalled 1,185 kilo tonnes (“kt”), a 4% increase from the previous year. Nevertheless, the mine’s 57.5% operator BHP Billiton noted that this was expected to decline to between 940 and 1,030kt in the FY2021, mainly due to lower copper grades in the mined ore.¹² Collahuasi produced 565,435 tonnes of fine copper in 2019 and more recently it reported a 9.4% year-on-year increase in output in September 2020.¹³¹⁴

Smelting and refining of copper

Asia is the global leader in both smelter and refined copper production, reaching an estimated 20 and 24 million tonnes respectively in 2019.¹⁵ Asia’s share of the world’s copper smelter output increased from 27% in 1990 to 65% in 2019, mainly due to the rapid growth of smelter production in China. According to the ICSG, China accounted for 50% of global copper smelter production in 2019 and it is home to eight out of the 20 largest copper smelters by capacity. Other leaders in smelter production were Japan (8%),

⁸ [Operations](#), CODELCO, accessed on 12 February 2021

⁹ [The World’s Top 10 Biggest Copper Producers in 2019](#), *Mines and Metals*, 30 March 2020

¹⁰ [Full Year 2019 Production Report](#), Glencore, 4 February 2020

¹¹ [BHP Copper facts](#), BHP Billiton, accessed on 12 February 2021

¹² [Escondida, Key developments during FY2020](#), BHP, accessed on 12 February 2021

¹³ [BHP’s Escondida copper mine sees output fall in September, Codelco boosts production – Cochilco](#), Reuters, 3 November 2020

¹⁴ [Financial Statements 2019](#), Collahuasi, 17 April 2020

¹⁵ According to the USGS, global refined copper production increased slightly to an estimated 25 million tons in 2020

Chile (5%) and Russia (5%). The world's largest smelter is China's Jiangxi Copper Corp's Guixi (600 thousand metric tonnes) followed by the Chilean state controlled Chuquibambilla (450 thousand metric tonnes) and Hidalgo's Birla Copper smelter in India (500 thousand metric tonnes).

Table 2: Global copper refinery production (metric tonnes) - United States Geological Survey

	2019 (tonnes)	2020 (tonnes)
US	1,030,000	910,000
Australia	426,000	380,000
Canada	281,000	290,000
Chile	2,270,000	2,400,000
China	9,780,000	9,800,000
DRC	1,080,000	1,100,000
Germany	630,000	670,000
Japan	1,500,000	1,600,000
Kazakhstan	512,000	540,000
Korea	665,000	680,000
Mexico	477,000	470,000
Peru	308,000	330,000
Poland	566,000	550,000
Russia	1,050,000	1,060,000
Zambia	262,000	360,000
Other countries	3,640,000	3,500,000
Total (rounded)	24,500,000	25,000,000

European copper production

In 2018 the EU 27 produced 911,703 tonnes of mined copper, which amounted to 4.3% of total global production of 21 million tonnes.

Table 3: Copper production in Europe in 2018¹⁶

	Copper production in tonnes (2018)		Copper production in tonnes (2018)
European Union		Rest of Europe	
Bulgaria	112,850	Russia	785,300
Cyprus	908	Serbia	44,096
Finland	46,755	Armenia	68,928
Poland	401,300	Albania	3780
Portugal	49,064	Azerbaijan	1650
Romania	8165	Georgia	15,250
Spain	186,500	Turkey	87,000
Sweden	106,140		
Slovakia	21		
Total	911,703		1,006,004

¹⁶ [World Mining Data](#); accessed 14 February 2021

According to the ICSG, in 2019, the EU accounted for 13% of the world's mined copper production. Its top producing countries – Poland and Spain – are ranked 12th and 17th respectively in the global top 20 producing countries. Both countries produced less than 0.5 million tonnes in 2019.¹⁷ Other European producers include Germany, Bulgaria, Sweden, Finland, and Belgium while Germany, Spain and Belgium lead the continent's refined production.

Europe's largest producer is the Warsaw Stock Exchange-listed mining group KGHM Polska Miedź SA ("KGHM"). In 2019, KGHM recorded 702,000 tonnes of payable copper production from its mines in Poland, Chile, Canada and the US.¹⁸ The group's primary assets are three major copper and silver mining sites in the Legnica-Głogów Copper Belt in Lower Silesia, south-western Poland:

- The Rudna operation is one of the largest deep copper mines in the world. According to KGHM's website, Rudna's current average production capacity is around 12 million tonnes of ore per year, but no further information was identified regarding its more recent production output.¹⁹
- KGHM's Polkowice-Sieroszowice is a large mine in the west of Poland near Polkowice. According to the company's website, the mine currently has a total production capacity of around 12 million tonnes of ore per year. In 2018, the mine extracted over 196,000 tonnes of copper, over 300,000 tonnes of rock salt and over 428,000 kg of silver.²⁰
- The Lubin copper and silver mine is located on the northern border of Lubin, in Lower Silesia and is the oldest mine in the Polish copper belt. In 2019, Lubin's total output amounted to 8,160 million mg, including 73,448 Mg of copper and 348 Mg of silver.²¹

Supply and consumption

According to data from the USGS, global refined copper production totalled 25 million tonnes in 2020 (compared to 24.5 million tons in 2019) with nearly 40% (9.8 million tonnes) refined in China (9.78 million tonnes in 2019). According to 2018 figures, Europe refines approximately 7% (or 1.7 million tonnes) of global refined production²². China was the largest producer of refined copper with half of the world's largest copper refineries located in the country. A further 2.4 million tonnes was refined in Chile (2.27 million in 2019) and 1.6 million tonnes in Japan (1.5 million tonnes in 2019). In terms of consumption, China was the largest consumer of refined copper in 2019, of approximately 12.7 million tonnes. In 2019, Europe reportedly consumed 17% - or 4.2 million tonnes – of global refined copper.

3.2 Nickel

As of 2018, nickel was mined and smelted and refined in over 30 countries globally.²³ Although global demand for nickel is mainly led by the engineering (31%), metal goods (22%) and construction and building (16%) sectors, forecasts by a recent study commissioned by the European Commission from the consultancy Roskill indicates that automotive electrification is expected to represent the single-

¹⁷ [The World Copper Factbook 2020](#), ICSG, October 2020

¹⁸ [Results for 2019](#), KGHM, 18 March 2020

¹⁹ [Rudna](#), KGHM, accessed on 12 February 2021

²⁰ [Polkowice-Sieroszowice](#), KGHM, accessed on 12 February 2021

²¹ [Lubin](#), KGHM, accessed on 12 February 2021

²² [World Mining Data](#), accessed 14 February 2021

²³ [The world nickel factbook 2018](#), International Nickel Study Group, 2019

largest growth sector for nickel demand globally over the next 20 years.^{24 25}The study estimates that the sector's nickel ore demand globally will increase by 2.6 million tonnes to 2040, up from only 92,000 tonnes in 2020. In the EU, specifically, demand is expected to increase by 543,000 tonnes by 2040, from 17,000 tonnes in 2020.²⁶

Global nickel production

Recent statistics by the USGS record that global nickel production was approximately 2.61 million tonnes in 2019, a figure that is expected to decrease to approximately 2.5 million tonnes in 2020.²⁷ In 2018 global production was 2.26 million tonnes, with the EU contributing just 64,212 tonnes (<0.5%) to that figure from mines in Finland (43,572 tonnes), Greece (19,980 tonnes) and Poland (660 tonnes).

In recent years, global nickel mine production has been dominated by the Asia Pacific region, the largest producer being Indonesia which accounted for over 30% of global production in 2019 and 2020. Indonesia is followed by the Philippines (12%) Russia (10.7%) and New Caledonia in the southwest Pacific Ocean (8%).

Table 4: Global nickel mine production (metric tonnes) - United States Geological Survey

	2019 (tonnes)	2020 (tonnes)
US	13,500	16,000
Australia	159,000	170,000
Brazil	60,600	73,000
Canada	181,000	150,000
China	120,000	120,000
Cuba	49,200	49,000
Dominican Republic	56,900	47,000
Finland	Unknown	39,000
Indonesia	853,000	760,000
New Caledonia	208,000	200,000
Philippines	323,000	320,000
Russia	279,000	280,000
Other countries	Unknown	251,000
Total (rounded)	2,610,000	2,500,000

According to the Roskill study, global refined nickel production grew by 9.3% to 2.38 million tonnes in 2019.²⁸ China and Indonesia jointly accounted for approximately 40% of global production in 2019. China's refined nickel production has heavily relied on imports from Indonesia, the Philippines and New Caledonia and the sector was reportedly heavily affected by Indonesia's January 2020 ban of exports of unprocessed ores and concentrates. Nevertheless, recent disclosures by China's General Administration of Customs indicate that despite the ban Indonesia remained the country's second-largest nickel ore supplier with 3.4 million tonnes in 2020 (85.5% decrease in imports compared to the previous year).

²⁴ [End use of nickel](#), The Nickel Institute, accessed on 12 February 2021

²⁵ [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

²⁶ [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

²⁷ [Nickel](#), USGS: Mineral Commodity Summaries 2021, 29 January 2021

²⁸ [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

Ahead of Indonesia, the Philippines exported 31.98 million tonnes of nickel ore to China in the same year.²⁹

According to Roskill's study, global supplies of nickel over the next decade are expected to be led by Indonesia's increasing mine capacity as well as new projects in Australia and Brazil. The study estimates that, by 2030, Indonesia will account for around 45% of global mine supply, feeding its domestic nickel pig iron (NPI) and ferronickel smelters as well as battery-grade intermediate nickel plants. Indonesia is widely expected to have a significant role in the production of nickel for the battery industry, and media reports have highlighted the government's recent discussion with Tesla over a potential investment in the development of Li-ion batteries in the country.³⁰

Largest nickel producers

The world's largest global nickel producer is Vale SA, a Rio de Janeiro-based global mining company with nickel mines and operations in Brazil, Canada, Indonesia, and New Caledonia, as well as fully owned and joint-venture refineries in China, South Korea, Japan, the UK and Taiwan.^{31,32} Vale recorded 208,000 tonnes of nickel output in 2019 (a 15% drop from 244,600 tonnes in 2018), and 214,700 tonnes in 2020.^{33,34} Vale's majority-owned subsidiary PT Vale Indonesia Tbk ("PT Vale") operates one of the world's largest integrated lateritic nickel mining and processing operations that is located near Sorowako on the Island of Sulawesi in Indonesia. No recent information about the Sorowako operation's total output was identified, but PT Vale reported total production of 71,025 tonnes of nickel in 2019.^{35, 36}

The world's largest nickel producing companies also include Russia's diversified mining group Norilsk Nickel (also known as "Nornickel") which produced 229,000 tonnes of nickel and 499,000 tonnes of copper in 2019.³⁷ The Russian company's main asset is its wholly owned subsidiary Kola Mining and Metallurgical Company ("Kola MMC") which operates the company's nickel refining hub in the Kola Peninsula, northwest of Russia. In 2019, Kola MMC reportedly produced 166,265 tonnes of nickel which accounted for approximately 73% of the group's total nickel products in 2019.³⁸

Hong Kong-listed Jinchuan Group International Resources Co Ltd is the third largest nickel producer with estimated production of 150,000 tonnes in 2019.^{39,40} The company operates three mines in the Central African Copperbelt, namely, the Ruashi copper and cobalt mine, and the Kinsenda copper mine in the DRC and the Chibuluma copper mine in Zambia.

²⁹ [Indonesia stays China's second-biggest nickel ore supplier despite export ban](#), Reuters, 20 January 2021

³⁰ [Nickel price: Indonesia confirms Tesla talks](#), Mining, 12 February 2021

³¹ [Profiling the world's top five nickel-producing companies](#), NS Energy, 8 October 2020

³² [Nickel](#), Vale, accessed on 12 February 2021

³³ [Production and sales in 4Q19](#), Vale, 11 February 2020

³⁴ [Vale's production and Sales in 4Q20 and 2020](#), Vale, accessed on 12 February 2021

³⁵ [Our operation](#), Vale, accessed on 12 February 2021

³⁶ [PT Vale releases fourth quarter 2019 Production Report](#), PT Vale, 11 February 2020

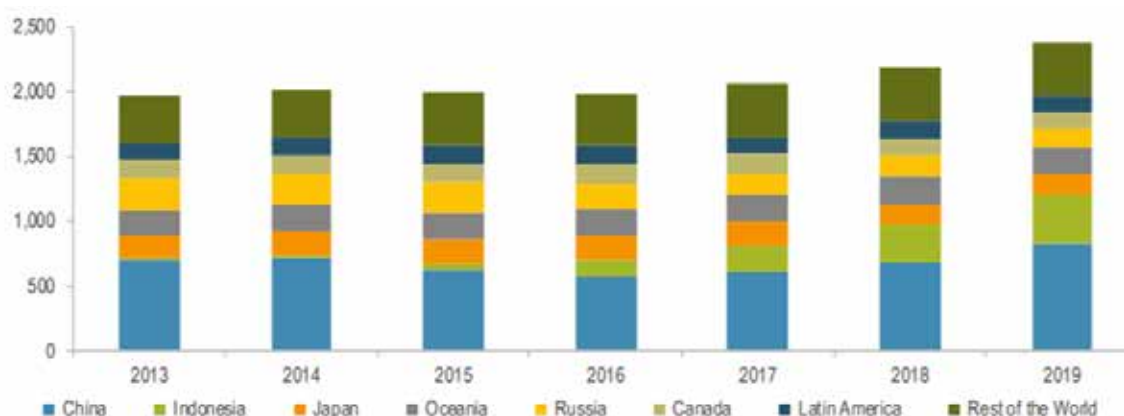
³⁷ [Nornickel Announces Preliminary Consolidated Production Results For FY2019](#), Nornickel, 31 January 2020

³⁸ [KOLA MMC, KOLA PENINSULA](#), Nornickel, 2020

³⁹ [Profiling the world's top five nickel-producing companies](#), NS Energy, 8 October 2020

⁴⁰ [Company overview](#), Jinchuan Group International Resources, July 2020

Figure 1: Refined nickel production by country, 2013-2019 (kt Ni)



Source: Study on future demand and supply security of nickel for electric vehicle batteries, Roskill 2021.⁴¹

European nickel production

Greece and Finland are currently the only producers of nickel in Europe. According to the Roskill study mentioned above, in 2019, mined production accounted for 2.1% of global supplies. Finland produced 39,000 tonnes of nickel-in-ore in 2019, mainly through the mining operations of state-owned Terrafame Oy and Swedish Boliden AB. Meanwhile Greece's General Mining and Metallurgical Company SA entered liquidation in 2020 leading to a decline in production. The same study estimates that Finland is also responsible for approximately 95% of intermediate nickel production (62,000 tonnes in 2020), and approximately 76% of refined nickel production (71,800 in 2019) in the EU27.⁴²

- Boliden mainly produces zinc, copper, lead and nickel from six mines in Sweden (Aitik, Garpenberg and the Bolden Area); Finland (Kevitsa, Kylylahti), and the UK (Tara) and five smelters in Sweden (Bergsöe, Rönnskär), Finland (Harjavalta, Kokkola) and Norway (Odda).⁴³

Boliden also produces two intermediate nickel products, nickel matte (26,000 tonnes in 2019 and 31,000 tonnes in 2018) and nickel sulphate (10,000 tonnes in 2019 and 14,000 tonnes in 2018), a high-purity chemical product primarily used in Li-ion batteries. These are primarily sourced from Boliden's mine on the Kevitsa deposit in Sodankylä (Finland) and the Aitik mine in Sweden and also as a by-product from the company's copper production in the Rönnskär (Sweden) and Harjavalta (Finland) smelters.^{44,45}

- Terrafame operates the Talvivaara mining operation in Sotkamo, one of the largest nickel mines in Finland and Europe's largest source of nickel for electric car batteries. The company is also in the process of building a battery chemicals plant in Sotkamo set to be operational in early 2021.⁴⁶ In 2019, Terrafame has a total mining volume of 32.3 million tonnes and produced 27,468 tonnes of nickel (27,377 tonnes in 2018).⁴⁷
- The Greek partially state-owned General Mining and Metallurgical Company SA ("LARCO") operated mines in the region of Euboea, Neo Kokkino, Kastoria and Servia and a smelting plant in Larymna and

⁴¹ [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

⁴² [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

⁴³ In 2019, Boliden produced a total of 121,000 tonnes of copper in concentrates in the Aitik, Kevitsa, Kylylahti, Kristineberg, Renström and Mauriliden mines.

⁴⁴ [Boliden Annual and Sustainability Report 2019](#), Boliden, 2020

⁴⁵ [Terrafame to serve European EV sector with world's largest nickel sulfate plant by early 2021](#), Fastmarkets, 18 September 2020

⁴⁶ [Finland's plans to boost nickel mine output sparks environmental fears](#), WSJ, 17 November 2020

⁴⁷ [Financial Review 2019](#), Terrafame, 4 March 2020

had an average ferronickel production of 18,000-20,000 tonnes per annum before it entered liquidation in early 2020.⁴⁸

Supply and consumption

According to Morgan Stanley, global demand for stainless steel will rise by 6% in 2021, requiring an additional 150,000 tonnes of nickel.⁴⁹ The bank also forecasts the need for an extra 34,000 tonnes of nickel to supply the rise in electric vehicle manufacturing, taking total rise in demand to 6.4% over the year. The Roskill study estimates that total nickel sulphate production (the type of nickel required for batteries) will grow at 13.5% per year from 159,000 tonnes in 2020 to approximately 2 million tonnes by 2040.

3.3 Cobalt

Cobalt is found in a variety of different ores and is predominantly mined as a by-product of copper and nickel mining and refining operations. The end-use of cobalt can be subdivided into two broad segments, namely chemical (dominated by the rechargeable batteries segment) and metallurgical applications (superalloys, hard metals, magnets).

Global cobalt production

According to the USGS, the total global mine production of cobalt amounted to approximately 144,000 tonnes in 2019, which fell to 140,000 tonnes in 2020.⁵⁰ The DRC is the largest producer of mined cobalt globally, accounting for approximately 70% of world production with 95,000 tonnes produced in 2020 and 100,000 tonnes in 2019. The DRC is followed by Russia, (6,300 tonnes in both 2020 and 2019) and Australia (5,700 in 2020 and 5,740 in 2019). In 2018 global production was 156,483 tonnes, with the EU – through Finland – contributing just 1,377 tonnes (0.9%) to that figure.

⁴⁸ [Greece to sell troubled nickel producer Larco's assets: minister](#), Reuters, 24 January 2020

⁴⁹ [Nickel Soars And Could Keep Flying As Demand Rises And Supply Falls](#); Forbes, 21 January 2021

⁵⁰ [Cobalt](#), USGS: Mineral Commodity Summaries 2021, January 2021

Table 5: Global cobalt mine production (metric tonnes) - United States Geological Survey

	2019	2020
US	500	600
Australia	5,740	5,700
Canada	3,340	3,200
China	2,500	2,300
Cuba	3,800	3,600
DRC	100,000	95,000
Madagascar	3,400	700
Morocco	2,300	1,900
Papua New Guinea	2,910	2,800
Philippines	5,100	4,700
Russia	6,300	6,300
South Africa	2,100	1,800
Other countries	6,320	6,400
Total (rounded)	144,000	140,000

Although the DRC is a clear global leader in cobalt mining, global production of refined cobalt is dominated by China which accounted for more than 60% of the world total in 2018.⁵¹ Most of this is produced from partially refined cobalt imported from the DRC. At the same time, China was also the world's leading consumer of cobalt, with more than 80% of its consumption being used by the rechargeable battery industry.⁵²

Largest cobalt producers

Glencore is the single largest cobalt producer in the world. Cobalt has been mainly produced as a by-product of the company's copper mining operations in the DRC, but also as a by-product of nickel mining in Australia and Canada. Glencore's own sourced cobalt production amounted to 46,300 tonnes in 2019 but is expected to fall to 27,400 tonnes in 2020, due to the temporary closure of the company's Mutanda mine in the DRC in 2019.⁵³ Mutanda is the world's largest cobalt mine. Prior to being put on care and maintenance for at least two years at the end of 2019, it was responsible for a fifth of global cobalt output, producing 27,000 tonnes of cobalt as well as 199,000 tonnes of copper in 2018. Glencore's other wholly owned mining operation in the region is the Katanga mine, a large-scale copper-cobalt operation that is expected to become the world's largest cobalt producer in the following years. According to Glencore's Annual Report for 2019, following a mining optimisation review of its operation, Katanga is expected to produce approximately 30,000 tonnes of cobalt per year.^{54 55 56}

The DRC's largest mines also include the Tenke Fungurume ("TFM") copper and cobalt mine located in DRC's Lualaba province. The operation is 80% owned by China Molybdenum Co Ltd ("CMOC") and 20% by state mining company Gecamines and produced 16,098 tonnes of cobalt and 177,956 tonnes of copper in 2019.^{57 58}

⁵¹ [Cobalt resources in Europe and the potential for new discoveries](#), S. Horn; A. G. Gunn and others – *Ore Geology Reviews* 130 (2021), 5 December 2020

⁵² [Cobalt](#), USGS: *Mineral Commodity Summaries 2021*, January 2021

⁵³ [Glencore to Cut Production at Major Copper, Cobalt Mine](#), WSJ, 19 February 2019

⁵⁴ [Welcome to Katanga Mining Limited](#), Katanga, 12 February 2021

⁵⁵ [Cobalt](#), Glencore, accessed on 12 February 2021

⁵⁶ [Annual Report 2019](#), Glencore, 4 March 2020

⁵⁷ [China Moly's Congo copper-cobalt mine expects stable output this year](#), *Mining*, 22 May 2020

⁵⁸ [Annual Report 2019](#), CMOC, 27 March 2020

European cobalt production

Today, 86% of the EU's cobalt is imported, primarily from the DRC (68%) and French Guiana (5%).⁵⁹ Due to increasing demand for electric vehicles ("EV"), batteries and energy storage, the EU would need to increase its cobalt supplies by five times by 2030 and over 15 times by 2050 compared to current levels. A recent study by the British Geological Survey identified 104 deposits in Europe that are currently being explored for cobalt, of which 79 are in Finland, Norway and Sweden.⁶⁰

According to the EU's latest list of critical materials (2020), Finland currently provides for just 14% of the EU's cobalt consumption needs mainly through mined cobalt production by Boliden's Kevitsa and Kylylahti deposit and Terrafame's black shale-hosted deposit at Sotkamo (Talvivaara). Since cobalt production is only a secondary operational area for both Boliden and Terrafame, the companies did not disclose their respective production volumes for 2019. Nevertheless, Terrafame's stated that its battery chemicals plant scheduled to become operational in 2021, will have a nickel sulphate capacity for approximately one million EVs per year, while its cobalt sulphate capacity will be sufficient for the production of 300,000 EVs per year.⁶¹

3.4 Vanadium and lithium

According to the USGS, in 2020 five mineral operations in Australia, two brine operations each in Argentina and Chile, and two brine and one mineral operations in China accounted for the majority of world lithium production. Global lithium mine production amounted to a total of 82,000 tonnes in 2020, almost 50% of which – 40,000 tonnes – was produced in Australia.⁶² Global vanadium mine production totalled 86,000 tonnes in 2020 (86,800 tonnes in 2019), over 60% of which – 53,000 tonnes – was produced in China.⁶³

Lithium and vanadium were added to the EC's fourth list of critical raw materials in September 2020.⁶⁴ In the case of processed lithium, the EU recorded 100% import reliance on Chile (78%), the US (8%) and Russia (4%) and noted that the EU would need up to 18-times more lithium for EV batteries by 2030 and almost 60 times more by 2050.

⁵⁹ [Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability](#), EC, 3 September 2020

⁶⁰ [Cobalt resources in Europe and the potential for new discoveries](#), BGS Press, 26 January 2021

⁶¹ [Financial Review 2019](#), Terrafame, 4 March 2020

⁶² [Lithium](#), USGS: *Mineral Commodity Summaries 2021*, 29 January 2021

⁶³ [Vanadium](#), USGS: *Mineral Commodity Summaries 2021*, 29 January 2021

⁶⁴ [Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability](#), EC, 3 September 2020

4 Electric Vehicles

Copper, nickel and cobalt are all vital components of the batteries used in Battery Electric Cars (BEVs) and Plug-in Hybrid Vehicles (PHEVs). The most common type of battery used is the nickel-manganese-cobalt cathode (NMC) lithium-ion which is typically 60% nickel and 20% each of cobalt and manganese. BMW, Hyundai, Nissan, Chevy and Renault all use NMC batteries while Tesla uses the alternative Nickel Cobalt Aluminium Oxide (NCA) chemistry.⁶⁵

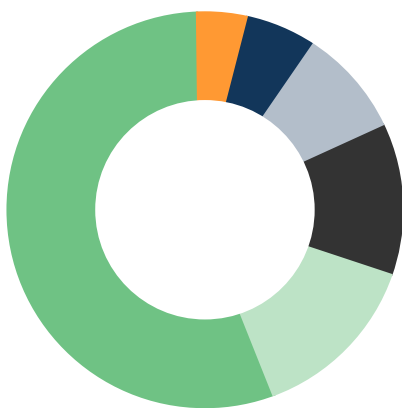
A review of the relevant literature indicates that the average electric car that has an NMC622 cathode 55kWh battery pack would typically require approximately 83kg of copper, 30 kg of nickel, and 12kg of cobalt and 7.5kg of lithium.^{66 67} While these figures are appropriate for the average car battery today it should be considered that two factors will alter the amounts of materials required in future batteries: over the next decade the proportion of BEVs as compared with PHEVs will increase and BEVs require reduced amounts of each material. Meanwhile battery manufacturers are currently looking to reduce the amount of cobalt required and increase the amount of nickel for both NCA and NMC batteries. Higher nickel content provides greater energy density and storage at lower cost, giving vehicles a longer range. Nickel in each battery could increase to as much as 80%.

4.1 Copper

Electric vehicles (EVs) contain approximately four times more copper than conventional cars. The metal is used in batteries but also within electric motors, wiring, busbars and charging infrastructure.

Figure 2: Copper use in electric vehicles

- Conventional cars 23kg
- Hybrid electric vehicles (HEV) 40 kg
- Plug-in hybrid electric vehicles (PHEV) 60kg
- Battery electric vehicles (BEVs) 83kg
- Hybrid electric bus (Ebus HEV) 89kg
- Battery powered electric bus (Ebus BEV) 224-369kg



Source: International Copper Association⁶⁸

⁶⁵ [How Nickel is Replacing Cobalt in Electric Vehicles](#), PR News, 9 October 2020

⁶⁶ [Copper Drives Electric Vehicles](#); Copper Development Association accessed 14 February 2021

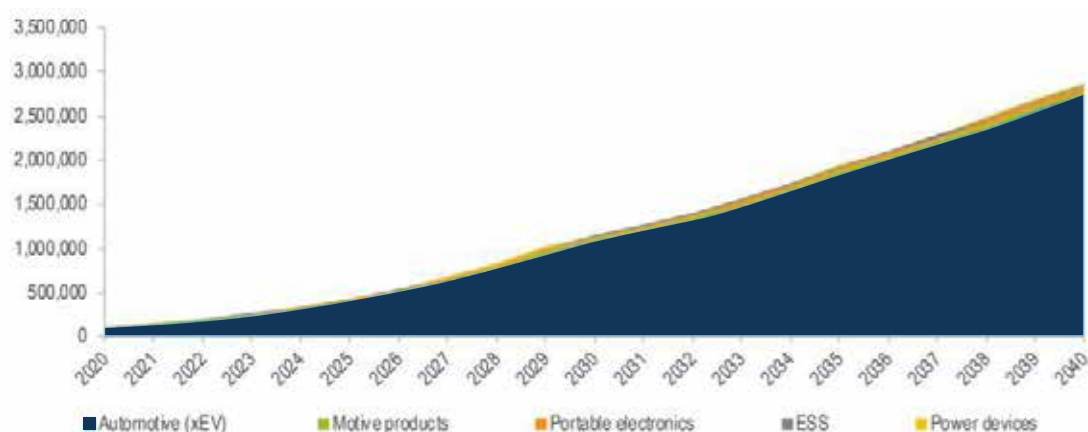
⁶⁷ [Lithium and Cobalt, a tale of two commodities](#); McKinsey & Company, June 2018

⁶⁸ [Copper intensity in the electrification of transport and the integration of energy storage](#), International Copper Association, April 2017

4.2 Nickel

Nickel demand across all battery applications is forecast to total 2.86Mt Ni by 2040, of which 95% will be required by the electric vehicle industry.⁶⁹ Of the various battery chemistries in widespread production, four currently use nickel: nickel metal hydride (NiMH), nickel cadmium (NiCd), nickel-manganese-cobalt (NMC) and nickel-cobalt-aluminium oxide (NCA). Given the longer ranges and efficiencies associated with the metal, both Asian and European countries are expected to focus on high nickel- cells in the long term. Lithium-ion batteries require nickel sulphate whose demand is set to increase to 1,200kt Ni by 2030 and 3,000kt Ni by 2040 based almost solely on the battery sector.⁷⁰

Figure 3: Nickel demand by battery application, based on expected product sales, 2020-2040



Source: Study on future demand and supply security of nickel for electric vehicle batteries, Roskill 2021⁷¹

4.3 Cobalt

The growing adoption of electric vehicles as part of the global energy transition will lead to a significant increase in demand for cobalt. Estimates vary as to the scale of that demand increase which is dependent on the growth of the electric and hybrid vehicle markets as well as the development of battery technology. A 2018 report by the consultancy McKinsey estimated demand would increase by 60% from 136kt in 2017 to 222kt in 2025. More recent studies have produced more conservative estimates, largely due to lower projected vehicle volumes. According to a recent study on cobalt published in the journal *Ore Geology Reviews*, the total amount of cobalt required for lithium-ion batteries in electric cars and vans produced in the EU in 2025 is estimated at 52,000 tonnes.⁷²

⁶⁹ [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

⁷⁰ [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

⁷¹ [Study on future demand and supply security of nickel for electric vehicle batteries](#), Publications Office of the European Union, 2021

⁷² [Cobalt resources in Europe and the potential for new discoveries](#) *Ore Geology Reviews*, March 2021

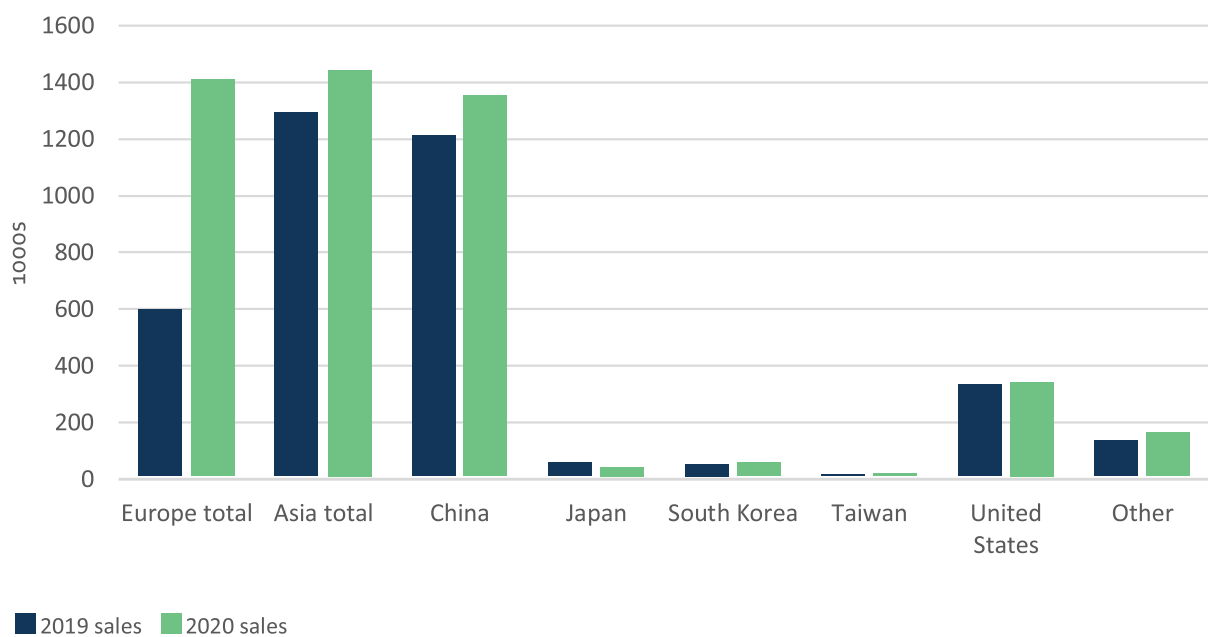
5 European electric vehicle sales

In 2020, sales volumes of electric cars in Europe surpassed China for the first time. Europe's market increased by 137% on 2019 levels compared to growth in China of just 12% where the market was held back by the Covid-19 pandemic.⁷³ This followed growth of 44% in Europe during 2019 and Q1 2020.⁷⁴ In 2019 sales increased by more than 10% in almost every European country with The Netherlands and Germany contributing to almost half of that growth.

The recent increase in EV sales in Europe has led to supply bottlenecks at battery cell makers in Asia, even before the pandemic prompted wider disruptions to supply chains. In March 2020 it was reported that Audi had to slow down production of electric cars at its plant in Brussels due to a battery cell shortage. Volvo and Volkswagen were also facing challenges after battery supplier Samsung issued a profit warning due to the coronavirus outbreak and Jaguar Landrover admitted to flying components from China to the UK in suitcases.⁷⁵

German car makers have an 18% share of the country's EV market however it is reported that in 2019 almost every one of those cars was built with imported batteries.⁷⁶

Figure 4: Electric vehicle sales (BEV and PHEV) 2019 and 2020



Source: EV volumes.com, the electric vehicle world sales database.

⁷³ [EV volumes.com](https://www.evolumes.com) accessed 14 February 2021

⁷⁴ [McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales](#), McKinsey & Company, 17 July 2020

⁷⁵ [Explainer: Why automakers are on a drive to sell electric cars in Europe](#), Reuters, 3 March 2020

⁷⁶ [Can Europe be a contender in electric-vehicle batteries?](#) Chemical and Engineering News, 13 July 2020

5.1 European electric vehicle production

Figures from McKinsey's Future Mobility Initiative suggest that global EV production will increase from 3.2 million units in 2017 to 13 to 18 million units in 2025 and 26 to 36 million units in 2030.⁷⁷

According to IHS Markit figures, Europe produced around 750,000 EVs in 2019, a total which is set to rise to more than 4 million in 2025. This equates to an increase from 4% of market share in 2019 to 22% market share in 2025.⁷⁸ Production growth can be broadly split between Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) with BEV increasing the share of overall production over the next decade.

According to a report by the European Federation for Transport and Environment, by 2025, Germany, France, Spain, Italy and the UK will produce about 85% of Europe's EVs. However, Europe's leading manufacturers will split operations between Europe and Asia. For example, BMW is forecast to see nearly 52% of its EV production in Europe in 2027 and 44% in China. Volkswagen AG is expected to also concentrate more than half of its EV production in Europe through 2027, followed by 40% in China.⁷⁹

Increased EV production in Europe is being driven by consumer choice and EU regulations which oblige carmakers to reduce the average emissions from their vehicles to 95g of CO₂ per km. In the first six months of 2020, average emissions fell from 122g to 111g, the largest six-month drop in more than a decade.⁸⁰ According to the consultancy McKinsey, manufacturers will have to bring over 2 million electric cars onto the market in 2021 to avoid fines being paid to the European Union.⁸¹

China's sales and production of EVs was badly hit by the Covid-19 pandemic in 2020 however it is forecast that it will return to double-digit growth during 2021. Specifically, around 3.5 million EVs are forecast to be sold in 2021, with China producing an estimated 6.4 million EVs in 2025.

Table 6: European and China EV production 2019-2025 (forecast)

	2019	2021	2025
Europe			
BEV	450,000	1 million	2.5 million
PHEV	300,000	1 million	1.8 million
Total	750,000	2 million	4.3 million
China			
Total	1.2 million ⁸²	3.5 million ⁸³	6.4 million ⁸⁴

Sources: Carmakers' electric car plans across Europe 2019-2025, Transport and Environment, July 2019; Electric mobility after the crisis: Why an auto slowdown won't hurt EV demand; IHS Markit forecasts global EV sales to rise by 70% in 2021.

⁷⁷ [Lithium and Cobalt, a tale of two commodities](#); McKinsey & Company, June 2018

⁷⁸ [Carmakers' electric car plans across Europe 2019-2025](#), Transport and Environment, July 2019

⁷⁹ [EV Production: Where, How Soon?](#) SME, 31 August 2020

⁸⁰ [Electric car sales triple in race to meet Europe CO₂ rules](#), Financial Times, 12 October 2020

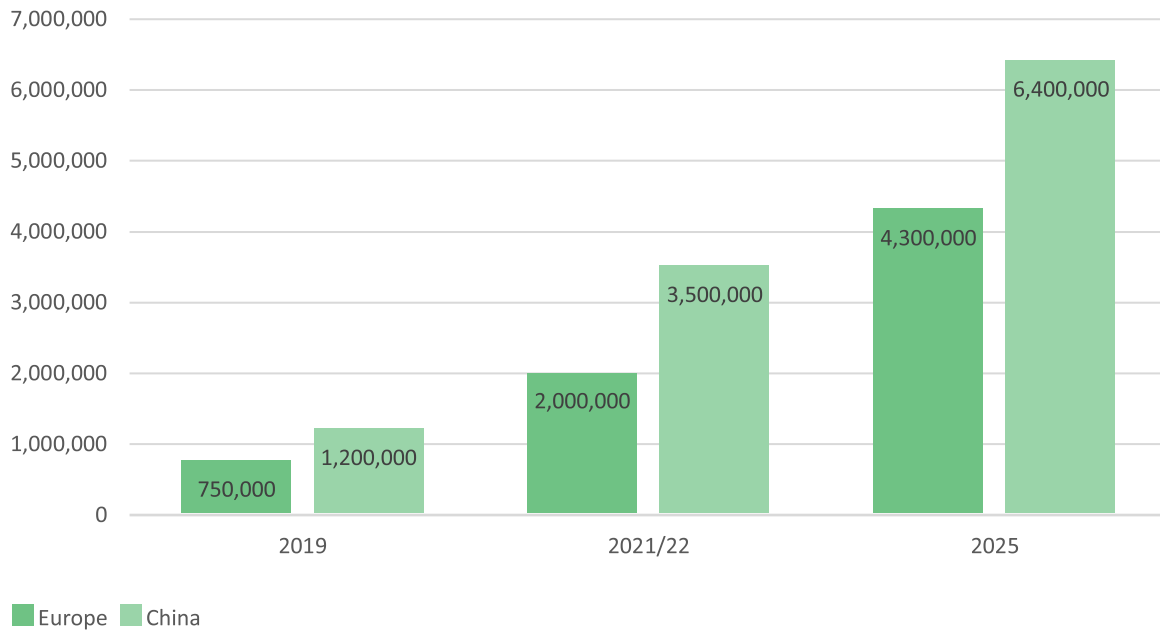
⁸¹ [Electric Vehicle Index: Europe is becoming a hotspot for electromobility](#), McKinsey & Company, 2 March 2020

⁸² [Electric mobility after the crisis: Why an auto slowdown won't hurt EV demand](#) McKinsey & Company, 16 September 2020

⁸³ [Electric mobility after the crisis: Why an auto slowdown won't hurt EV demand](#) McKinsey & Company, 16 September 2020

⁸⁴ [IHS Markit forecasts global EV sales to rise by 70% in 2021](#), IHS Markit, 19 January 2021

Figure 5: European and Chinese EV (BEV and PEV) production forecast:



5.2 Quantities of critical materials required for the electric car revolution

Based on the European production figures and forecasts, an estimate was made regarding the quantities of copper, nickel and cobalt required to support the manufacture of Battery Electric Vehicles and Plug-in Hybrids on the continent.

Table 7: Materials requirements forecast for EVs

	No. EVs produced	BEV / PHEV	Copper (BEV=83kg and PHEV = 60kg)	Nickel (30kg)	Cobalt (12kg)
2019	750,000	40% BEV 60% PHEV	51,900 tonnes	22,500 tonnes	9,000 tonnes
2021	2 million	50% BEV 50% PHEV	143,000 tonnes	60,000 tonnes	24,000 tonnes
2025	4.3 million	60% BEV 40% PHEV	317,340 tonnes	129,000 tonnes	51,600 tonnes

According to the European Federation for Transport and Environment report, based on forecasted battery sizes, the total lithium-ion battery demand from EV (BEV, PHEV and hybrid) production volumes within the EU is expected to reach 112 GWh in 2023 and 176 GWh in 2025.

From 2023 Europe's own gigafactories will account for a total of at least 131 GWh of annual battery production capacity. Based on current EV production estimates, this will be around 15% more than the demand from electric cars and vans in the same year.

Table 8: Forecast battery capacity requirements in Europe

	2019	2023	2025
Europe			
BEV	-	91 GWh	148 GWh
PHEV	-	17 GWh	23 GWh
Full Hybrid	-	4 GWh	7 GWh
Total	-	112 GWh	176 GWh

Source: Carmakers' electric car plans across Europe 2019-2025, Transport and Environment.⁸⁵

⁸⁵ [Carmakers' electric car plans across Europe 2019-2025](#), Transport and Environment, July 2019

6 Electric bikes

6.1 European E-bike production

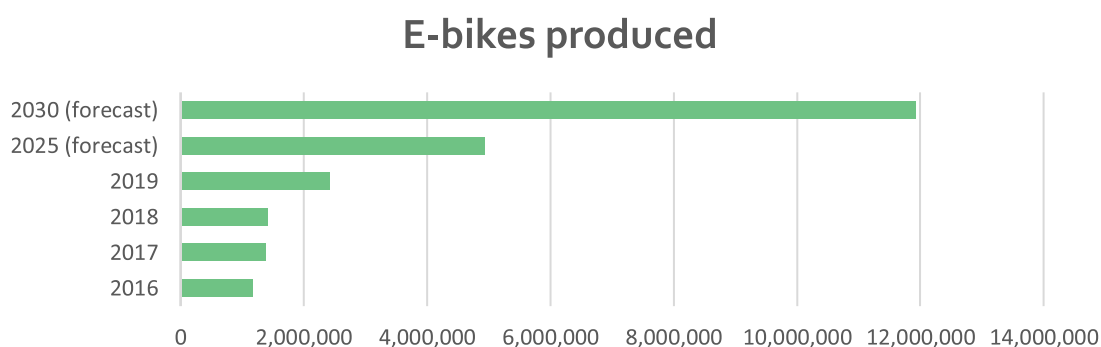
According to the European Bicycle Manufacturers' Association, in 2016 a total of 1,164,000 e-bikes were produced in the EU, an increase of 13% on the previous year⁸⁶. In 2017 Europe produced between 1.3 and 1.4 million e-bikes, rising by a further 0.7% in 2018.⁸⁷ By comparison, in 2016 China reportedly produced 51 million e-bikes, 23 million more than its domestic consumption capacity.

Following the European Union's introduction of anti-dumping tariffs on e-bikes from China in January 2019, it was reported in February 2020 that e-bike production in the EU grew by more than 100% in a single year.⁸⁸ The anti-dumping duties reportedly led to a 91% drop in imports into the EU during the first six months of 2019.⁸⁹ In 2019 2.3 to 2.4 million e-bikes were produced in the EU.

The EU has not reaped all the benefits from the drop-off in Chinese imports since 2019. As a result of the tariffs, other countries such as Taiwan, Vietnam, Thailand and Turkey have increased their exports to the EU. Meanwhile, Asian investors such as the e-bike motor manufacturer Bafang have opened an operation in Poland.

The Confederation of the European Bicycle Industry forecasts that by 2025 a total of 7 million e-bikes will be sold in Europe annually and that 4.9 million of these (70%) will be manufactured in Europe.⁹⁰ Others view this estimate as conservative and predict that at the current pace of growth, by 2024 there will be 10 million e-bikes sold in Europe each year⁹¹. Sales of e-bikes in Europe are predicted to reach 17 million in 2030.

Figure 6: E-bikes produced in the EU



Source: The European Bicycle Manufacturers' Association and the Confederation of the European Bicycle Industry.

⁸⁶ [European Bicycle Manufacturers Association EU anti-dumping complaint to stop China dumping e-bikes](#) accessed 14 February 2021

⁸⁷ [Press release: The 2020 Bicycle Industry & Market Profile with 2019 figures is now available](#), Confederation of the European Bicycle Industry, 13 July 2020

⁸⁸ [EBMA President: 'E-Bike Production in EU to Triple in Next Five Years'](#), 4 February 2020

⁸⁹ [EU e-Bike production up 100% in one year](#) *Cycling Industry News*, 5 March 2020

⁹⁰ [Volume European E-Bike Market Forecasted to Triple within Next Five Years](#), *Bike Europe*, 2 October 2019

⁹¹ [E-Bike Sales To Grow From 3.7 Million To 17 Million Per Year By 2030](#), *Forecast Industry Experts*, *Forbes*, 2 December 2020

6.2 Materials requirements of e-bikes

E-bikes typically use the same NMC lithium-ion batteries commonly found in electric cars although a typical e-bike battery would be about a tenth of the size of an electric vehicle at 36v. Based on this figure, the quantities of materials for an electric vehicle NMC battery were divided by a factor of ten. According to this calculation, a typical electric bike would require 8.3kg of copper, 3kg of nickel and 1.2kg of cobalt.

Table 8: Materials requirements forecast for e-bikes

	E-bikes produced	Copper (8.3kg)	Nickel (3kg)	Cobalt (1.2kg)
2019	2,400,000	19,920 tonnes	7,200 tonnes	2,880 tonnes
2021 (forecast)	4,900,000	40,670 tonnes	14,700 tonnes	5,880 tonnes
2025 (forecast)	11,900,000	98,770 tonnes	35,700 tonnes	14,280 tonnes

6.3 Battery production and localisation of markets

European car manufacturers have struggled to secure sufficient battery supply and investments in battery technology have tended to be concentrated in Asia. As recently as 2019, 46 of the 70 planned gigafactories globally were based in China. Unlike China, Europe has not benefitted from an industrial strategy to attract battery manufacturing.⁹²

Today, car manufacturers and the makers of components are looking to localize production in key target European markets. According to a July 2020 McKinsey report, McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales, this trend is leading the likes of Tesla to establish a production plant in Germany while brands such as Volkswagen and Toyota have plans to establish plants in China. By 2040, based on a range of scenarios, European EV production could require EU-based battery manufacturing of 0.7–1.5 TWh a year, the equivalent of 45–95 gigafactories.⁹³ The value of the battery cell market on its own would be around EUR 90 billion per year.⁹⁴

According to McKinsey, in 2019 the total lithium-ion–battery market for EV passenger cars grew by 17% to 117 gigawatt-hours, enough to power 2.4 million standard BEVs.⁹⁵ It is reported that most of the new capacity will be established in Central Europe, with companies preparing to meet demand throughout the region.

Growth in battery-cell manufacturing in Europe means the continent could be self-sufficient and no longer have to rely on imported batteries by 2025.⁹⁶ In Europe there are currently 15 large-scale battery cell factories under construction on top of existing facilities. Existing and planned facilities include:

⁹² [Recharging economies: The EV-battery manufacturing outlook for Europe](#), McKinsey & Company, 2019

⁹³ [Recharging economies: The EV-battery manufacturing outlook for Europe](#), McKinsey & Company, 2019

⁹⁴ [Recharging economies: The EV-battery manufacturing outlook for Europe](#), McKinsey & Company, 2019

⁹⁵ [McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales](#), McKinsey & Company, 17 July 2020

⁹⁶ [EU says it could be self-sufficient in electric vehicle batteries by 2025](#) Euractiv.com, 25 November 2020

Northvolt: plant in Skelleftea, Sweden with an initial line of 16 GWh (2021), increasing to 32 GWh in 2023. A second plant in Salzgitter, Germany in cooperation with Volkswagen to start in March 2020 with 12 GWh.

CATL: the Chinese battery maker is building a facility in Erfurt, Germany with 14 GWh as of 2021, rising to 60 GWh from 2026 (and likely boosted further to 100 GWh).⁹⁷

SK Innovation: the South Korean firm is building a second plant in Hungary.

German partnership (BMZ & others): Company formerly known as TerraE consortium, aiming at two factories and capacity of 34 GWh by 2028.⁹⁸

Tesla: has begun construction of its first European gigafactory in Berlin, Germany.

LG Chem: is building a battery Gigafactory in Wroclaw, Poland which is scheduled for completion in 2022 and will produce 65-70GWh per year.⁹⁹

Umicore: the Belgian materials technology and recycling group has received financing for a cathode factory in Poland.

Automotive Cells Company (ACC): in 2020, the energy firm Total announced a joint project with French carmaker Groupe PSA to manufacture batteries for EVs in Europe. ACC is expected to start production in 2023. The project is expected to attract investment of USD 5.9 billion, with EUR1.3 billion already secured from the governments of France and Germany. Total's subsidiary, SAFT, will reportedly provide research and development expertise while PSA is expected to provide car manufacturing capacity. An R&D centre in Bordeaux and a pilot site in Nersac, France. Following the R&D phase, the companies are planning to open a gigafactory in Douvrin, France and a second one in Kaiserslautern, Germany.

Verkor: the firm's first gigafactory is scheduled to begin production in 2023 with 16GWh capacity¹⁰⁰. The company has backing from Schneider Electric, real estate group IDEC and the EU's European Institute of Innovation & Technology (EIT) with initial investment of about EUR 1.6 billion.

BritishVolt: plans to develop the UK's first gigafactory in South Wales with the start of production targeted for 2023.

Freyr: the Norwegian company is seeking funding for a EUR 4.5 billion EV gigafactory in northern Norway.

AESC: Built in Sunderland in the UK, 2 GWh.

Skeleton Technologies: The Estonian firm is developing technology to increase charging speeds for electric vehicles.¹⁰¹ The firm is developing the SuperBattery, a graphene battery with a 15-second charging time with minimal degrading over time. The company is partnered with the Karlsruhe Institute of Technology to complete the project.

Pensana Plc: in January 2021 the company submitted a planning application for its proposed rare earth oxide separation plant in Yorkshire, UK. The plant would be the first rare earths processing facility in Europe.¹⁰²

The European Battery Alliance has targeted manufacturing capacity of 200 GWh/year by 2025. It is expected that Sweden's Northvolt and France's SAFT will own about 25% share of the supply in Europe while LG Chem, Samsung SDI and SK Innovation may take about 48% of share, and a China's CATL and SVOLT a further 22%.¹⁰³

⁹⁷ [Carmakers' electric car plans across Europe 2019-2025](#); Transport and Environment, July 2019

⁹⁸ [Carmakers' electric car plans across Europe 2019-2025](#); Transport and Environment, July 2019

⁹⁹ [EV gigafactories: Europe moves up a gear](#); *TXF* 9 September 2020

¹⁰⁰ [Europe is making faster cars and better batteries than Tesla](#); *Sifted*, 7 September 2020

¹⁰¹ [Europe is making faster cars and better batteries than Tesla](#); *Sifted*, 7 September 2020

¹⁰² [Pensana submits application for Europe's first rare earths processing plant](#); *Mining Technology*, 25 January 2021

¹⁰³ [The Future is Electric](#); *JP Morgan*, 17 November 2020

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