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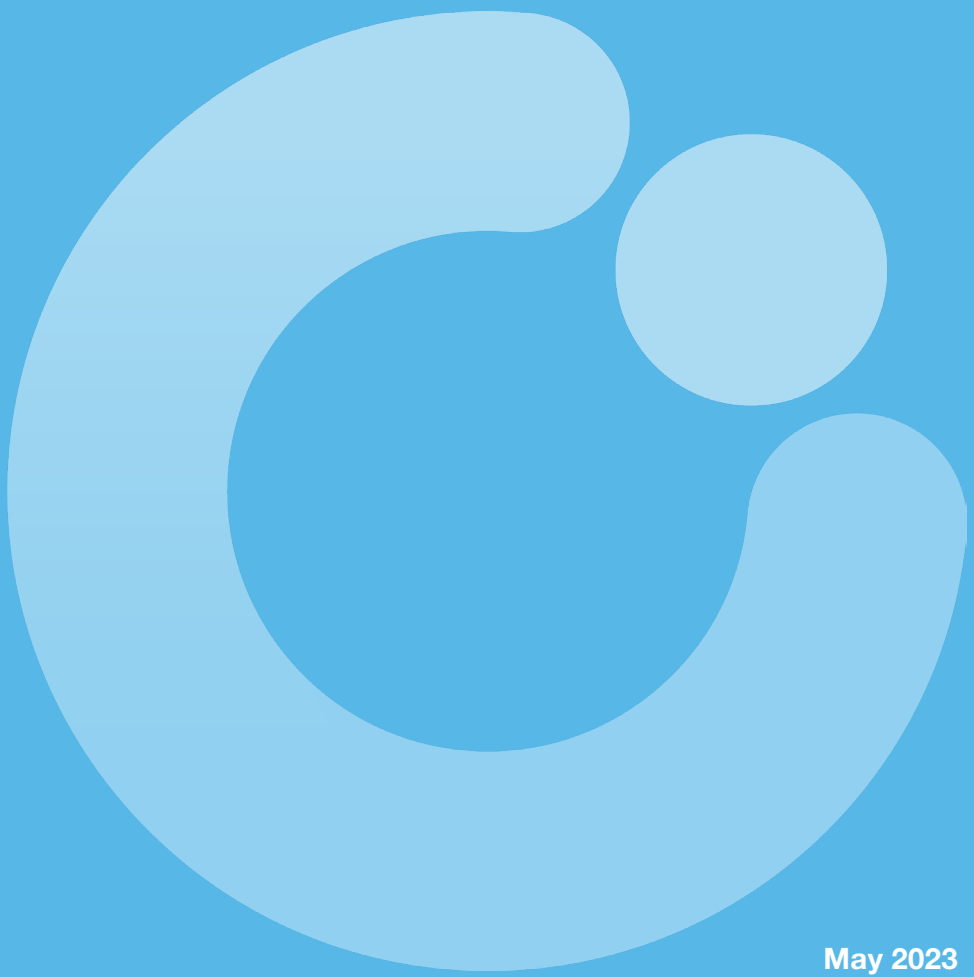
Cobalt Market Report 2022



May 2023

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BENCHMARK

Benchmark Mineral Intelligence was commissioned by The Cobalt Institute to prepare the 2022 Cobalt Market Report, summarising the key trends in the cobalt market across demand, supply, prices and geopolitics.

This was prepared using Benchmark's Quarterly Cobalt Forecast and the Cobalt Price Assessment which is published every two weeks. In addition, Benchmark's Recycling and ESG reports have also been referenced.

1 | FOREWORD:

"COBALT IS PART OF THE SOLUTION TO A GREEN AND JUST ENERGY TRANSITION"

– CAROLINE BRAIBANT, INTERIM DIRECTOR GENERAL, HEAD OF SCIENTIFIC AND REGULATORY AFFAIRS, COBALT INSTITUTE

In the context of growing demand for critical minerals and increased geopolitical activity to achieve security of supply, cobalt is considered as part of the solution to achieving green, equitable and just energy transition.

The publication of the Cobalt Institute's "Cobalt Market Report" – the most comprehensive market overview to date – provides an in-depth analysis of the trends driving the demand for this unique commodity. The Cobalt Institute publishes this report to make the supply chain data accessible to everyone and to help underpin a broader approach to transparency.

For the first time, the report looks at the market trends through the prism of the policy environment. Legislative initiatives such as the US Inflation Reduction Act and the EU Critical Raw Materials Act can change the future of cobalt as governments aim to secure access to critical raw materials, whilst ensuring the longevity of domestic industries and lifting living standards.

2022 was a turbulent year for cobalt demand: market conditions have weakened and the price environment was challenging. In the longer term, demand for cobalt is expected to outpace supply, lifting prices and supporting a new wave of investment.

Indonesia became the second largest cobalt producer in 2022, and has the potential to increase cobalt supply by 10 times by 2030, with new projects being announced on a regular basis.

On the demand side, the EV sector became by far the largest cobalt consumer and now accounts for 40% of total cobalt demand. To 2030, global cobalt demand is set to double, driven by battery applications in EVs.

All cobalt stakeholders – industry, governments, civil society – should build on this momentum to use cobalt's potential to achieve the green and just energy transition and make a cleaner world a reality.

2 | EXECUTIVE SUMMARY

2022 WAS A TALE OF TWO HALVES FOR THE COBALT MARKET

The first four months of the year were characterised by a strong price environment with prices in April reaching close to the last peak in 2018. However, market conditions quickly unravelled as supply chain constraints eased, cobalt supply growth continued and demand stumbled, particularly for portable electronics. As a result, cobalt metal prices halved from the April peak to year end.

After becoming the largest end use sector for cobalt in 2021, EVs gained further ground in 2022 and now account for 40% of total cobalt market end use demand. EVs alone supported 86% of annual demand growth whilst the traditional, non-battery applications accounted for just 6% of growth (with a 28% share of 2022 demand). Total cobalt demand rose 13% y/y in 2022 to 187 kt.

Nickel-cobalt-manganese (NCM) chemistries became the largest driver of cobalt demand, above all other end-use markets. 2022 was the first year in which lithium cobalt oxide (LCO) demand was not the primary driver of cobalt demand from battery applications. Weakness in the portable electronics markets was a major theme for cobalt in 2022 – LCO cathodes are the most cobalt-intensive of the major chemistries and account for close to 80% of the portables market.

Mined supply grew faster in 2022 than in 2021 (21% vs 14% y/y) and approached 200 kt, alongside easing supply chain constraints. The DRC remained the major supplier, with a 73% share, and contributed 70% of annual growth. **Indonesia became the second largest producer in 2022**, due to the rapid development of domestic nickel-cobalt mines and high pressure acid leach capacity, overtaking established producers including Australia and the Philippines. With 5% of 2022 supply, it remains a long way behind the DRC, despite supporting 20% of global annual growth; although long term growth potential is high.

Cobalt is expected to remain a key raw material for the entire battery supply chain, despite the persistent theme of substitution of cobalt in battery applications. Multiple cell formulations (mostly NCM and lithium iron phosphate, LFP) will support the major end-use sectors, with no single battery cell technology expected to dominate. Nickel-cobalt chemistries will maintain a large share of demand and a number of recent announcements from major downstream players also **reinforces cobalt's key position in the energy transition.**

Demand is forecast to rise by more than 200 kt to 2030 with the market size doubling relative to 2022 and approaching 400 kt – this demand story shows a strong outlook for cobalt despite some efforts to reduce material intensity.

On the supply side, the **DRC will continue to play a major role** and will contribute 44% of growth to 2030. This will be **closely followed by Indonesia's rapidly growing cobalt and nickel markets** – the country has the potential to support 37% of mined supply growth to 2030 as supply increases 10-fold.

Secondary cobalt supply from recycling has provided minimal volumes to date (5% of total supply in 2022) but is expected to support 15% in 2030 and more than 40% by 2040.

Market conditions have weakened substantially since the price peak in 2022. This dynamic will likely remain through to 2024, as a plentiful and growing supply surplus maintains pressure on prices. **In the longer term, demand for cobalt will outpace supply, lifting prices and supporting a new wave of supply side investment.**

The policy environment has changed markedly in the last 12 months with the Inflation Reduction Act (IRA) in the US and the Critical Raw Materials Act (CRMA) in the EU being announced for these major lithium-ion battery growth markets. Both will change the future of cobalt and other battery raw materials markets as policies aim for a greater proportion of demand to be met by regional supply.

3 | GEOPOLITICAL SPOTLIGHT

FOR MANY COMMODITY MARKETS, THE GEOPOLITICAL LANDSCAPE IS COMPLEX, AND IT IS NO DIFFERENT FOR COBALT, OR THE LITHIUM-ION BATTERY VALUE CHAIN AS A WHOLE. THIS SECTION PROVIDES AN OVERVIEW OF THE MOST IMPORTANT CONSIDERATIONS FOR THE COBALT MARKET, BOTH THROUGH THE DEVELOPMENTS OF 2022 AND ALSO KEY POLICY DRIVERS EVOLVING IN 2023.

3.1 | THE IMPORTANCE OF THE USA'S INFLATION REDUCTION ACT FOR THE ENTIRE BATTERY SUPPLY CHAIN

To advance the US' transition to cleaner energy over the next decade and beyond, in August 2022, US President Joe Biden signed into law the Inflation Reduction Act (IRA). The IRA has wide-reaching implications for the battery supply chain. The Act stipulates that a certain percentage of the value of critical minerals in a battery be mined or processed in the US or in a country with which it has a Free Trade Agreement (FTA), in order to qualify for the credits, as defined below. In addition, batteries must not contain components that are manufactured or assembled by a foreign entity of concern (FEOC) as well as critical minerals that are extracted, processed, or recycled by a FEOC – the Internal Revenue Service (IRS) will further clarify on the definition of FEOC in future guidance(s).

The policy continues to evolve, however in the latest guidance, the Treasury Department and the IRS propose to identify the countries with which the United States has FTAs in effect for purposes of Section 30D of the IRA.

The US already has comprehensive FTAs with 20 countries – Australia, Bahrain, Canada, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Jordan, South Korea, Mexico, Morocco, Nicaragua, Oman, Panama, Peru, and Singapore.

The Treasury Department and the IRS also propose to include additional countries as FTA partners for the purposes of the IRA credits. Japan, for example has recently concluded a Critical Minerals Agreement (CMA) with the US containing robust obligations to help ensure free trade in critical minerals. In a similar way, the US and the European Union (EU) are in discussions on a targeted critical minerals agreement for the purpose of enabling relevant critical minerals extracted or processed in the EU to count toward requirements in Section 30D (clean vehicle tax credits) of the IRA.

China dominates processing of critical battery raw materials – regionalised supply chains particularly in North America and Europe need to be developed, requiring significant investment and cooperation. Securing and/or localising the cathode value chain for North America will require policy support in the form of guarantees, tax credits and subsidies. The IRA along with other pieces of US legislation have created demand and supply side incentives for stimulating the whole battery metal value chain towards onshoring of manufacturing in the US market. Since the IRA was announced, there have been a number

of significant announcements, such as LG committing $5.5 billion on a battery plant in Arizona, $3.6 billion from Tesla for an expansion in Nevada, Ford investing $3.5 billion in an EV battery plant and General Motors planning a new battery plant with Samsung SDI, both in Michigan. Tesla has also announced that it will focus on expansions in the US following the IRA.

The most notable parts of the IRA are as follows (available funding is based on the latest official estimates and is subject to change):

- **The Clean Vehicle Credit** to incentivize the flow of raw materials and cell components to the USA as automotive OEMs seek to meet supply chain conditions. A tax credit of up to $7,500 per passenger vehicle is available, with $3,750 if critical minerals are sourced from North America and compliant countries and $3,750 if battery components are sourced from North America.

- **The Advanced Manufacturing Production Credit** to incentivize the mid and downstream stages of the US lithium-ion battery (LiB) supply chain (active material, cell and module production in the US). For critical minerals and battery active materials, a 10% production tax credit is available. For batteries – $35/kWh for cells and $10/kWh for modules.

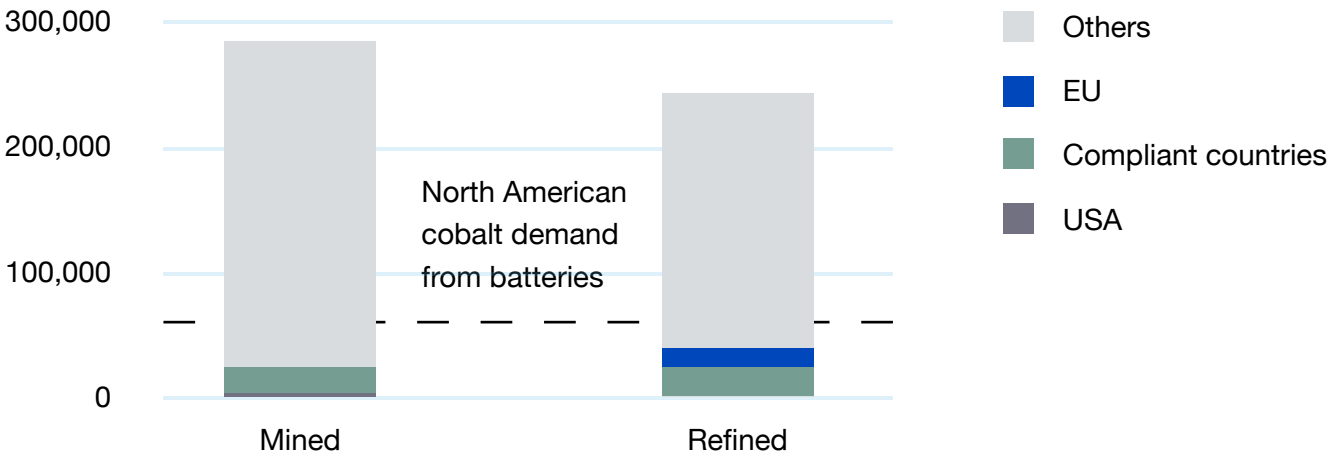
- **The Advanced Energy Project Credit** for the build out of energy storage projects. It includes a 6% base tax credit with up to 30% (+10%) of additional credits available.

For cobalt, similar to other critical battery raw materials, the IRA is likely to re-shape global supply chains, with compliant countries benefitting from the proposed incentives. Based on current guidance, FTA countries and Japan (and potentially the EU) are likely to be the biggest beneficiaries – of the major cobalt-producing countries, Australia, Canada, Morocco and Finland are in this category and they accounted for just 7% of global mined output in 2022.

The chart below clearly shows the gap between supply from the US and compliant countries and regional demand in 2025. It is likely that origination rules, and specifics around the location of refining primary units, will need to relax further to allow US companies to satisfy requirements for cobalt (and other minerals), particularly in the mid to long term. Countries such as Australia and Canada are likely to benefit from accelerated project development to fill the gap, although the supply pipeline is currently limited.

Major cobalt producers that are not currently listed as compliant under the IRA include the DRC, Indonesia, Madagascar and the Philippines (with a combined 82% of mined cobalt in 2022). Cobalt units from these countries are likely to be required for refining feedstock in the US or other compliant countries.

Figure 1: Mined & refined cobalt supply in 2025, compared to North American demand



Data: Benchmark Mineral Intelligence – Cobalt Forecast.

3.2 | THE EU'S APPROACH – THE CRITICAL RAW MATERIALS ACT

Since the announcement of the IRA, the EU has been under pressure to clarify its position on supply chain localisation, particularly as the IRA could starve ex-North America regions of investor appetite and the capital required to rapidly develop their own LiB supply chains. The EU's response came in March 2023 as it pledged to substantially increase mining and mineral processing of critical raw materials this decade, as part of plans to build a European clean energy economy and reduce reliance on China.

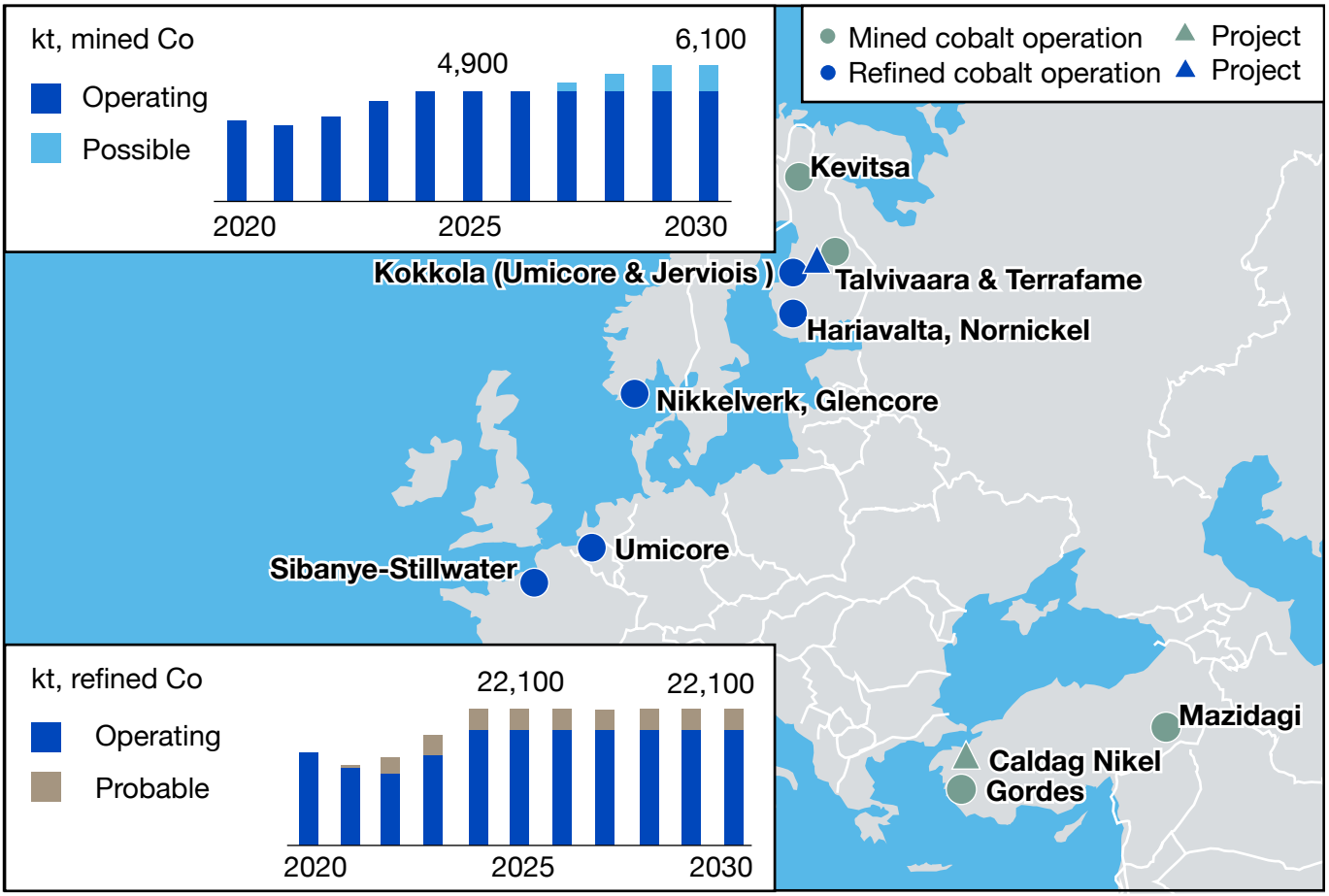
The proposed Critical Raw Materials Act (CRMA) aims, by 2030, for at least 10% of the EU's annual consumption of strategic raw materials to be met by European mining, and at least 40% of its processed minerals demand. At least 15% of the mineral consumption should come from European recycling and the EU proposes that no more than 65% of Europe's demand will come from any single non-EU country. Another important aspect is the classification of strategic projects to speed up permitting processes and the assessment of a project's environment footprint.

Cobalt is listed as a strategic and critical raw material alongside other important battery metals. Currently Europe only accounts for 2% of mined and 12% of global refined cobalt – based on the size of known reserves and current development plans, this share is unlikely to change markedly in the mid to long term.

Given that only 10% of the EU's consumption is aiming to come from mining in the region, and there is limited supply growth potential, it is likely that the existing major players (the DRC and Indonesia) will remain key suppliers. Investment will be required (alongside accelerated permitting) to achieve the CRMA's objectives – it is most likely at the refined, rather than mining, stage of the supply chain by bringing cobalt sulphate production closer to the growing end use markets, as the mid and downstream sector develops. Given a relatively straightforward logistics route, new European refining capacity would likely rely on DRC feedstock.

Europe's ability to meet these targets will depend, in part, on the broader regulatory environment it creates. For example, it is currently proposing an Occupational Exposure Limit for cobalt that could have a major effect on the economic viability of all cobalt refining and recycling facilities in the EU. A low exposure limit could offset the benefits of the CRMA and redirect funding out of the EU, where the beneficiaries might be countries with less strict regulation, such as the US or UK, or refining to remain within China.

Figure 2: European mined & refined cobalt operations & projects expected to be in operation by 2030



Data: Benchmark Mineral Intelligence – Cobalt Forecast.

3.3 | THE RELATIONSHIP BETWEEN THE DRC & CHINA

China has been a key player in cobalt mining in the DRC since the Sino-Congolaise des Mines (Sicomines) agreement was signed in 2007 – the majority of operations in the DRC are now fully or partially Chinese-owned. In recent times, however, the relationship has become more complicated. In 2021, President Tshisekedi accused the previous government of signing lopsided contracts with mining companies, particularly those in China, and indicating that he wanted these to be renegotiated. The DRC is also under pressure from the International Monetary Fund (IMF) to address contract concerns as a condition of further credit support.

In March 2022, a temporary administrator was appointed by the DRC courts to operate CMOC Group Ltd's (CMOC) Tenke Fungurume Mining (TFM) operation. In July 2022, TFM was banned from exporting cobalt or copper by the administrator, following a dispute about CMOC incorrectly declaring reserves at the world's second largest cobalt-producing mine, thus impacting royalty payments to Gécamines. The dispute highlights the DRC Government's commitment to addressing concerns about prior agreements with mining companies, seemingly particularly those agreed with Chinese companies. It has set a precedent for negotiations with other miners operating in the DRC, with Sicomines now in discussions as well.

The export ban lasted for 10 months until late April 2023 when CMOC and Gécamines reached an agreement. Exports are expected to resume in late April with a large volume of stockpiles understood to be on site – we estimate this to be more than 16 kt of cobalt. It is likely to take at least a year to clear the backlog.

TFM accounted for 13% of the DRC's and 10% of global production in 2022 and the outcome of the prolonged dispute had the potential to fundamentally change the dynamics of the global cobalt market.

At the same time as these ongoing disputes, in January 2023, the USA signed a Memorandum of Understanding (MOU) with the DRC and Zambia on electric vehicle battery value chains as part of a broader effort to improve cooperation and opportunities in Africa and reduce reliance on China for critical minerals. President Biden hosted more than 40 African leaders in December 2022 and a number of senior US officials have visited Africa since then. Most recently, Vice President Kamala Harris, the highest-ranking official to date, undertook a week long tour of Africa, including a visit to Zambia. The EU had been less visible in the DRC, but most recently, following a visit to the DRC from high level officials in March 2023, the EU has invested EUR 50 million into the DRC's critical minerals sector and infrastructure projects. This forms part of the EU's Global Gateway Initiative in response to China's Belt and Road Initiative.

3.4 | INDONESIAN MARKET SHARE BUILDING – CHINESE INVESTMENT & ESG CONSIDERATIONS

As discussed later in this report, Indonesia is a key growth market for cobalt (and nickel) – supply has the potential to increase by more than 10 times to 2030 and account for a third of global growth. There are two key areas to consider as part of this thematic – Chinese investment and ESG considerations.

LEVEL OF CHINESE INVESTMENT

All four of the high pressure acid leach (HPAL) facilities currently operating or planning to start in 2023 are run by Chinese-Indonesian companies – PT Lygend, Huayue Nickel & Cobalt, PT QMB and PT Huayu. As such, the majority of these mixed hydroxide precipitate (MHP) volumes are destined for China. Despite initial industry scepticism, the ramp up of HPAL operations in Indonesia has been successful and faster than expectations. Much of this is due to the expertise of the Chinese processing companies involved and the efficiency of the supply chain between Indonesia and China, providing access to equipment, spare parts and other input materials.

Other smaller cobalt volumes, as a by-product of nickel matte, are produced by Jinchuan, a Chinese company, as well as others.

The dominance of China in Indonesia poses risks for the wider market, similar to the dominance of DRC production. This is particularly the case with developing policy from the US and Europe to reduce reliance on China across the Li-ion value chain and push for greater diversification of supply. With 75% of cobalt refining already in China, a rising share of intermediate material from Chinese-Indonesian projects risks moving further away from a greater degree of self-sufficiency for other markets. It remains unclear if Indonesian cobalt will eventually be IRA- compliant.

Investment in Indonesian HPAL capacity remains very limited from companies outside of China and Indonesia, with only BASF and Eramet announcing a project to date – due to start in 2026. Other companies such as LG Energy Solutions, Volkswagen and EcoPro have announced projects, although these all involve Chinese partner(s).

The current outlook indicates that a large proportion of Indonesia's cobalt and nickel expansions will be from Chinese-Indonesian companies which risks the success of the IRA and the EU's CRMA.

ESG CONSIDERATIONS

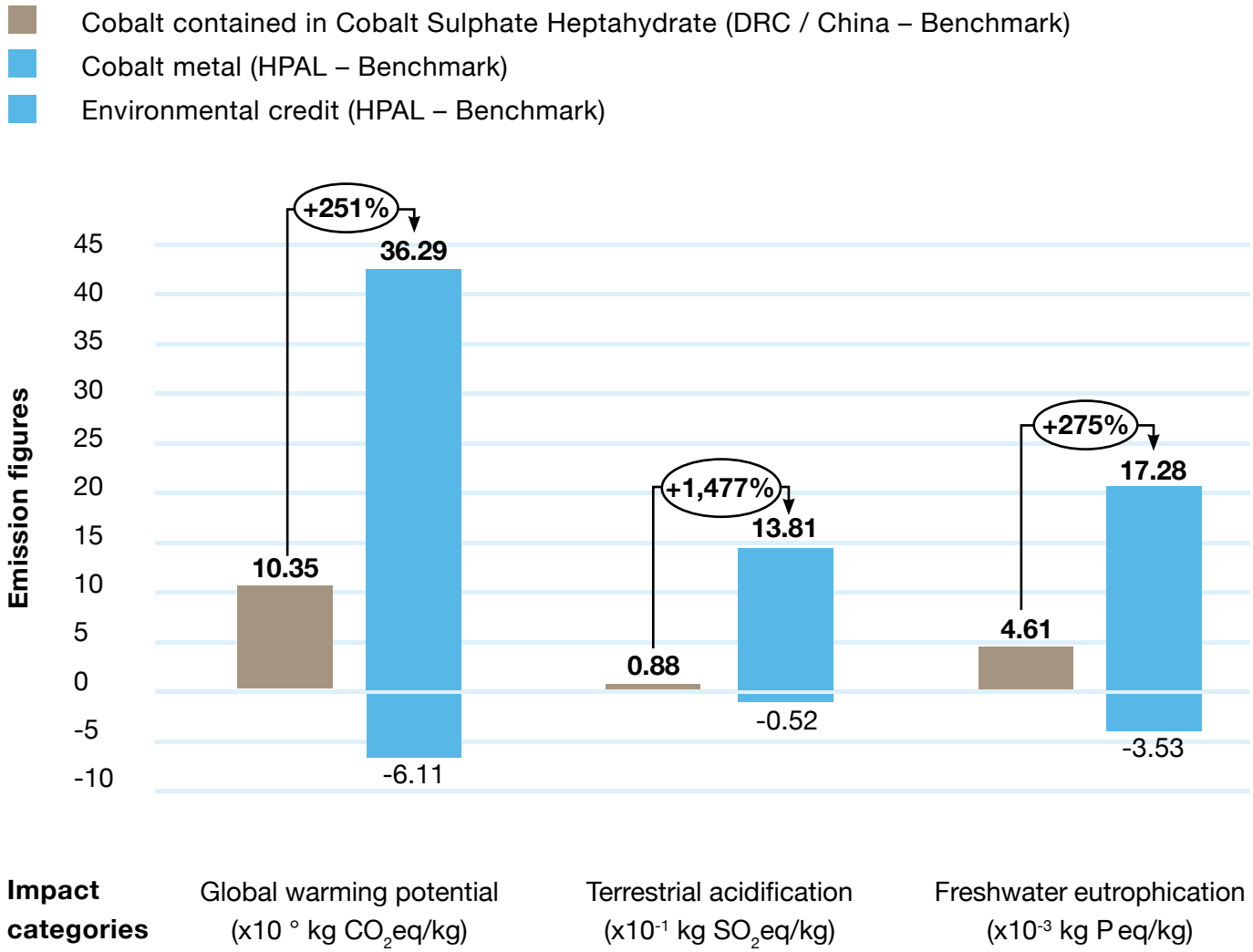
With production ramping up so rapidly in Indonesia and the country growing in importance for the future of the cobalt and nickel markets (and the wider battery value chain), there are increased concerns about the adherence to environmental standards, particularly for waste treatment, and safety at operations, with a number of major accidents being reported. Indonesian cobalt is of high biodiversity concern, with average species richness and rarities of 73% and 95% respectively. With increasing scrutiny from the wider industry, some of these aspects are likely to improve, and the involvement of major Western companies should also support adherence to higher operating standards as ESG-compliance is critical for these organisations.

Benchmark's life cycle assessment (LCA) has analysed emissions factors of the main cobalt production routes. The major route to cobalt sulphate, from mining in the DRC to refining in China, has been compared to the emerging Ni-Co HPAL route in Indonesia. Modelled routes are not based on primary data for a single site, and as such assumptions (such as for fuel usage / grid mix / process emissions, etc) have been made.

HPAL demonstrates higher global warming potential (36 kg of carbon dioxide equivalent, CO2eq, against 10 kg CO2eq), and also has a higher impact in acidification and eutrophication burdens – see figure below. Because of the low volume of cobalt produced in HPAL (primary nickel route), more materials and more energy are consumed to produce the same quantity of cobalt due to the lower ore grade in Indonesia. The global warming potential could be improved in future if Indonesia can reduce their reliance on coal and diesel fuel sources and transition to a larger share of renewable energy sources.

A $20 bn fund was announced at the 2022 G20 summit to accelerate Indonesia's shift to renewable energy. The Just Energy Transition Partnership (JETP) is likely to help cobalt and nickel producers to reduce the carbon footprint of their products.

Figure 3: Global cobalt LCA analysis – summary of key metrics (2023 basis)



Data: Benchmark Mineral Intelligence – Cobalt ESG Report & LCA analysis.
Note: CO2 = carbon dioxide, SO2 = sulphur dioxide, P = phosphorous, eq = equivalent.
For both the DRC and Indonesian HPAL routes, electricity and production direct emissions are the main contributors to the Global Warming Potential (GWP). These will vary from site-to-site and our model is an average and includes the country-level electricity mix. Limestone is a common material in both routes and is responsible for CO2 emissions in the chemical reaction of these processes. Electricity contribution to GWP varies from a 20% share in HPAL to 26% for the DRC-China route.

3.5 | RUSSIA'S POSITION IN THE COBALT MARKET

Since Russia's invasion of Ukraine in February 2022, flows of Russian cobalt (and nickel) have been disrupted due to a combination of self-sanctioning by end users and impacts on logistical routes. The overall market impact has been muted, however, due to Russia (specifically Nornickel) not being a large-scale cobalt producer – in 2022, Nornickel accounted for 2% of mined and 1% of refined globally supply, with a similar share in 2021.

Some sales to existing contract customers have continued but there has been reports of larger volumes of cobalt and nickel sales to China, using a combination of LME prices and Shanghai Futures Exchange prices in yuan.

3.6 | GEOPOLITICAL SUMMARY & RISK MATRIX

The risk matrix below provides a summary of the geopolitical aspects discussed in this section and comments on the likelihood and level of potential impact to the cobalt market.

- **IRA:** re-shaping of supply chains, particularly benefitting the USA, FTA countries and Japan on the supply side.
- **CRMA:** refined capacity in Europe likely to benefit more than mining.
- **DRC & China relationship:** potential for disputes with other operators, impacting mined supply.
- **Indonesia:**
  - **Level of Chinese investment:** large, and growing, share of new supply development may impact IRA targets unless other trade/IRA- compliance measures are introduced. Diversification of investment is required.
  - **ESG considerations:** rising awareness and scrutiny should improve compliance – this will be necessary for Western end users otherwise alternative sources will be required, with limited supply growth elsewhere, except from the DRC.
- **Russia:** market has already adjusted to reduce the risk of potential sanctions.

Figure 4: Geopolitical risk matrix for the cobalt market

Risk matrix		Level of potential impact to the cobalt market				
		Negligible	Minor	Moderate	High	Significant
Likelihood of market impact	Very likely			CRMA	IRA	
	Likely			Indonesia-Chinese investment		
	Possible	Russia		Indonesia-ESG	DRC & China relationship	
	Unlikely					
	Very unlikely					

Source: Benchmark Mineral Intelligence. Note: categories are based on the level, or significance, of potential impact to the cobalt market, rather than being positive or negative.

4 | DEMAND: EV DEMAND GROWTH OFFSETS SLUGGISH PORTABLE ELECTRONICS MARKET

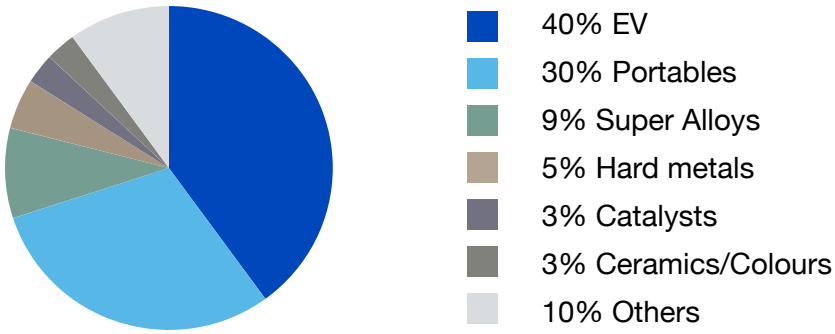
4.1 | OVERVIEW OF DEMAND IN 2022

2022 was a turbulent year for cobalt demand. The year started positively with momentum from 2021 and strong EV market growth, however widespread COVID- 19 lockdowns in China from March 2022 created significant disruption across the Li-ion battery supply chain, on both the supply and demand side.

EV and consumer electronics demand suffered and lithium iron phosphate (LFP) cathodes continued to gain market share in China, both setting the tone for much of the rest of the year. Despite this weakness in the second half, cobalt demand maintained annual growth (+13%), albeit weaker than 27% y/y in 2021.

Total cobalt demand rose to 187 kt in 2022, up 21 kt from 2021. Battery applications now account for 72% of cobalt demand, up from 55% in 2018 and 70% in 2021.

Figure 5: Demand share of cobalt end use sectors in 2022, %

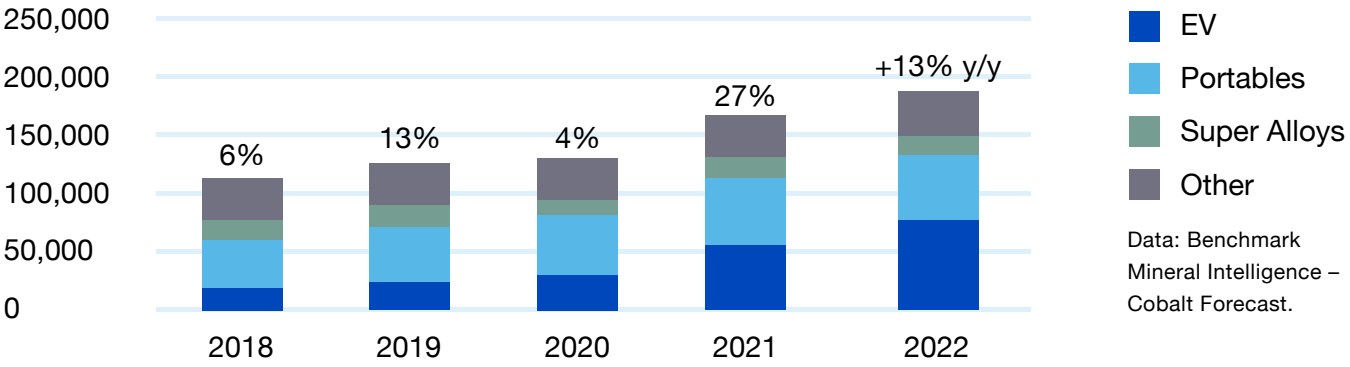


Data: Benchmark Mineral Intelligence – Cobalt Forecast.

Note: 'Others' includes hard facing, 4,295 t; magnets, 3,431 t, and other applications including energy storage, tyres, soaps and paint driers.

The EV sector was the strongest performer, contributing 86% of overall cobalt demand growth and rising 33% y/y. After becoming the largest end use sector for cobalt in 2021, EVs gained further share of demand, rising to 40% of the total market. The portable electronics sector also contributed to this dynamic as it was the only sector to see no growth in overall demand in 2022.

Figure 6: Cobalt demand growth by sector, tonnes of cobalt

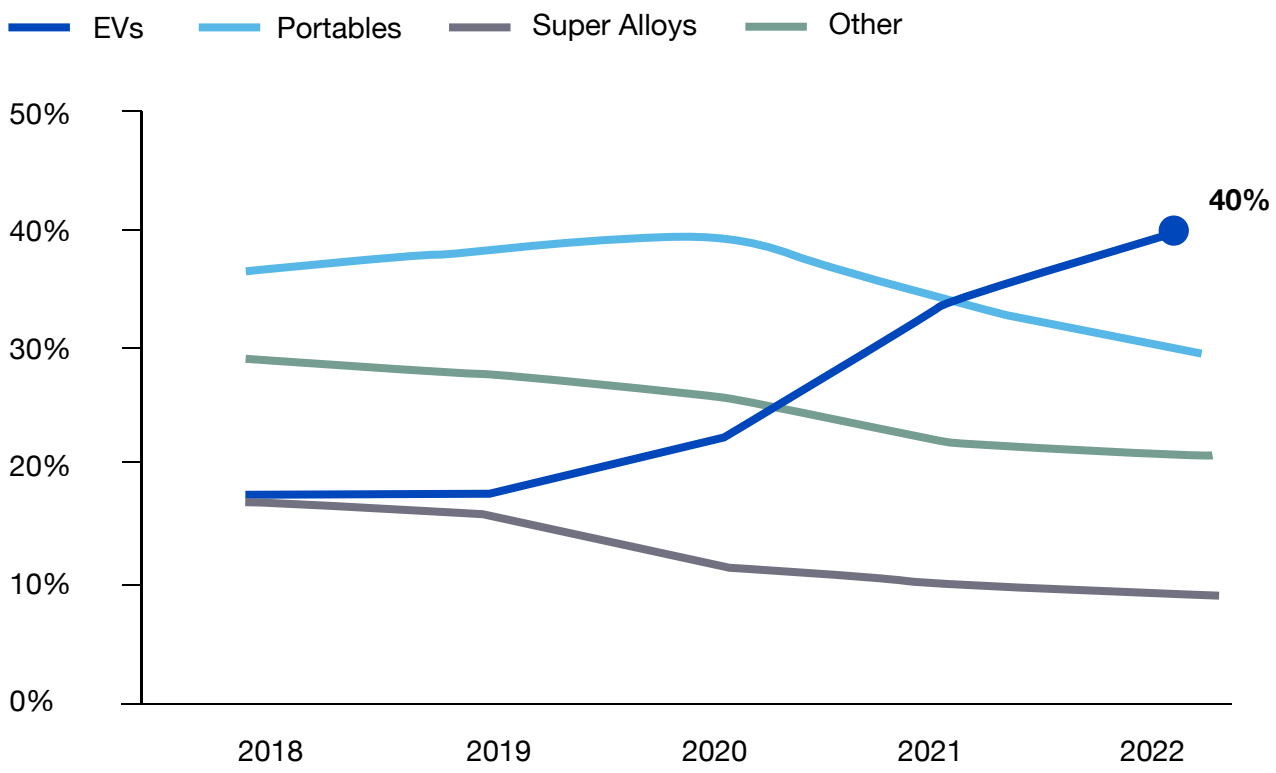


Data: Benchmark Mineral Intelligence – Cobalt Forecast.

Albeit from a low base, the energy storage sector was the best performer y/y in 2022 – cobalt demand grew 61% y/y; although this contributes only 2% of total demand currently.

The traditional end uses, including super alloys, saw growth rates of 2-3% y/y, contributing 6% to overall annual demand growth (1.3 kt combined). Despite the rapid growth of Li-ion battery applications, the traditional end uses still account for 28% of overall cobalt demand. Super alloys is the largest of these sectors with 9% market share.

Figure 7: Share of total cobalt demand by sector, %



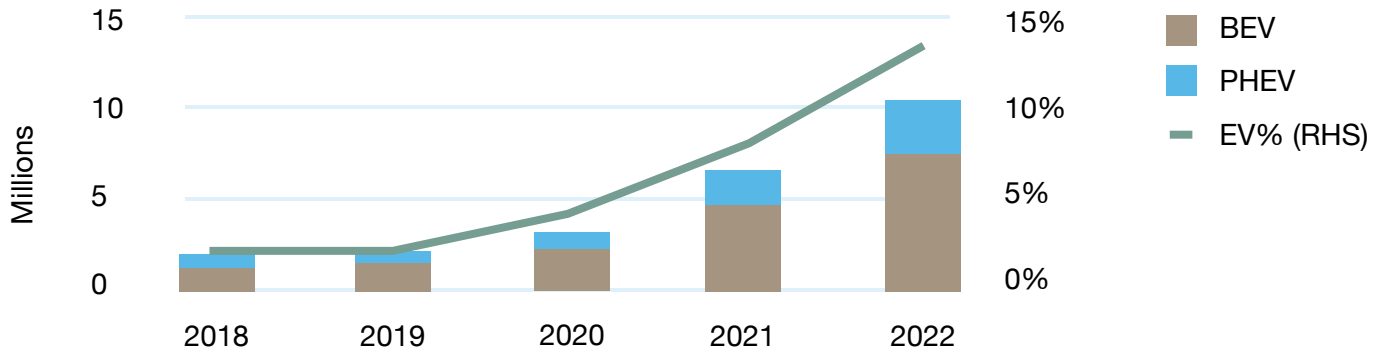
Data: Benchmark Mineral Intelligence – Cobalt Forecast.

4.2 | EV MARKET

After being neck and neck in 2021, the EV sector is now by far the largest cobalt consumer after pulling ahead of portable electronics – it now accounts for 40% of total cobalt demand, with this share continuing to rise. Demand from the sector reached 74 kt in 2022, up 33% y/y from 56 kt in 2021.

Global EV sales grew by more than 3.8 million units in 2022, larger than the entire global market in 2020, to 10.3 million units. BEVs supported close to 80% of overall EV sales growth, with total EV penetration rates rising to 13%, up from 8% in 2021.

Figure 8: Global passenger & light duty vehicle EV sales, millions of units



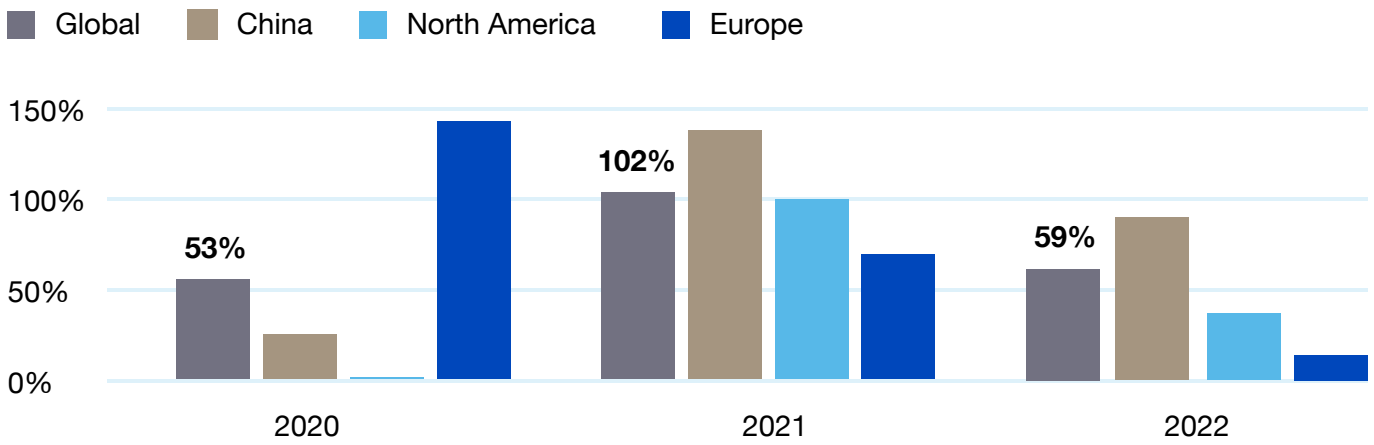
Data: Rho Motion.

Global EV sales grew 59% y/y, down from 102% y/y in 2021, however, maintaining very strong growth rates despite market headwinds, including China's COVID-19 lockdowns (EV production fell 33% m/m in April 2022 during the first month of lockdown and NEV sales declined 38% m/m), inflation and rising cost of living pressures, high battery raw material costs, semiconductor shortages and broader macroeconomic factors.

China continued to lead the charge in the global EV market, contributing 75% of global market growth, as sales exceeded 6 million units, close to doubling from 2021. Sales were particularly strong later in the year before the end of subsidies. EV penetration averaged more than a quarter of the total passenger vehicle market in 2022, with this share even higher later in the year. Chinese NEV exports are also increasing quickly, indicating rising demand for Chinese EVs internationally. This trend reflects China's dominance in battery components and the region's ability to scale supply to meet surging demand.

In Europe and North America, growth rates could not match 2021 but maintained strong momentum, rising 15% and 38% y/y, respectively. Penetration rates remain much higher in Europe, now above 20%, compared to 7% in North America.

Figure 9: Growth in total EV sales by major region, y/y %



Data: Rho Motion. Note: passenger & light duty vehicles only.

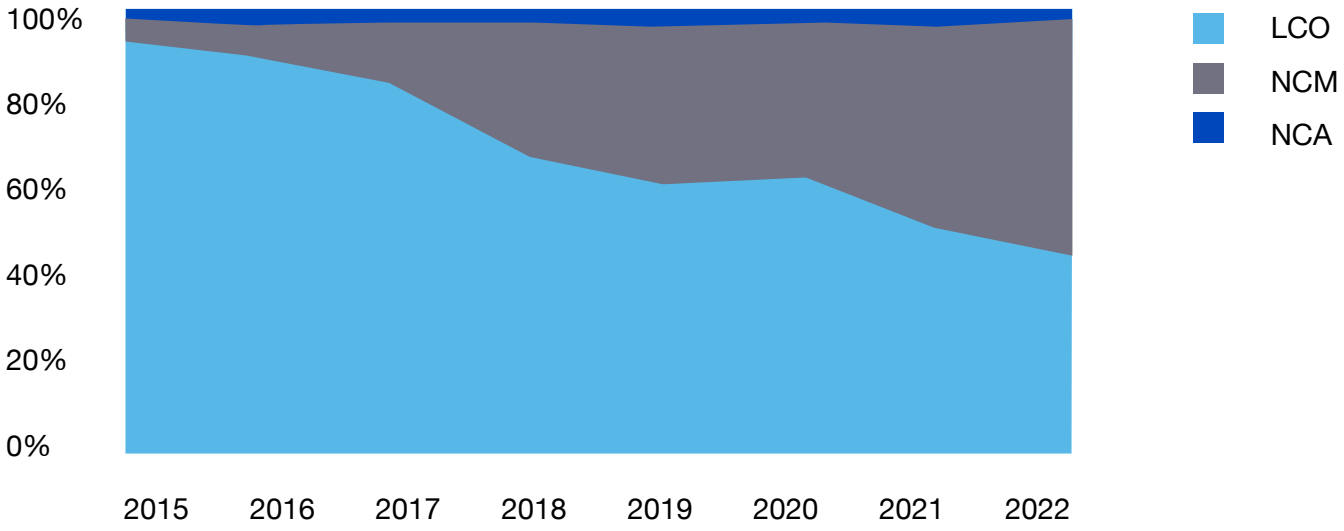
4.3 | PORTABLE ELECTRONICS

Portables battery demand has grown steadily in recent years and accelerated in 2020 (+22% y/y), as the COVID-19 pandemic significantly increased purchasing of portable devices, particularly laptops and tablets, and power tools. However, much of this demand was pulled forward and has slowed substantially since.

Portable electronics demand continued to stumble in 2022 which was a key theme for the cobalt market – it was the only sector where cobalt was flat y/y. This sector is important for cobalt, as 77% of portables demand is for lithium cobalt oxide (LCO) cathodes which have the highest cobalt intensity of the major chemistries and more than 4 times as much cobalt as nickel-cobalt-manganese (NCM) 622 on a kg/kWh basis.

In fact, 2022 was the first year in which LCO was not the largest driver of cobalt demand from batteries, as it was overtaken by NCM. LCO's overall share has fallen quickly in recent years as the EV sector has dwarfed portable electronics – 94% of cobalt demand from batteries was from LCO in 2015, falling to 46% in 2022.

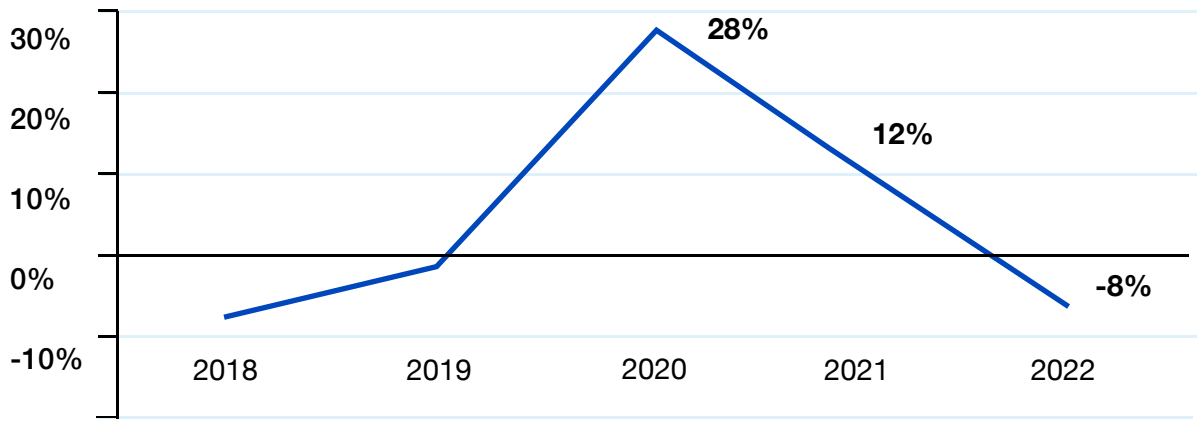
Figure 10: Share of cobalt demand from batteries by chemistry, %



Data: Benchmark Mineral Intelligence – Cobalt Forecast.

Cobalt demand for portables was flat y/y in 2022, with LCO demand falling by 8% y/y on a MWh basis. Market weakness was exacerbated by rising cost of living pressures forcing consumers to curb expenditure; supply chain constraints (exacerbated by the war in Ukraine) put further pressure on the sector. According to the International Data Corporation (IDC), a market intelligence firm for consumer electronics, global smartphone shipments declined 11.3% y/y in 2022. Laptop and tablet markets were also under pressure throughout the year. As a result, several consumer electronics manufactures have been forced to downgrade their production targets after a fall in shipments in 2022, with Apple reporting in Q4 that production of the iPhone 14 would be 3 million units lower than previous guidance.

Figure 11: Annual LCO demand, y/y %

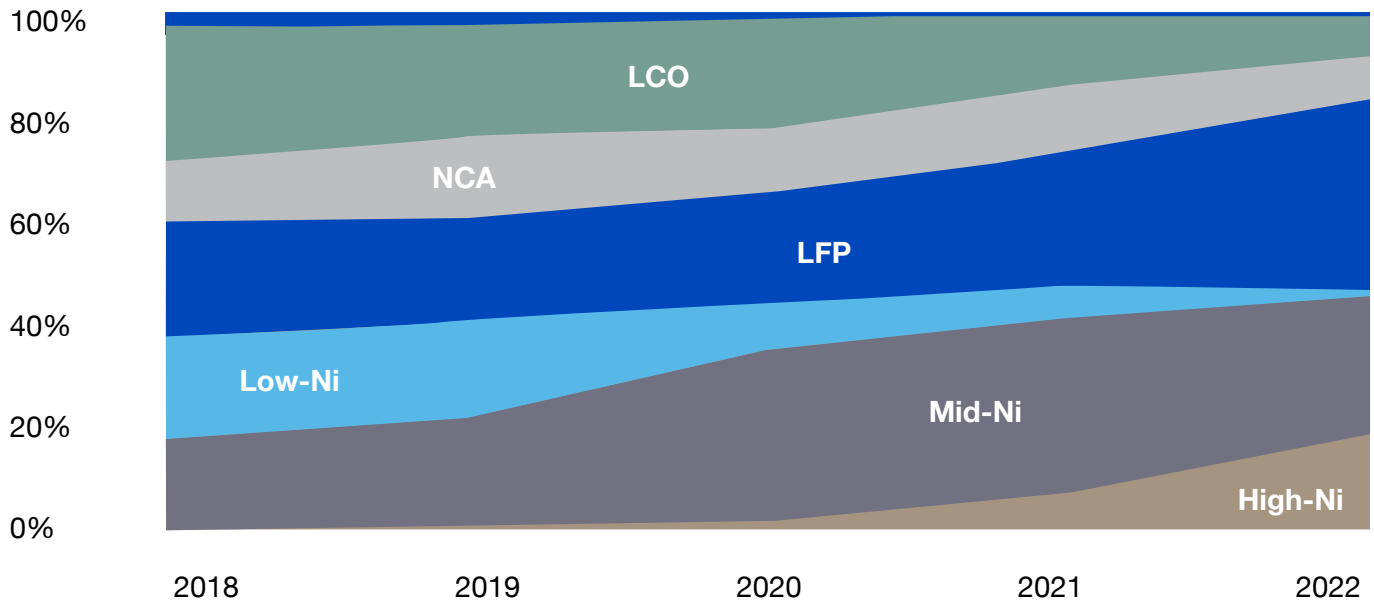


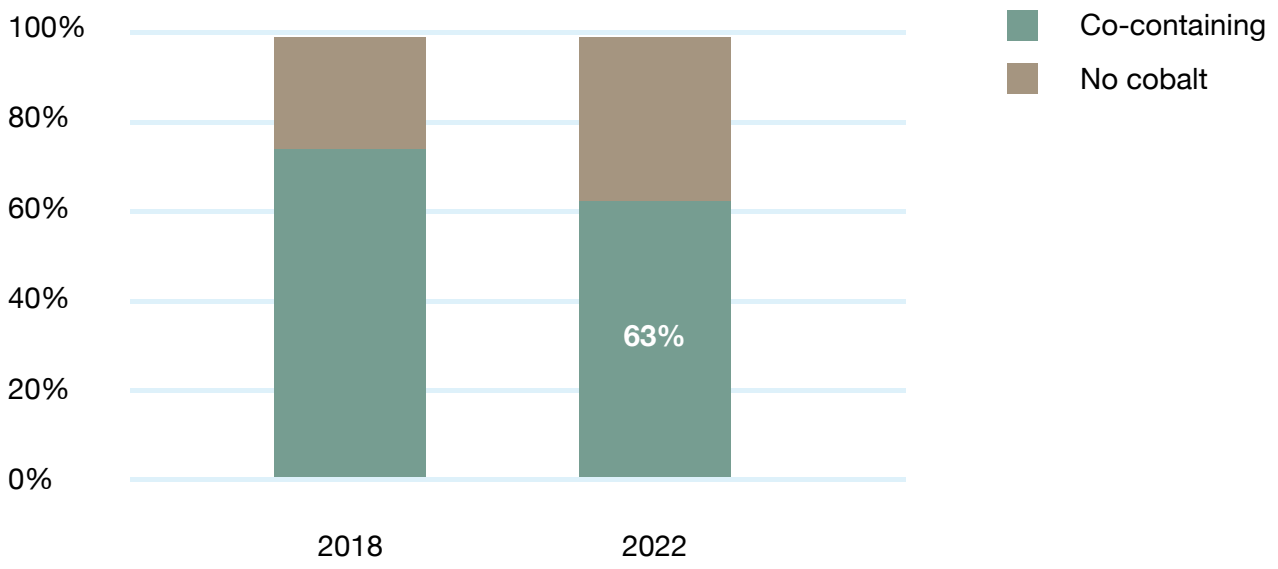
Data: Benchmark Mineral Intelligence – Cobalt Forecast.

4.4 | CATHODE CHEMISTRY TRENDS

The NCM cathode chemistries are now the major driver of cobalt demand from batteries as LCO demand remains weak. Within NCM, mid-nickel maintains the largest share of cathode demand (in MWh), at 27%. To benefit from higher energy densities, the sector continues to transition towards higher nickel and lower cobalt intensities in NCM – from 2020 to 2022, the share of low-nickel fell 18% points, mid- nickel rose 9% and high-nickel rose 19%, whilst LFP gained 14%. High-nickel (811+) is expected to gain the largest share from 2023 onwards. Despite the declining intensity, cobalt remains key for safety and stability – cobalt containing chemistires represented 63% of cathode demand in 2022.

Figure 12: Share of cathode demand by chemistry, %





Data: Benchmark Mineral Intelligence – Cobalt Forecast.

The cobalt industry continues to face pressure despite its importance in the battery supply chain due to:

- Cost – as the most expensive battery raw material on a unit basis
- Efforts to increase energy density – lower cobalt intensities in higher nickel NCM chemistries
- Responsible sourcing and ESG – particularly from the DRC and Indonesia.

NICKEL-COBALT CHEMISTRIES TO REMAIN A CRITICAL PART OF THE EV SECTOR

The view of cathode demand is predominantly based on original equipment manufacturer (OEM) statements of intent regarding cell technology roadmaps. To date, for EV applications, there has been a clear preference for nickel-preference for nickel- cobalt-manganese (NCM)/nickel-cobalt-aluminium oxide (NCA) cathodes, moving towards higher nickel NCM grades over time. Broadly, preferences are split into high-performance applications, which suit high-nickel NCM chemistries (e.g. NCM712+, but more likely NCM811+), or preferences for cycle life, safety and cost, but lower energy density and lower driving range, such as LFP. For energy storage, the long term outlook favours LFP due to safety and cycle life.

No single battery cell technology is expected to prevail, and outlook shows that multiple cell formulations (mostly NCM and LFP) and formats will support the major end-use sectors. High-performance EVs will continue to favour nickel-rich cathodes, such as NCM811+, due to superior energy densities. Demand for low-nickel chemistries is expected to shrink, whereas the mid-nickel market will continue to grow. Regional preferences will vary, with Ni-Co chemistries to remain dominant in Europe and North America, and LFP in China.

LFP technology has improved relative to NCM over the last few years, but possible improvements to come are likely to be equally applicable to NCM – this is a key factor against a comprehensive switch from NCM to LFP. OEM production cycles are typically at least 6-7 years which also limits the rate at which major change in technologies can occur.

A number of Western OEMs have expressed their interest in LFP, particularly for standard-range EVs, including Tesla, VW, Stellantis and Ford. However, outside of China, there remains very little LFP cathode capacity in the pipeline – only 6% of LFP capacity is forecast to be outside of China by 2030. This will also limit a widespread technology shift in Western markets, particularly considering developing policy around sourcing of batteries and raw materials.

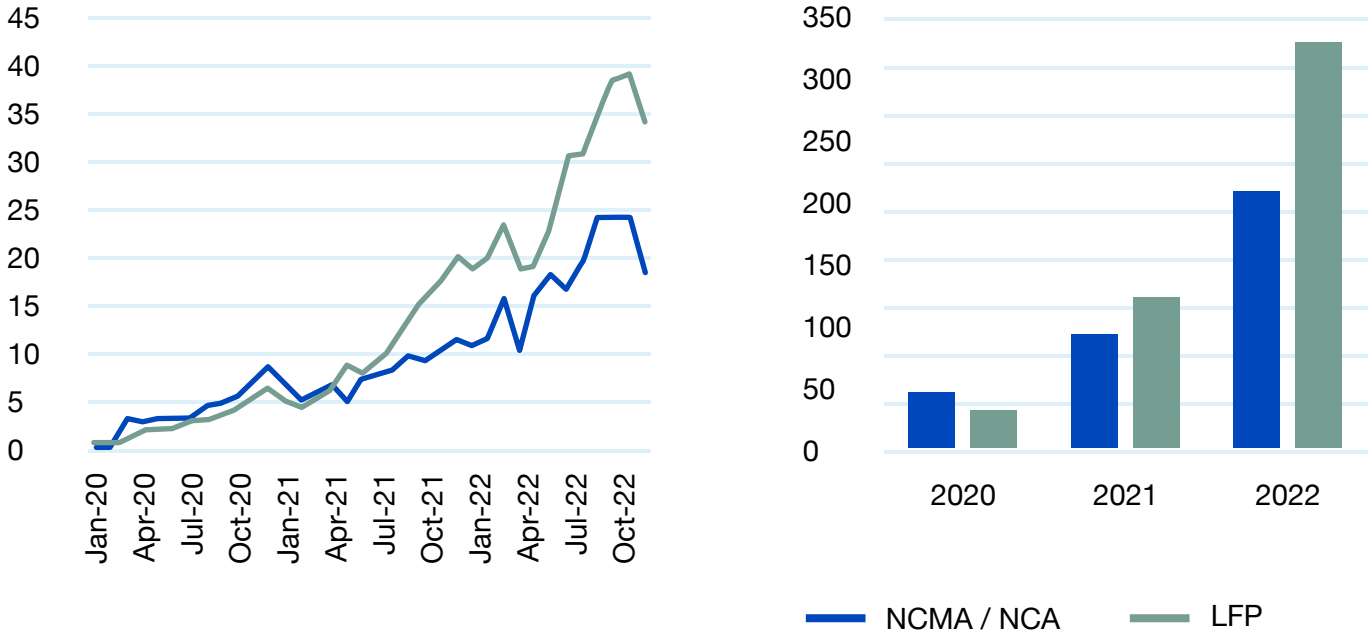
High-manganese, cobalt free chemistries (e.g., LMNO, NMx, NCM307) are being developed and may be a viable alternative, but are likely to account for only a small proportion of total battery demand by 2030, and primarily for EV applications. We remain relatively conservative of new chemistries in the medium term due to the long duration of development and lead time for commercialisation.

This transition in cathode technologies, both within the Ni-Co chemistries and the cobalt-free formulations (namely LFP) caused the weighted average cobalt intensity in the battery sector to fall to 0.16 kg/kWh in 2022, down from 0.59 in 2015 and 0.24 in 2021. However, despite this trend, cobalt demand continues to see strong annual growth with a robust outlook (discussed later in the report) supported primarily by the EV sector.

LFP gained 10% share of global cathode demand in 2022, primarily driven by China where LFP's share is rising quickly due to large capacity additions since mid-2021. LFP capacity rose 269% y/y in 2021 and 164% y/y in 2022, compared to 100% and 124%, respectively, for NCM/NCA. In 2022, 61% of new additions were for LFP capacity, compared to 42% in 2020.

The primary driver of LFP demand growth is the EV sector, accounting for 80% of total LFP demand in 2022. Energy storage is also gaining share, up to just under 20% in 2022 from 9% in 2021.

Figure 13: Cathode capacity installations in China by chemistry, GWh



Data: CAAM/CABIA, Benchmark Mineral Intelligence.

4.5 | DOWNSTREAM ACTIVITY REINFORCES THAT COBALT REMAINS A KEY BATTERY METAL

Cobalt remains a key part of the energy transition in Li-ion battery applications. In addition to the key demand trends discussed above, we have identified a number of key announcements from major players in the downstream in 2022 which emphasise that cobalt remains a critical battery raw material:

- March: **VW** signs MOU with **Huayou** and **Tsingshan** to secure nickel and cobalt supply – first Western OEM to invest directly in the upstream in Indonesia.
- April: **Glencore** signed multi-year deal with **General Motors (GM)** for cobalt from Murrin Murrin.
- April: **LG Energy Solutions** investing $9 billion in battery supply chain in Indonesia.
- June: **Managem** signed multi-year deal with **Renault**.
- July: **Ford** involved in Pomalaa HPAL project with **Vale & Huayou.**
- July: Subsidiary of **CATL** (Sichuan CATL) secured 25% stake of **CMOC**. This is in addition to the 25% stake acquired in the Kisanfu project in 2021.
- October: **Stellantis** signs MOU with **GME Resources** for future nickel and cobalt volumes from development project in Western Australia.
- October: **GM** secures equity in **Queensland Pacific Metals.**

4.6 | SPOT MARKET DEMAND & OTHER COBALT-CONSUMING SECTORS

Purchasing on the spot market was volatile during 2022 as the market was influenced by a number of key events (specifics on pricing trends will be discussed in more detail in Section 6):

- High prices at the start of the year, particularly in Q1, reduced spot market activity.
- In March, demand was stronger outside of China, particularly from the continued recovery in the aerospace sector as travel activity trended back towards pre-COVID levels.
- As the war in Ukraine started, increased purchasing was seen for alternative supply sources as Russian volumes faced potential sanctions.
- Due to extended COVID-19 lockdowns in China from March, there was a slowdown in Chinese purchasing – inventories rose which meant there was a delay in further purchasing post-lockdown.
- Prices started to turn from May onwards as negative sentiment built in the market and end users delayed purchasing until prices fell further from the peak.

- Macroeconomic headwinds (e.g. inflation) impacted a number of cobalt- consuming sectors throughout the year. Despite this, the super alloy sector performed well in the second half as robust aerospace and military demand helped to support metal consumption despite bearish sentiment permeating throughout the market.
- Rising energy costs, particularly in Europe stemming from the war in Ukraine, impacted demand from energy-intensive end markets such as the industrial and ceramics sectors.
- Demand for super alloys from the medical, aerospace, and military sectors remained robust later in the year, whilst energy-intensive industries showed some signs of improvement given lower-than-expected gas prices.
- Despite pressure on a number of the traditional cobalt-consuming sectors in 2022, the metal market remained relatively tight throughout the year given strong demand from the aerospace, military, and medical sectors. Demand is expected to remain relatively steady given the maturity of most metal-consuming markets.

5 | SUPPLY: INDONESIA JOINS THE DRC AS A MAJOR DRIVER OF SUPPLY

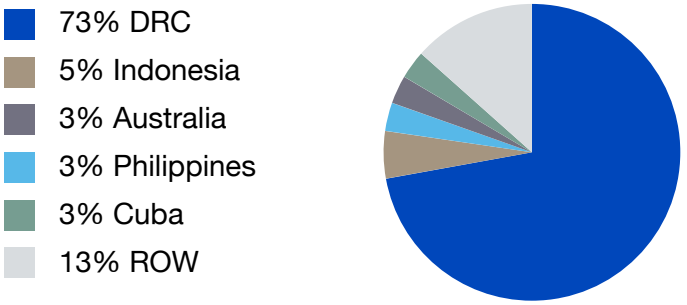
5.1 | KEY SUPPLY - SIDE EVENTS IN 2022

- **January:** Trafigura announced financing of $600 million with Chemaf for the Mutoshi project in the DRC.
- **February:** first shipment of MHP from Huayue HPAL in Indonesia.
- **April:** Glencore (Murrin Murrin, Australia) signed multi-year supply deal with GeneralMotors (GM).
- **April:** extensive flooding in Durban, South Africa worsened cobalt supply chain constraints. Glencore declared force majeure.
- **July:** subsidiary of CATL (Sichuan CATL) secured 25% stake of CMOC. In addition to the 25% stake acquired in the Kisanfu project in 2021.
- **July:** DRC government bans exports from CMOC's Tenke Fungurume in due to an ongoing dispute over royalty payments.
- **August:** Tesla signed long term NCM supply agreement with Huayou and CNGR - nickel and cobalt from Indonesia.
- **August:** QMB HPAL starts production in Indonesia.
- **November:** PT Vale Indonesia and Huayou sign Definitive Cooperation Agreement to develop Pomalaa project in Indonesia.
- **December:** ERG and Gecamines restart production at Boss Mining.

5.2 | OVERVIEW OF MINED SUPPLY IN 2022

Global mined cobalt supply rose close to 198 kt in 2022, up 21% y/y (+34 kt), compared to 14% y/y in 2021. The major producers are the DRC and Indonesia, accounting for a combined 78% of output in 2022, and 89% of y/y growth.

Figure 14: Share of mined cobalt supply in 2022, %

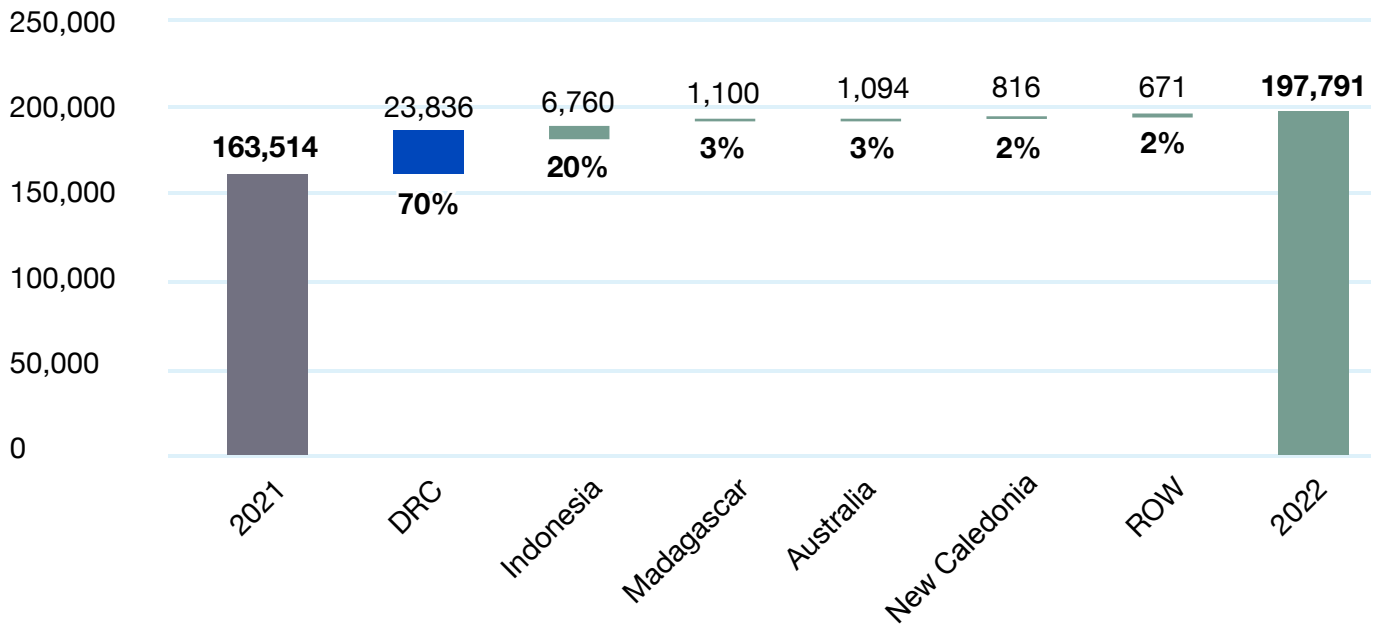


Data: Benchmark Mineral Intelligence – Cobalt Forecast.

Note: 'ROW' includes (in descending order) Russia, Madagascar, Canada, Papua New Guinea, Turkey, New Caledonia, Morocco, Zambia, Finland, China, USA, Mexico and South Africa.

The DRC maintained a steady share of 73% of production and contributed 70% of annual growth (+24 kt). Indonesia became the second largest producer, overtaking established producers including Australia, the Philippines and Cuba. Having produced minimal volumes prior to 2021, Indonesia's rise has been fast owing to existing mining expertise in the country from other commodities and the successful construction and ramp up of HPAL capacity, producing cobalt and nickel, from Chinese-Indonesian companies. Indonesia accounted for 20% of global mined supply growth in 2022 (+6.8 kt). Additions elsewhere were limited to small volumes at existing operations in Australia (3% of global growth) and the Philippines (1%).

Figure 15: Growth in mined supply by major country in 2022, tonnes of cobalt



Data: Benchmark Mineral Intelligence – Cobalt Forecast.

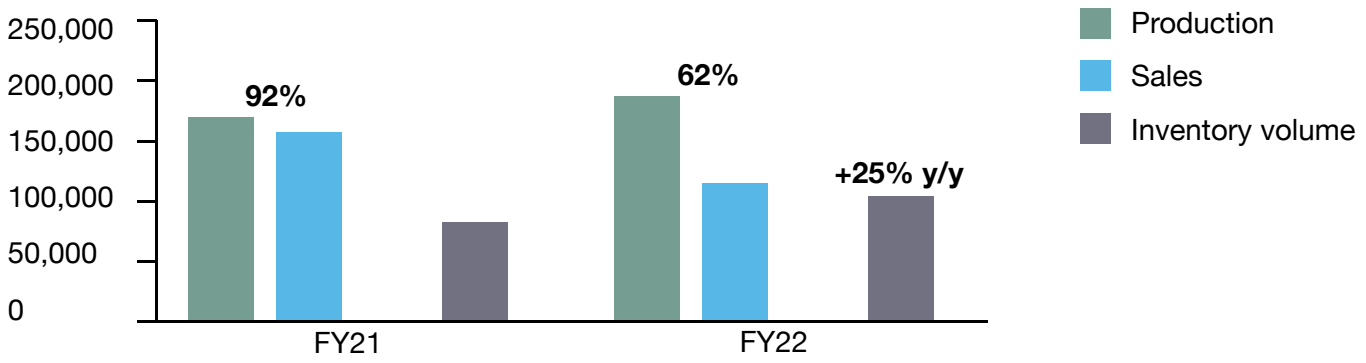
5.3 | KEY PRODUCERS IN THE DRC

Glencore remained the largest producer in the DRC in 2022, despite a reduction in output at Katanga (Kamoto Copper Company, or KCC). The mine's output dropped by 8% y/y following a number of setbacks including geotechnical constraints and power supply issues. However, Mutanda's output almost quadrupled as mining resumed after the restart of processing stockpiles in 2021. The ramp up was faster than guidance indicated as volumes were prioritised to offset losses at Katanga. Overall, Glencore's production increased by 10 kt – Mutanda alone supported 49% of the country's annual growth.

The other major producer in the DRC, CMOC, endured a difficult 2022 as exports were banned from their TFM operation from July onwards as their royalties dispute with the DRC government and Gécamines escalated. An agreement was reached in late April 2023 with exports expected to resume. CMOC reported in their 2022 annual results that cobalt inventory volumes rose 25% in 2022, and the conversion of cobalt production to sales fell from 92% in 2021 to 62% in 2022. We estimate that there is more than 16 kt of stockpiles (cobalt contained) at TFM.

Geopolitical considerations are discussed in more detail in Section 3.

Figure 16: CMOC's reported cobalt metrics



Data: CMOC Annual Reports, Benchmark Mineral Intelligence – Cobalt Forecast.

Elsewhere for CMOC, construction at the Kisanfu (KFM) mining project continued with production expected to start from mid-2023 onwards. In July 2022, the Sichuan subsidiary of CATL purchased a 25% share of CMOC, following CATL's investment in 25% of the Kisanfu project in 2021.

In January 2022, Trafigura announced financing of $600 million with Chemaf for the Mutoshi project which has been under development for a number of years. Previously this was being trialled for a proposed formalisation of the artisanal and small scale mining (ASM) sector but the operation has now been fully mechanised instead. It has yet to start production but the ramp up is expected to begin in 2023.

Eurasian Resources Group's (ERG) Metalkol Roan Tailings Reclamation (RTR) operation continued to increase output, rising to 18 kt in 2022. In December, ERG and Gécamines restarted production at Boss Mining.

Production from the ASM sector accelerated in late 2021 and early 2022, supported by strong prices. However, as prices began to unravel from May onwards, ASM supply tailed off in the second half and has now fallen by more than 50% from the peak.

ESG CONSIDERATIONS FOR THE COBALT SECTOR IN THE DRC

Environmental challenges for cobalt mining in the DRC are not widely discussed by the market, however after many years of poor mining standards, the country's industry faces a number of issues, including water impacts, waste (tailings) management, biodiversity risks and air pollution. The Central Zambezian Miombo Woodland Ecoregion is one of two major ecoregions in the DRC – 70% of these woodland environments are in the Katanga region, key for cobalt mining, posing high biodiversity risk to the area, yet only one third of operating miners and converters have reported on biodiversity monitoring strategies put in place by the company.

Social impacts remain in the spotlight which has helped to see progress in addressing some of the main issues, such as child labour and human rights, with a number of international organisations partnering with governments and industry to develop and monitor projects, mostly relating to artisanal communities. Security and working conditions remain key topics as well as the safeguarding of women inside and

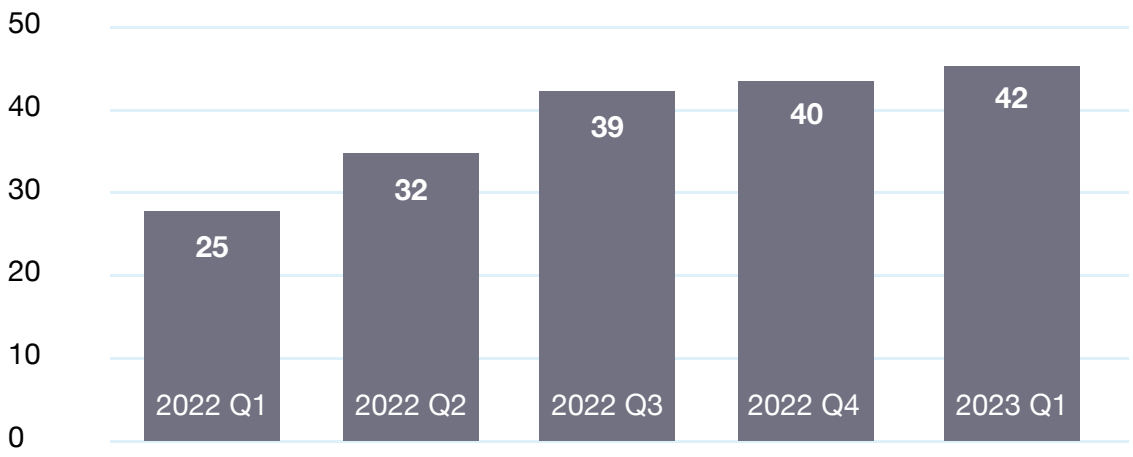
outside of the workplace – only 35% of operating cobalt miners and converters have gender-related policies in place.

Governance topics including due diligence, whistleblower policies, code of conduct disclosures, subcontractor use, responsible sourcing and tax transparency remain important. Transparency should be highlighted in general as, for example, 48% of producers (on a volume basis) do not produce publicly-accessible ESG reports. However, 58% of operating miners and 74% of operating converters disclose they have whistle-blower polies in place with similar proportions employing a code of conduct and responsible sourcing policies.

5.4 | INDONESIA – THE NEW GROWTH MARKET FOR COBALT

Indonesia is currently a focal point for both the cobalt and nickel markets as large volumes of new capacity are developed – cobalt production in the country has the potential to increase by more than 10 times by 2030 and 14 times by 2040, with new projects being announced on a regular basis. To demonstrate this, 10 Indonesian cobalt and nickel projects were tracked in early 2021, up from just 4 in early 2020, with this rising to 42 projects as of early 2023. Production to 2030, which could contribute more than a third of global growth, now has the potential to be almost double that in our forecasts from early 2022.

Figure 17: Number of Indonesian Co-Ni projects in Benchmark's supply database



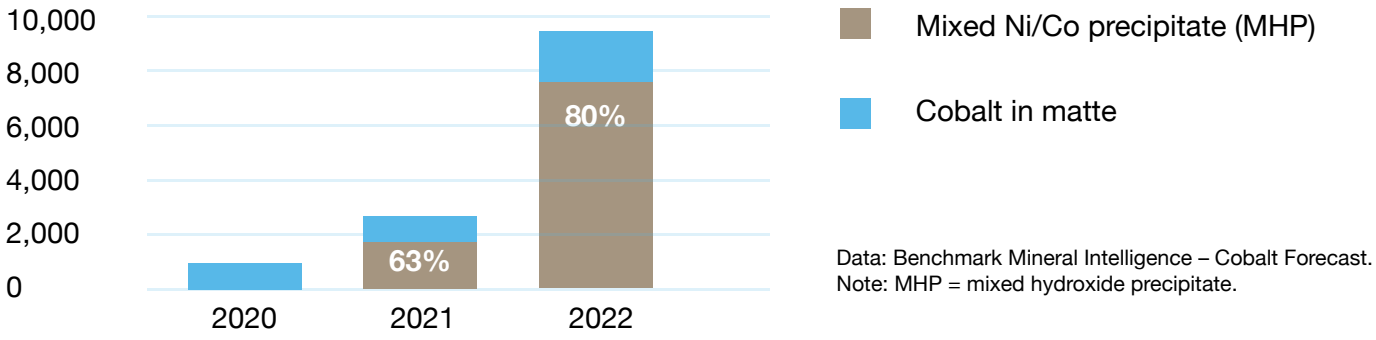
Data: Benchmark Mineral Intelligence – Cobalt Forecast.

In 2020, Indonesia produced less than 1 kt of cobalt – this increased to 9.5 kt in 2022. PT Halmahera Persada Lygend (PT Lygend) continued to ramp up in 2022, with the Phase 2 expansion also starting, after first production in 2021 as the country's first HPAL operation. It produced 2.8 kt of cobalt in 2022, 38% of Indonesia's annual production.

Huayue Nickel & Cobalt was the second HPAL to commission, with the first shipment in February, producing 2.4 kt in its first year in 2022 (25% of Indonesia's total) followed by PT QMB, producing 1.6 kt after starting production in August. In 2023, PT Huayu in Weda Bay is expected to commission as the 4th HPAL in Indonesia.

With the rise of HPAL capacity in Indonesia, sourced from domestic ore feedstock, MHP containing both cobalt and nickel has quickly become the dominant intermediate product – 80% of total production in 2022. Prior to 2021, Indonesia only produced cobalt as a by-product of nickel matte production. New cobalt supply will come from matte in future, however this accounts for only 7% of potential additions to 2030 – 93% is from MHP via the HPAL route. Several projects have already announced major capacity expansions, such as PT Lygend committing to a 50% increase in cobalt output and Huayue doubling initial planned capacity, indicating confidence in the technology and production route.

Figure 18: Share of Indonesia's cobalt production by intermediate product (MHP and matte)



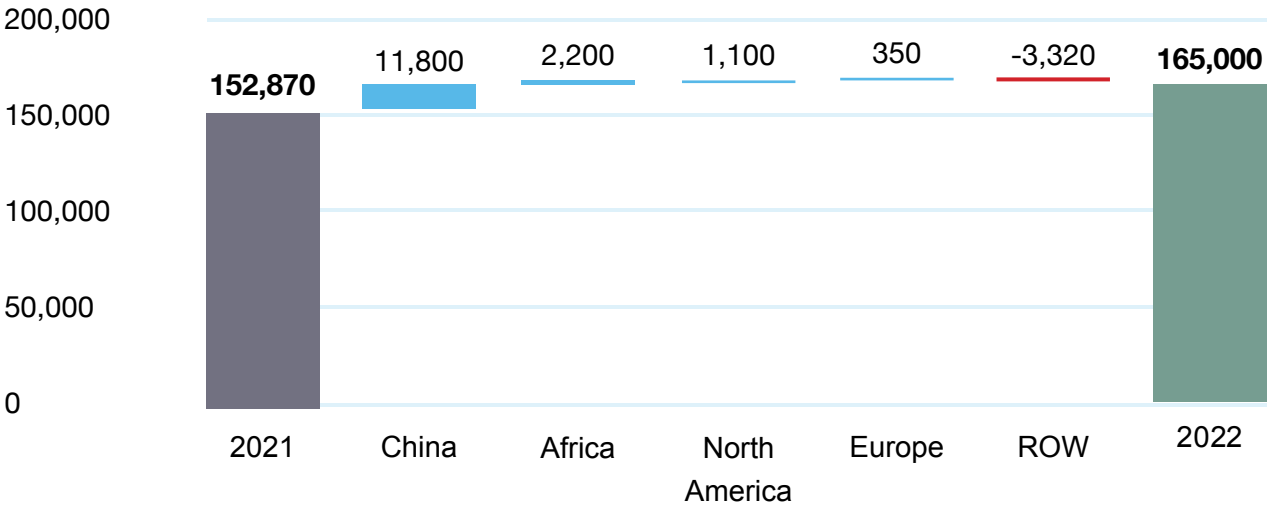
Data: Benchmark Mineral Intelligence – Cobalt Forecast.
Note: MHP = mixed hydroxide precipitate.

5.5 | OVERVIEW OF REFINED SUPPLY IN 2022

Refined cobalt supply maintained robust growth in 2022, increasing 8% y/y by 12 kt, to 165 kt.

As the major global refiner, maintaining a ~75% share in recent years, China contributed 97% (+12 kt) of growth, with Africa (Madagascar and the DRC) accounting for 18% (+2.2 kt). Despite being the second largest growth market, Africa only accounts for 4% of global output. The second largest region, Europe, only increased output marginally and lost overall market share, as the cobalt industry remains reliant on China for refining.

Figure 19: Growth in refined supply by region in 2022, tonnes of cobalt

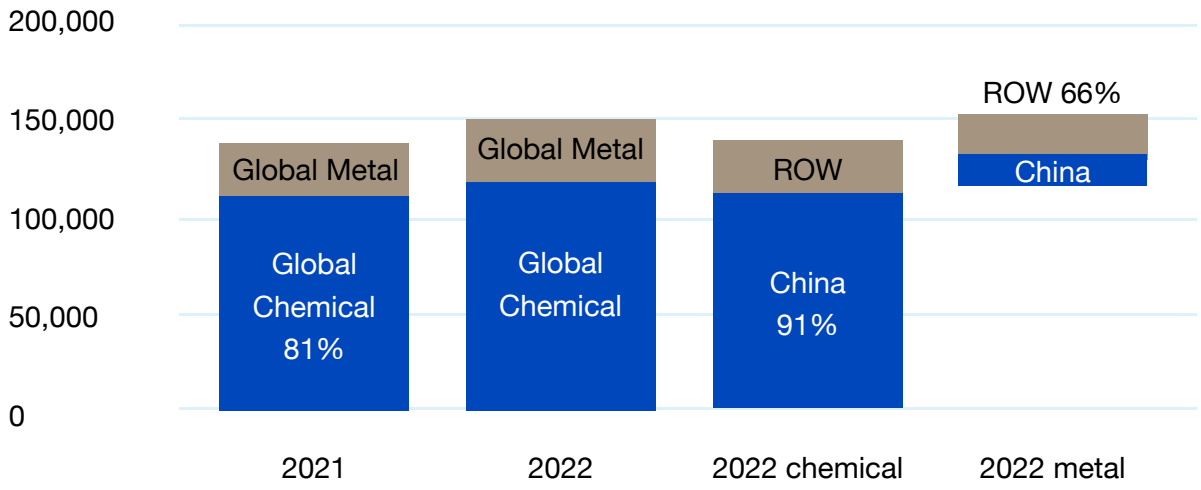


Data: Benchmark Mineral Intelligence – Cobalt Forecast.

With end users increasingly using refined chemicals (cobalt sulphate and other salts) for battery applications, chemical refining accounts for 80% of total refined production. Chemical supply grew 7% y/y in 2022 (+7.5 kt) compared to 14% y/y for metal (+3.7 kt).

China dominates chemical refining with 91% of global production in 2022, whereas the ROW is the major metal producer, with a 66% share. The largest metal refiners excluding China include Canada, Norway and Australia (64% combined share).

Figure 20: Refined capacity by type and region in 2021 and 2022, tonnes of cobalt



Data: Benchmark Mineral Intelligence – Cobalt Forecast.

Table 1: Share of global refined production by country, %

Country	Share of global refined production	
	2021	2022
China	74%	76%
Finland	10%	10%
Canada	4%	4%
Norway	2%	2%
Australia	2%	2%
Madagascar	1%	2%
DRC	1%	1%
Morocco	1%	1%
Russia	1%	1%
ROW	4%	1%

Data: Benchmark Mineral Intelligence – Cobalt Forecast.

In China, 80% of sulphate capacity is integrated with downstream precursor active material (PCAM) capacity, including Huayou, Shenzhen GEM, CNGR and others. The share has steadily increased in recent years. However, integrated capacity is significantly lower outside of China with only Umicore in Belgium currently integrated with PCAM.

5.6 | SUPPLY CHAINS EVENTUALLY EASE PRESSURE ON COBALT

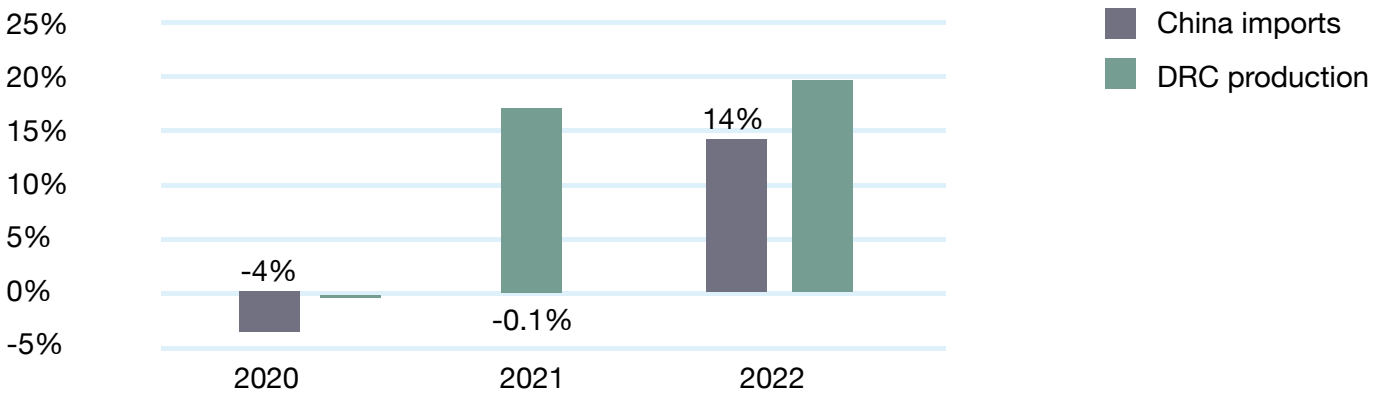
Supply chain constraints were a major theme for the cobalt market in 2021 but eased through 2022 despite several key, global events. Early in 2022, supply chains were still gradually recovering post-COVID but faced new challenges from the start of the war in Ukraine in February and widespread lockdowns in China in April and May. In addition, major flooding in the KwaZulu-Natal Province and at the port of Durban in South Africa (the primary port used to ship DRC cobalt hydroxide to China) in April threatened to further extend the impacts on cobalt, with Glencore even declaring force majeure on some of their contracts during this period, as most shipments stopped through April and May.

Despite this, freight routes recovered relatively quickly into the second half of the year and world container rates, a proxy for freight dynamics for cobalt, declined through most of 2022. They have recently returned to levels last seen in early 2020, before the COVID-19 pandemic. Drewry's World Container Index was around $10,000 in early 2022, just below the peak of $10,400 in September 2021, but fell to around $2,000 by the end of 2022. It was $1,800 as of March 2023.

Chinese imports of cobalt intermediates also recovered in 2022, following 2 years of turbulent market conditions. Intermediates are primarily composed of hydroxide from the DRC (with small volumes of concentrates) and increasingly MHP from Indonesia. After no growth in 2021, Chinese imports rose 14% y/y in 2022, supported by 20% growth in DRC cobalt production.

However, we still estimate that stocks remain high across the industry and there will be increasingly large volumes of cobalt for export from CMOC's TFM operation now that the dispute with Gécamines has been resolved.

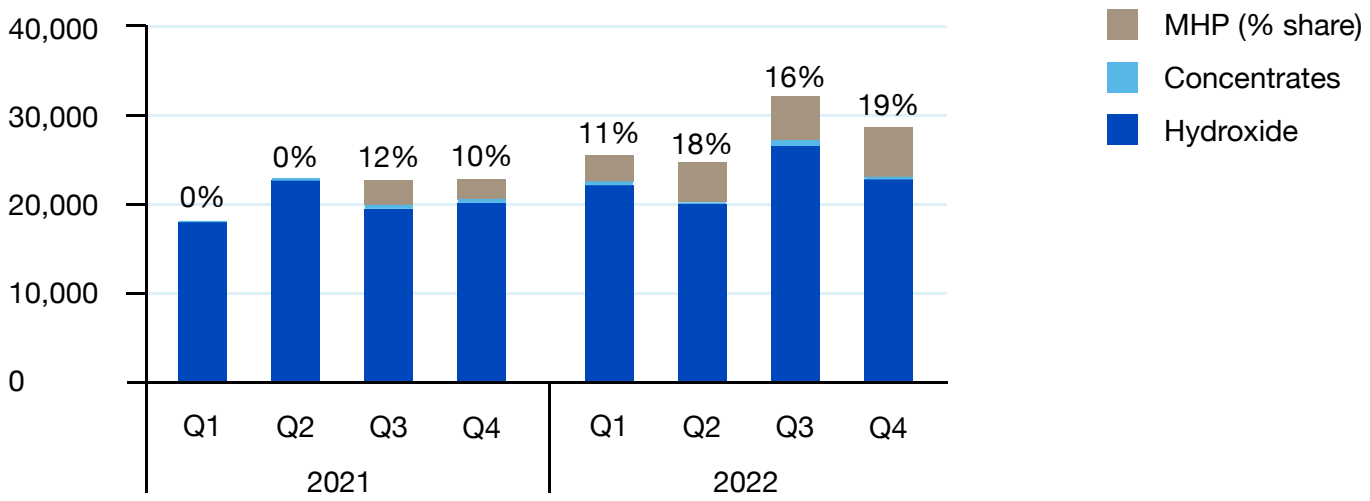
Figure 21: Imports of cobalt hydroxide and concentrate into China compared to DRC production, y/y % change



Data: Benchmark Mineral Intelligence.

In addition to the traditional feedstock of hydroxide, and declining volumes of concentrate, MHP imports into China are rising steadily as new HPAL capacity in Indonesia ramps up. Shipments started in July 2021 (PT Lygend) and increased further through 2022, as Huayue Nickel & Cobalt and PT QMB both commissioned new capacities. In Q4 2022, MHP made up close to 20% of cobalt imports into China.

Figure 22: China cobalt imports by source, tonnes of cobalt



Data: China Customs data, Benchmark Mineral Intelligence.

5.7 | RECYCLING REMAINS A SMALL SHARE BUT WILL RISE IN IMPORTANCE

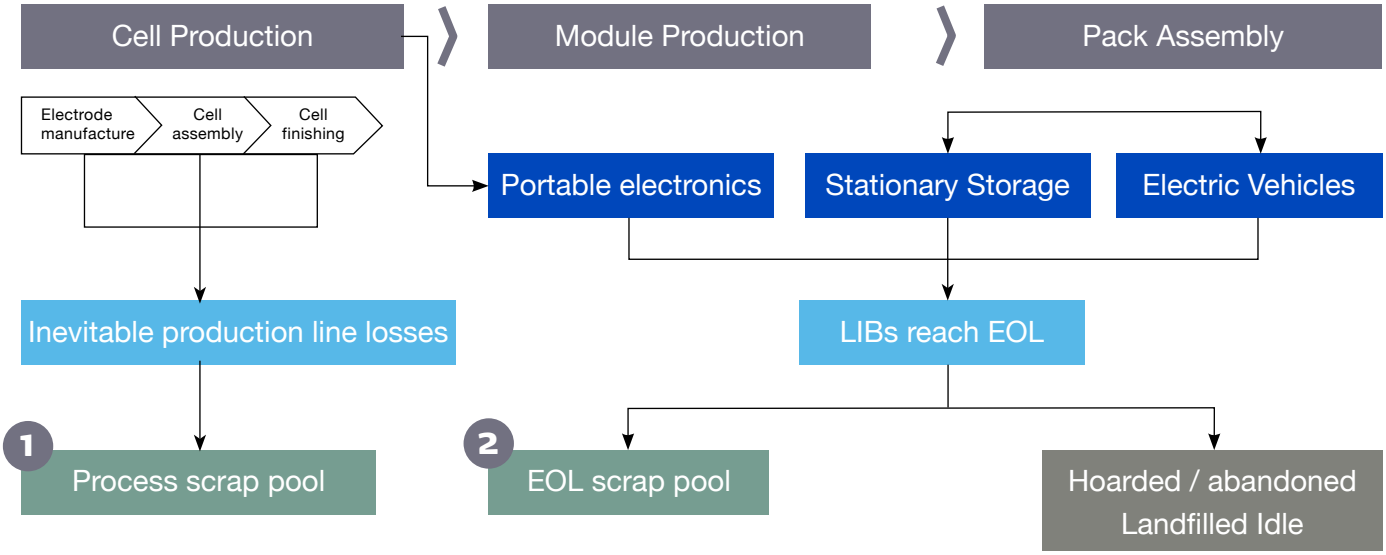
The electrification of transport and energy storage, as part of the wider energy transition, has brought the LiB supply chain into the spotlight. Governments around the world are committing to the phasing out of ICE vehicles, and widespread adoption of electric vehicles (EVs).

Demand for the critical materials required for LiBs is skyrocketing and forecast supply is expected to fall short of demand. Recycling materials from end of life (EOL) batteries and process scrap, the two distinct sources, presents an opportunity to plug this gap – the categories of scrap are explained further in the figure below.

In addition to the role of recycling in the supply of materials, ESG concerns with the upstream mining sector have boosted interest in attaining recycled materials for battery manufacturing. A rush for “green” materials has resulted in downstream consumers auditing their suppliers in attempts to secure the most sustainable materials.

Sourcing battery grade chemicals required for cell manufacturing via recycled materials facilitates this and reduces the need for mining virgin material, reducing stress on local environments and finite resources.

Figure 23: Sources of battery scrap

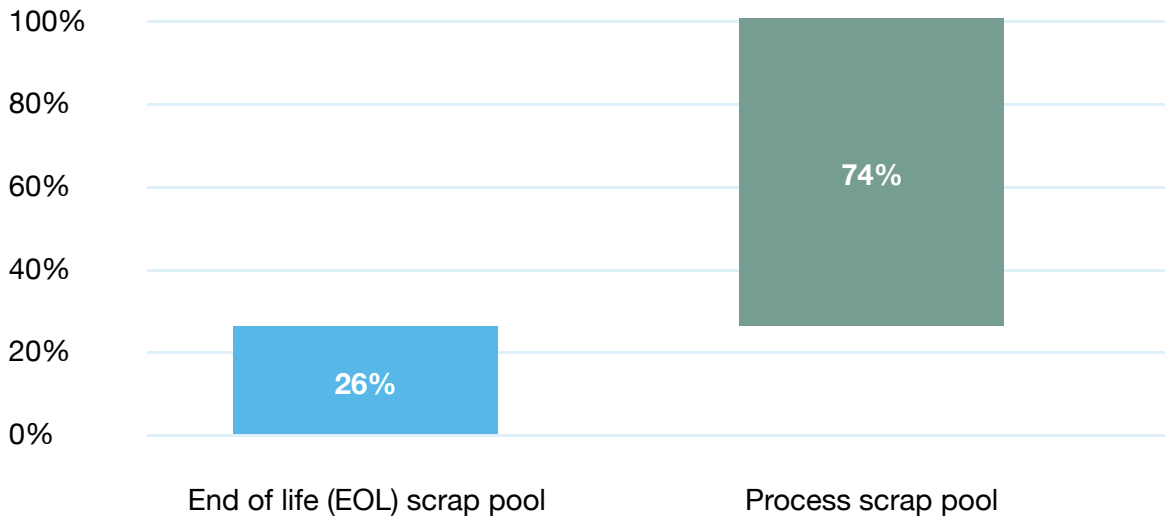


Data: Benchmark Mineral Intelligence – Recycling Forecast.

The total volume of recyclable material in 2022 was approximately 48 GWh – by 2040, this is forecast to reach over 2,948 GWh. In the short-term, scrap from the production of cells (process scrap) will account for the majority of this recycling feedstock. In 2022, process scrap accounted for 74% of the total scrap pool, with only 26% from EOL sources.

A significant shift in the proportion of scrap from OEL versus process scrap is not expected until at least the mid-2030s, when EOL batteries will comprise the majority of the scrap pool.

Figure 24: 2022 battery scrap pool composition, %

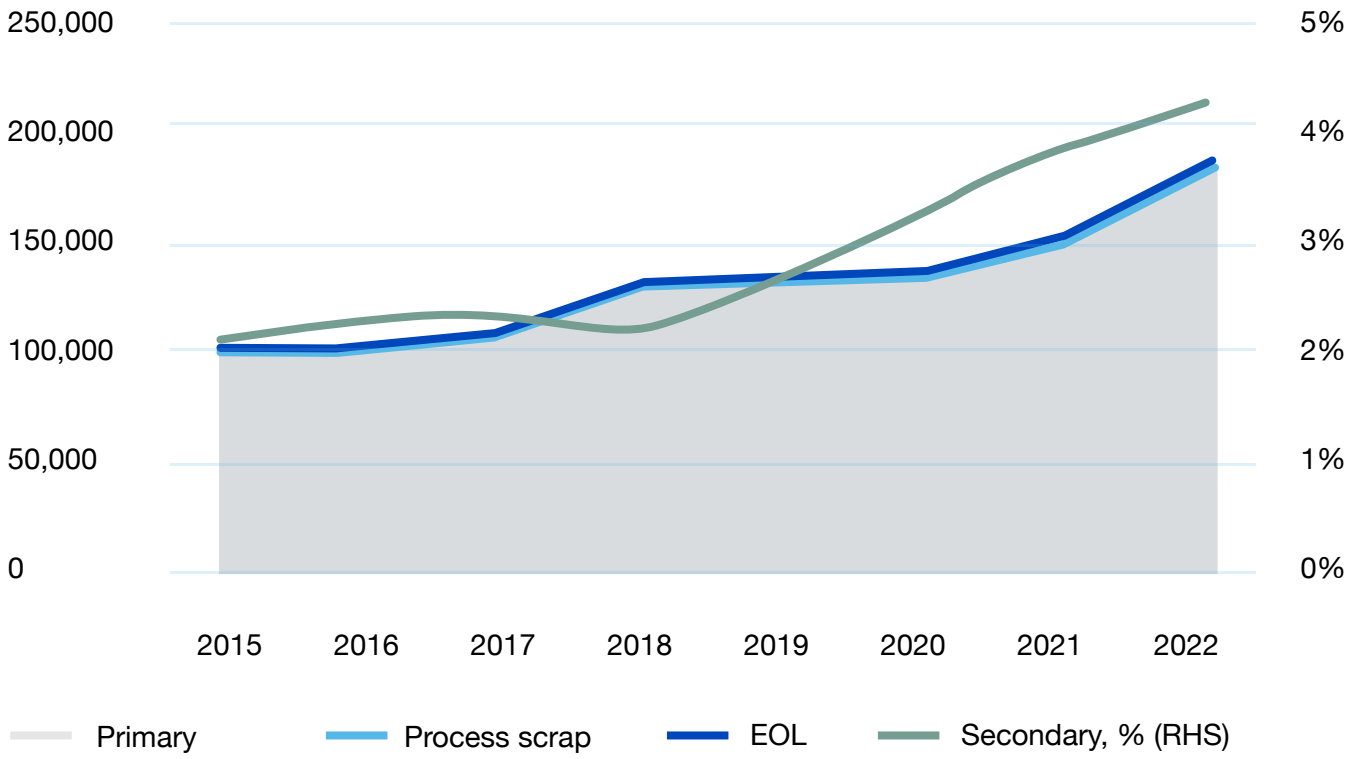


Data: Benchmark Mineral Intelligence – Recycling Forecast.

Traditionally, recycling technologies have favoured the recovery of cobalt- and nickel-rich chemistries. This is due to the relatively low recovery rates for lithium, given the limitations of dominant technologies such as pyrometallurgy, as well as the value of each mineral on a unit basis (cobalt is the highest value of the battery metals).

Scrap volumes still remain relatively low and as such secondary volumes only account for around 5% of total cobalt supply, with this share only rising marginally in recent years. In 2022, secondary production of cobalt totalled 9.3 kt (relatively even split of process and EOL sources) compared to 178 kt of primary production. However, with the total scrap pool expected to increase by 60 times to 2040, the share of secondary production has the potential to rise to 41% of total cobalt supply.

Figure 25: Share of secondary volumes relative to primary production, tonnes of cobalt & %



Data: Benchmark Mineral Intelligence – Recycling Forecast.

6 | PRICES: A TALE OF TWO HALVES FOR COBALT PRICES IN 2022

6.1 | COBALT HYDROXIDE

Cobalt hydroxide pricing had a positive start to 2022, rising consistently throughout Q1, following a strong second half of 2021. Prices reached their highest mark since May 2018 in April 2022, as limited supply and a rising underlying metal price drove up prices.

Throughout early-2022, logistical issues were a major driver of pricing, particularly in the hydroxide market, with high shipping costs and limited container availability symptomatic of the start of the year. These factors were compounded by delays at Chinese ports, given COVID-19 precautions, and limited trucking capacity in the DRC, leading to significant shipping delays of 2-3 months.

As a result, hydroxide producers in the DRC fell behind on their long-term obligations, reducing the amount of material available to purchase on the spot market. Meanwhile, demand for hydroxide was relatively robust given growing battery demand and the post-COVID aerospace sector recovery. As such, hydroxide was trading at an average of $76,145/t during April, its highest level in 2022.

Despite stringent Chinese COVID-19 lockdowns starting in April, prices continued to rise as hydroxide supply was further restricted by major flooding at Durban port, impacting operations for most of the month. However, as demand declined due to the lockdowns and the port became operational again, prices began to retreat.

From May to late August, prices decrease m/m as limited demand and negative sentiment plagued the market. Despite significant EV battery production growth during this period, consumers opted to work through existing raw material inventories over purchasing additional hydroxide in the negative price environment. Conversely, demand from the consumer electronics industry, historically the largest demand sector for cobalt, was severely limited in 2022 as sales dropped off sharply following particularly robust demand during the COVID- 19 pandemic.

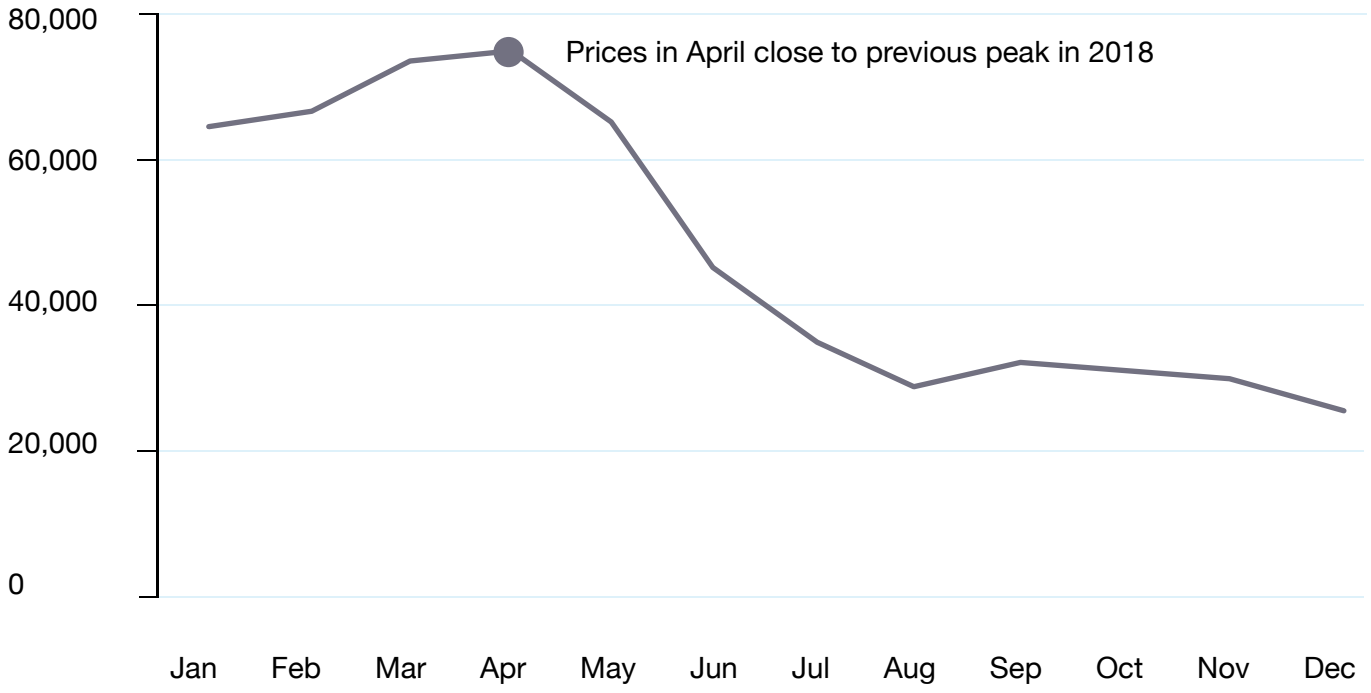
Meanwhile, growing volumes of cobalt contained in MHP entered the market as Indonesian HPAL projects ramped up production, with Indonesian cobalt supply increasing by over 200% y/y in 2022.

Notably, exports from CMOC's TFM operation were blocked from late-July due to a royalties dispute between the Chinese mining company and Gécamines. However, despite TFM being the second largest cobalt producing mine in the world, the impact on prices was marginal given weak limited demand for hydroxide.

Prices were briefly supported in late-August as the underlying metal price increased due to perceived alloy grade tightness in the US and speculative buying, however hydroxide prices began to retreat soon after the tightness subsided in September.

Prices declined for the rest of the year, decreasing by 17.4% in Q4, accelerating at years end with demand decreasing further in preparation for limited EV sales in Q1 2023, given the usual annual Q1 slowdown and the end of Chinese government EV subsidies. Furthermore, the spot market was particularly quiet in the lead up to the Christmas break and Chinese New Year celebrations.

Figure 26: Cobalt hydroxide prices in 2022, $/tonne (CIF Asia)



Data: Benchmark Mineral Intelligence – Cobalt Price Assessment.

As discussed elsewhere, although battery sector cobalt demand increased y/y, growth was slowed by higher shares of low cobalt and cobalt-free cathode chemistries This contributed to the weaker than expected demand and soft pricing conditions for much of 2022.

From early-year highs in April, hydroxide prices retreated by 64.9% to the end of the year. Large inventories, limited consumer electronics demand, and significant supply growth in the DRC and Indonesia were all major contributors to the negative pricing. With all these factors expected to continue into 2023, there are few signs of a significant shift likely for hydroxide pricing in the near-term.

Various projects in the DRC are anticipated to ramp up production in 2023, whilst increasing volumes of cobalt contained in MHP continue to flow out of Indonesia. Demand from the EV and LCO sectors show little-to-no signs of improvement, suggesting 2023 may be another tough year for hydroxide pricing.

6.2 | COBALT METAL

Cobalt metal prices experienced significant positivity in early-2022, as logistical issues in Africa limited feedstock availability, constraining metal production and increasing refining costs. Improving demand from major cobalt-consuming sectors, such as the EV market and aerospace industry, plus the ongoing bull run continuing over from 2021, facilitated positive sentiment throughout the market. Prices reached their highest mark since the 2018 cobalt price rally during Q1, averaging $38.08/lb ($83,941/t) in March.

Prices continued to rise on optimistic market fundamentals in April, reaching the 2022 peak with transactions recorded as high as $40.20/lb ($88,626/t). However, as prices approached the $40/lb mark, the rally lost momentum with Chinese metal producers selling their material into the international market at a discount. Moreover, stringent COVID-19 lockdown measures began in April, souring market sentiment and reducing Chinese demand significantly.

Following April, prices retreated consistently month-on-month through to September, despite Chinese COVID-19 lockdowns ending in early-June. A significant market surplus and limited cobalt demand from the battery industry, facilitated bearish sentiment, driving down prices.

Although limited purchasing occurred in the negative pricing environment, Chinese metal refiners continued to take advantage of the significant price arbitrage between the international and Chinese metal price, selling into the international market and creating downwards pressure on prices. During this period, metal prices retreated by 34.5% to an average of $24.25/lb ($53,462/t) in August.

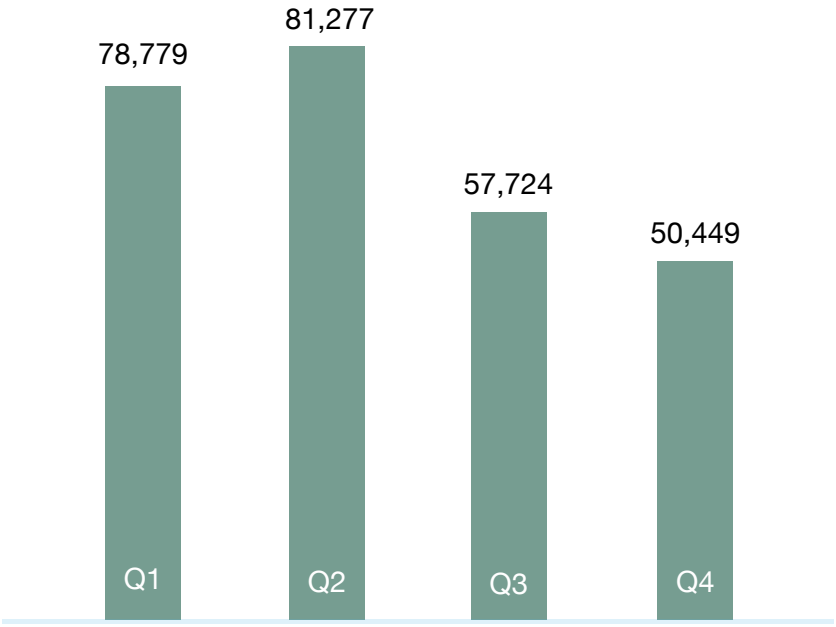
In late-August, metal prices did experience some positivity as industrial action at Glencore's Nikkelverk refinery created the perception of alloy grade metal tightness in the US. This was intensified by the 25% import tax which cuts off the US from the Chinese market. As such, prices increased by 6.2% m/m in September with trading activity also picking up following the seasonal summer slowdown. Moreover, rumours that the Chinese State Reserve Bureau (SRB) were purchasing metal helped to close the arbitrage between the international and Chinese metal price.

However, the price positivity was not to last and as the perceived tightness abated, prices continued their downwards trajectory in October. During late-Q3, it became clear cobalt demand from the consumer electronics industry, historically the largest cobalt demand sector, was down significantly following strong consumer electronic sales during the COVID-19 pandemic. This contributed significantly to the limited battery demand and overall bearish sentiment in 2022.

It is also important to note that throughout most of 2022, cobalt metal demand was relatively robust causing the market to be tight in comparison to the chemicals market. Alloy demand was strong from a post-COVID-19 aerospace industry recovery and military demand increased as a reaction to the Russia-Ukraine War. Despite this, there was a negative price environment for much of 2022 given the weak battery demand and oversupply in the large chemical market. Other smaller, energy intensive, cobalt consuming sectors struggled with rising energy costs for much of the year, also dampening demand.

Consequently, cobalt metal price ended the year falling to nineteen-month lows of $20.50/lb ($45,195/t) on average in December, with negative sentiment, limited battery demand, and a quiet spot market being symptomatic of Q4 2022. Despite a relatively tight metal market, the metal price retreated 49% from 2022 highs in April to December, with no signs of the bear run easing by year end.

Figure 27: Average quarterly cobalt metal prices in 2022, $/tonne (EXW Europe)



Data: Benchmark Mineral Intelligence – Cobalt Price Assessment.

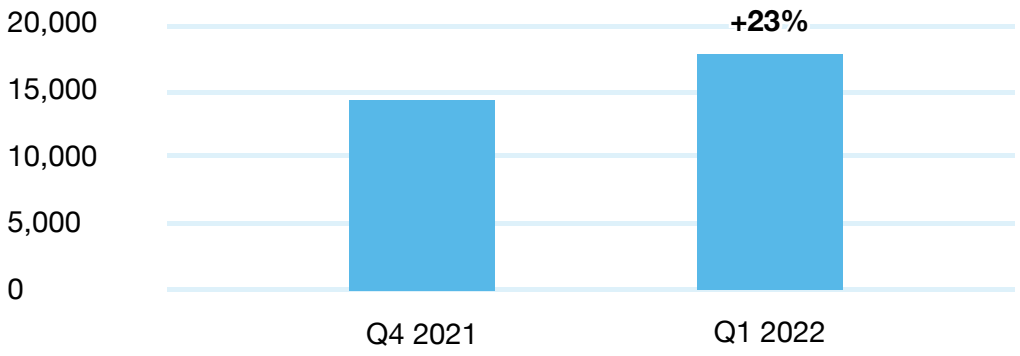
Looking ahead to 2023, the market oversupply is anticipated to grow with increasing volumes of cobalt hydroxide and MHP flowing into the market. Sizeable inventories are expected to consume much of the existing cobalt demand from the battery industry, limiting upwards price movement. However, the metal market remains tight, preventing prices from crashing, and both the NCM and LCO markets are expected to recover to some extent in 2023, supporting prices later in the year.

6.3 | COBALT SULPHATE

Early-2022 marked a period of positive pricing for the cobalt sulphate market, with prices increasing m/m throughout Q1. A tight intermediate market, given logistical delays between the DRC and China, drove rising feedstock costs, in turn pushing up sulphate prices.

Prices recorded gains of 23% on average in Q1 despite limited demand from downstream consumers. Spot demand from precursor and cathode production was relatively constrained in early-2022 with customers unwilling to purchase sulphate in the high price environment. As such, the price increase was primarily attributed to rising intermediate (primarily hydroxide, but also MHP) costs. By March 2022, average sulphate transactions concluded at the RMB 119,500/t ($18,881) mark, their highest level since the 2018 cobalt price rally.

Figure 28: Average quarterly cobalt sulphate prices, $/tonne (EXW China)



Data: Benchmark Mineral Intelligence – Cobalt Price Assessment.

However, the bull run was not to last as the market began to turn heading into April 2022. Stringent COVID-19 lockdown measures in China significantly reduced demand from downstream consumers. As such, sulphate prices consistently fell throughout Q2, with much of the Chinese battery value chain shutting down in April and May.

The lockdowns also reduced Chinese sulphate production by as much as 50% in May, however prices continued to retreat highlighting the lack of demand during this period. Notably, during Q2 there was an increase in sulphate produced using black mass (from recycling) as a feedstock, creating further downward pressure on pricing given the lower cost of recycled material.

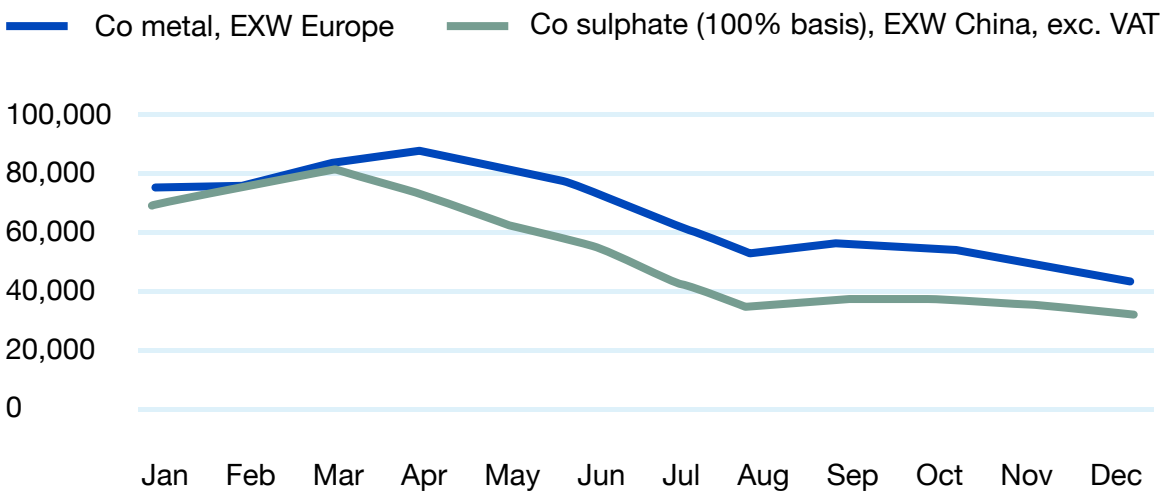
Despite the stringent Chinese COVID-19 lockdowns ending in early-June, reviving the battery market, downstream demand for cobalt sulphate did not recover. Prices continued to fall, and sizeable sulphate inventories offset the need to procure additional material, with consumers opting to wait for more favourable prices over restocking. As such, sulphate transacted at an average of RMB 88,000/t ($13,112) in June.

The downward trend continued for the majority of 2022 as bearish sentiment entrenched itself in the sulphate market. From 2022 highs in March, prices collapsed by 62.8% to the end of the year with limited demand, large inventories, and a quiet spot market key themes for the second half of the year.

During late-August and September 2022, sulphate prices did experience some positivity as consumers reacted to the rising cobalt metal price during this period. Speculation over the cobalt market reaching a pricing floor, due to alloy grade metal tightness, drove purchasing during this time. However, when this metal tightness abated, prices resumed their downward trajectory, and continued to retreat for the rest of 2022.

The price decrease accelerated in December when purchasing declined further in anticipation of reduced EV sales in Q1 2023, due to seasonal factors, such as the Spring Festival, and the end of Chinese government EV subsidies. Consequently, prices reach annual lows at the end of the year with sulphate trading at an average price of RMB 52,000/t ($7,488) in December.

Figure 29: Cobalt metal and sulphate prices in 2022, $/tonne



Data: Benchmark Mineral Intelligence – Cobalt Price Assessment.

Looking ahead to 2023, sulphate prices are anticipated to find some support when battery production increases in Q2 and consumers move to restock after months of inventories being run down. However, if intermediate costs remain low, sulphate producers will feel less pressure to increase their prices due to relatively low production costs.

6.4 | EVOLVING PRICING STRUCTURES

The growth of the battery market in recent years has facilitated a shift in cobalt market pricing as traditional mechanisms become less relevant to the overall market. The cobalt metal spot price has historically been the primary reference price for the cobalt market, with hydroxide transactions using a payable to the metal price.

However, the growth of the battery market has resulted in metal production constituting a smaller share of the cobalt market. Given hydroxide is the primary feedstock for cobalt sulphate refining, there has been significant growth in the chemicals market over the last decade, whilst the mature metal market's growth has been marginal.

Consequently, metal production accounts for approximately 18% of the cobalt market currently. Of this, only 10-15% is traded on the spot market, revealing that the metal reference price represents a minority share of the cobalt market. Moreover, as the EV battery industry continues to expand, whilst demand from metal consuming sectors remains relatively flat, this share will decrease further.

With chemical and metal market fundamentals diverging over the last year, given the relatively tight metal market and the intermediate oversupply, the metal price has often failed to represent the overall market balance. As such, alternative pricing methods are emerging in the hydroxide market, which avoid referencing the metal price.

Recently, hydroxide has been regularly transacted using a fixed dollar price to avoid the use of the metal reference. Alternatively, particularly in China, although recently elsewhere as well, hydroxide prices have been calculated using a cobalt sulphate formula. This uses the sulphate price minus the assumed refining costs for hydroxide to sulphate production.

In future, we expect that cobalt in MHP from Indonesia will start to influence pricing trends, however currently it is not impacting the pricing of DRC hydroxide.

7 | OUTLOOK: ROBUST MARKET OUTLOOK DESPITE SHORT TERM WEAKNESS

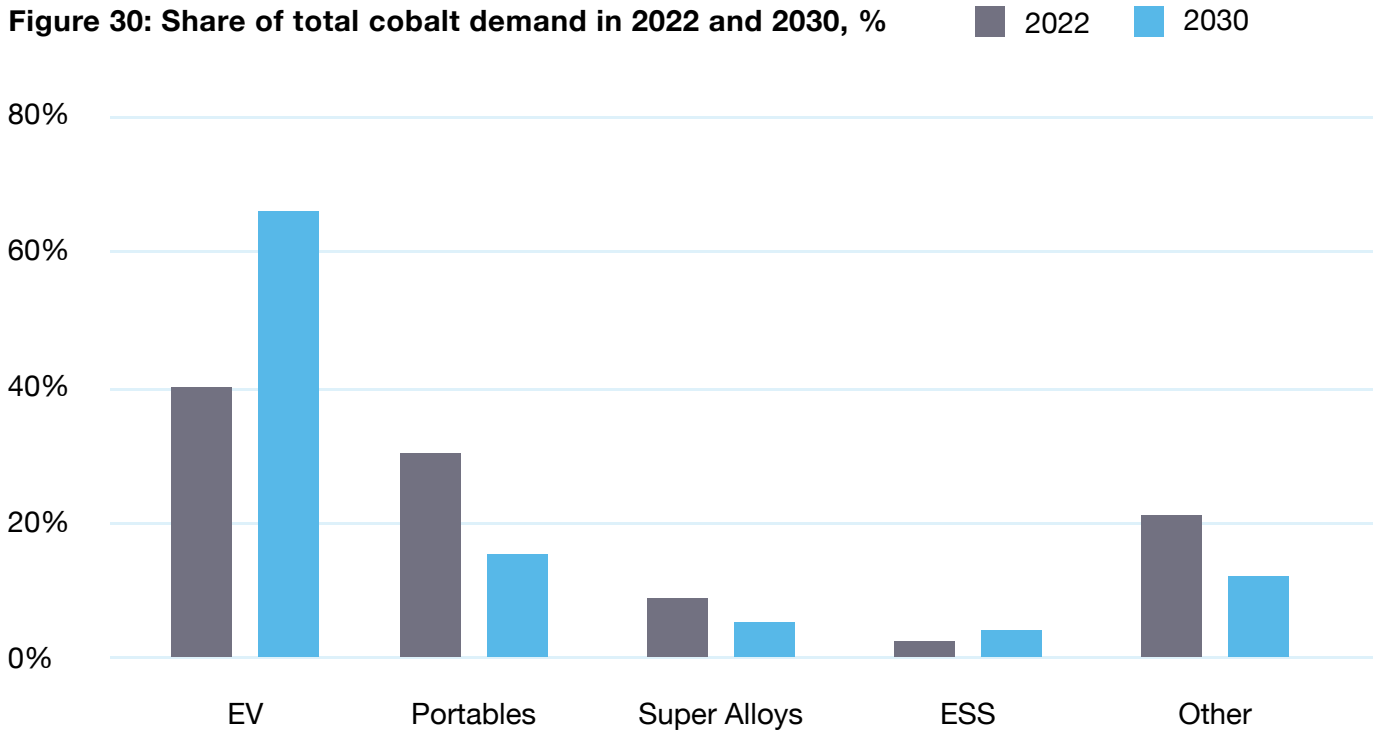
Since the price peak in April 2022, which approached the previous high in 2018, the cobalt market has faced rising pressure. From April to December, cobalt metal prices fell 50% and have continued to fall in early 2023 – down 60% from April 2022 to the end of March 2023. Following supply deficits in 2020 and 2021, supporting prices, the market has now shifted into surplus which is expected to persist until at least the mid-2020s.

COBALT DEMAND SET TO DOUBLE BY 2030

Despite weak market conditions persisting since April 2022, medium to long term fundamentals remain robust for the cobalt market. To 2030, demand is forecast to rise by 108% over 2022, to close to 388 kt (rising at a compound annual growth rate, CAGR, of 10%). This would see the cobalt market more than doubling in size relative to 2022.

The dominant driver of demand is the EV sector which will contribute 89% of growth to 2030, followed by energy storage (3%) and super alloys (2%). Once a key driver of cobalt demand, growth in the portable electronics market has slowed as the market matures – demand is forecast to rise at just 1% CAGR to 2030. The share of total demand will change markedly over this period as EVs rise from 40% in 2022 to two thirds of the market by 2030. Portables' market share will fall by half over this period. Battery applications combined will account for 84% of cobalt demand in 2030, compared to traditional applications which will fall from a share of 28% to 16%.

Figure 30: Share of total cobalt demand in 2022 and 2030, %



Data: Benchmark Mineral Intelligence – Cobalt Forecast.

Despite the rising share of LFP, cobalt-containing cathode chemistries (NCM, NCA and LCO) will remain as the preferred technology choice for battery applications – accounting for 59% of total cathode demand in 2030. NCM chemistries for EV applications will remain the major driver, shifting to higher nickel and lower cobalt intensities over time. LFP's share will rise further relative to 2022, reaching a 39% share in 2030, although we do not anticipate a widespread switch away from cobalt-containing chemistries (as discussed in Section 4.5).

DRC TO REMAIN AS THE LARGEST PRODUCER WITH INDONESIA A GROWING FORCE

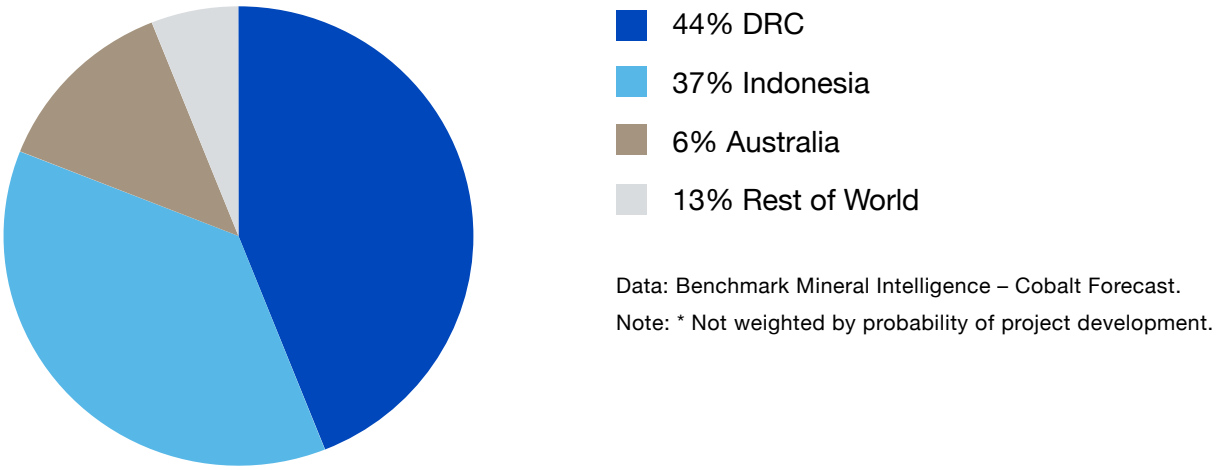
Global cobalt supply, both primary and secondary, will surpass 200 kt in 2023 and has the potential to more than double to 2030. On a weighted basis, base case forecast indicates total cobalt supply will rise to 318 kt (+122 kt from 2022,+6.2% CAGR).

Primary production will remain the key driver, however secondary supply from recycling will support a third of overall supply growth. The share of secondary supply will rise to 15% by 2030, up from 5% in 2022, as recycling capacity expands and larger volumes of battery scrap become available.

The DRC accounted for 73% of mined cobalt supply in 2022 and will remain the dominant producer, although this share will fall to 57% by 2030. Indonesia is the second largest market by some margin and will quickly catch up with the DRC as a major driver of growth. From 2022 to 2030, Indonesia has the potential to increase cobalt supply by 10 times, compared to the DRC's output rising by two thirds.

Despite not producing any MHP prior to 2021, the rapid development and build out of HPAL capacity in Indonesia has meant that cobalt in MHP is quickly becoming a key part of the global market. 93% of Indonesia's potential cobalt growth to 2030 will come from MHP, with the remainder from matte.

Figure 31: Share of potential* mined supply growth from 2022-30, %



Data: Benchmark Mineral Intelligence – Cobalt Forecast.
Note: * Not weighted by probability of project development.

PRICES TO REMAIN SUBDUED IN SHORT TERM UNTIL MARKET REQUIRES ADDITIONAL SUPPLY IN LATE 2020S

Supply will outpace demand in the short term, prolonging the market surplus that began in 2022 until at least the mid-2020s. After averaging $31/lb (cobalt metal, EXW Europe) in 2022, and peaking above $40/lb, we expect prices to average around $18/lb through 2023, at a similar level to prices in late March.

With the market remaining in a small surplus and weak sentiment persisting, metal prices are expected to remain below $20/lb and hydroxide payables around 60-65% due to a surplus of intermediates – both hydroxide from the DRC and increasingly MHP from Indonesia. Despite the surplus, metal supply will remain relatively tight which will prevent prices seeing further falls.

In the longer term, we expect the market to shift into a structural deficit from the mid to late 2020s as supply growth slows and demand continues to rise rapidly. Demand growth of 10% CAGR is forecast to 2030, compared to 6% for supply. With additional supply required to fill the widening forecast deficit, cobalt prices will move higher to incentivise investment.

8 | LIST OF FIGURES

9 | ABBREVIATIONS & DEFINITIONS

GENERAL

ASM: artisanal and small-scale mining.

Cobalt chemical: refined chemicals containing cobalt, in the form of cobalt sulphate for batteries, and other specialty products.

Cobalt metal: refined metal products in the form of briquettes, cathodes, broken cathodes and rounds.

CAGR: compound annual growth rate, %.

DRC: Democratic Republic of the Congo.

EOL: end of life material for recycling.

HPAL: high pressure acid leaching process for cobalt and nickel refining. kt: kilotonnes, equivalent to 1,000 metric tonnes.

Li-ion or LiB: lithium-ion battery, the current dominant battery technology. MHP: mixed hydroxide precipitate containing cobalt and nickel.

m/m: month on month change.

OEM: original equipment tmanufacturer, e.g. automotive company.

RHS: right hand size, typically for a chart axis. y/y: year on year change.

CATHODE CHEMISTRIES

LCO: lithium cobalt oxide

LFP: lithium iron phosphate (no cobalt)

NCA: lithium nickel cobalt aluminium oxide

NCM: lithium nickel cobalt manganese oxide. Typically referred to with the ratio of each metal e.g. 622 contains a 6:2:2 ratio of nickel to cobalt to manganese.

BEV: BATTERY ELECTRIC VEHICLE

BEV: battery electric vehicle.

EV: electric vehicle.

ICE: internal combustion engine, powered by either petrol of diesel.

NEV: new energy vehicle is a term typically used in China to describe battery electric (BEV), plug-in hybrid (PHEV) and fuel cell (FCEV) electric vehicles.

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