RAW MATERIALS FOR BATTERIES (COBALT, NICKEL, AND LITHIUM)

INDUSTRY ANALYSIS AND FORECAST

JULY 2023

THE RUSH TO ELECTRIC

- Raw materials are essential to underpin worldwide production of Electric Vehicles (EV's*) however, it must be noted that most raw materials used are also critical in other industrial applications which are outside the scope of this topic paper.
- Many earth elements are required to produce lithium-ion batteries to power EV's. Although EV batteries include other materials, such as copper, we have focused on lithium, cobalt, and nickel as these are critical components for current battery technology.
- There are unique structural challenges to increased production of each of these three earth elements.
- Certain applications for battery technology may become uneconomic as raw materials prices increase with demand, substantially in some cases. For example, large scale stationary energy storage and large EV trucks.
- There are significant uncertainties on the supply of raw materials post 2030, specifically;
  - Exponential growth in the demand for EVs in an effort to combat climate change.
  - A recent International Energy Agency (IEA) study concluded it takes an average of 16 years to open a new mine, suggesting the supply of raw materials may lag demand requirements.
  - There are a number of new battery technologies under development which may require different composition and quantity of raw materials.
- Based on Incorrys forecast of the number of battery electric vehicles (EVs), with significant investments in mining and refining, there will be a sufficient supply of Cobalt, Nickel and Lithium until at least 2030. There are significant undeveloped resources of raw materials to potentially meet demand for EV's world-wide.

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** Includes battery electric vehicles (BEV), hybrid electric vehicles (HEV), and plug-in hybrid electric vehicles (PHEV).*

INTRODUCTION: COBALT

- Cobalt is primarily used in the production of rechargeable lithium-ion batteries, which are essential for electric vehicles (EVs), portable electronics, and renewable energy storage systems.
- The demand for cobalt has increased significantly in recent years due to the growing popularity of EVs and the transition towards renewable energy sources.
- The Democratic Republic of Congo (DRC) is the world's largest producer of cobalt, accounting for almost 75% of global production. Other significant producers include Russia, Australia, and Canada.
- Cobalt mining often faces ethical and environmental challenges, with concerns regarding child labor, unsafe working conditions, and the ecological impact of mining activities.
- China is the global leader in the refining/processing of Cobalt representing about 75% of the total. This is a concern for many countries due to the real potential of supply disruptions.
- Cobalt prices have remained relatively since 2010, other than a few spikes in 2018 and 2022. Prices are expected to increase over the coming years as demand from EVs increases rapidly with a slower response from the mining sector.
- Almost half of proven cobalt reserves (4 million mt) are found in the Democratic Republic of the Congo..

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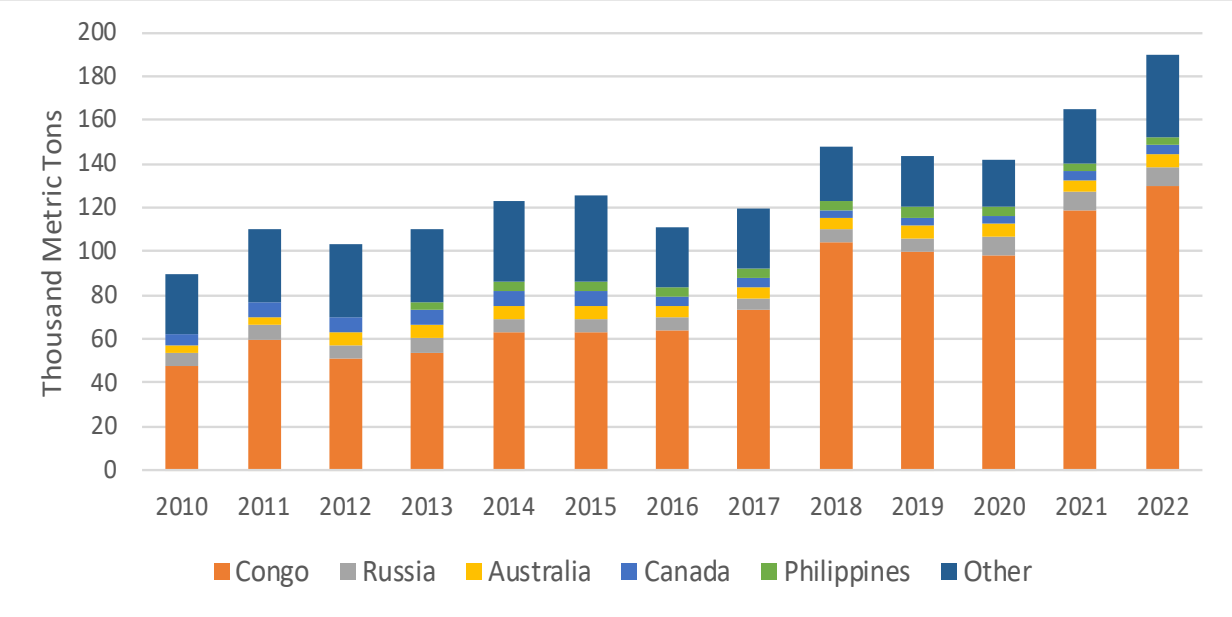
GLOBAL COBALT PRODUCTION



Global cobalt production has more than doubled from 90,000 metric tons (mt) in 2010 to 190,000 mt in 2022. The largest increase in production from 2016 to 2022, coincided with increased demand for EV batteries, up 70% over 6 short years.

The Democratic Republic of Congo (DRC) accounted for 50% of output through 2015 and has since increased their market share to 70%. In 2022, DRC produced 130,000 mt.

Other notable producers (and their 2022 production rate(s)) include Russia (9000 mt), Australia (6000), Canada (4000), and the Philippines (4000) - considerably less than DRC.

* Note that Russian production of cobalt is not under sanction.

Source: US. Geological Survey

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COBALT PRICE

This chart demonstrates the fluctuating nature of cobalt prices that are impacted by supply-demand dynamics, technological advancements, and market conditions.

Source: US. Geological Survey
Source: London Metal Exchange

Cobalt prices trended downward between 2010 and 2016 from a monthly high of USD $43,000 per metric ton (mt) to a low of just over $20,000. On an annual average basis, prices dropped from $40,000 to $26,000. This decline was driven by increased supply coupled with market concerns.

The price of cobalt surged from 2016 through 2018 from the low of $20,000 to a peak of almost $95,000. This jump in price was driven by a rapid increase in the demand for lithium-ion batteries.

Following the run-up in prices, adjustments to supply and market conditions stabilized the price in the $30,000 range for a couple of years.

A second price spike occurred starting in 2021 which saw prices jump to over $80,000 by early 2022 driven primarily by supply chain issues at the same time as demand for EV batteries increases.

An easing of the bottlenecks and increasing supply has pushed prices back down to the current level in the $35,000 range.

Going forward, cobalt prices are expected to increase as demand for the material outpaces available supply.

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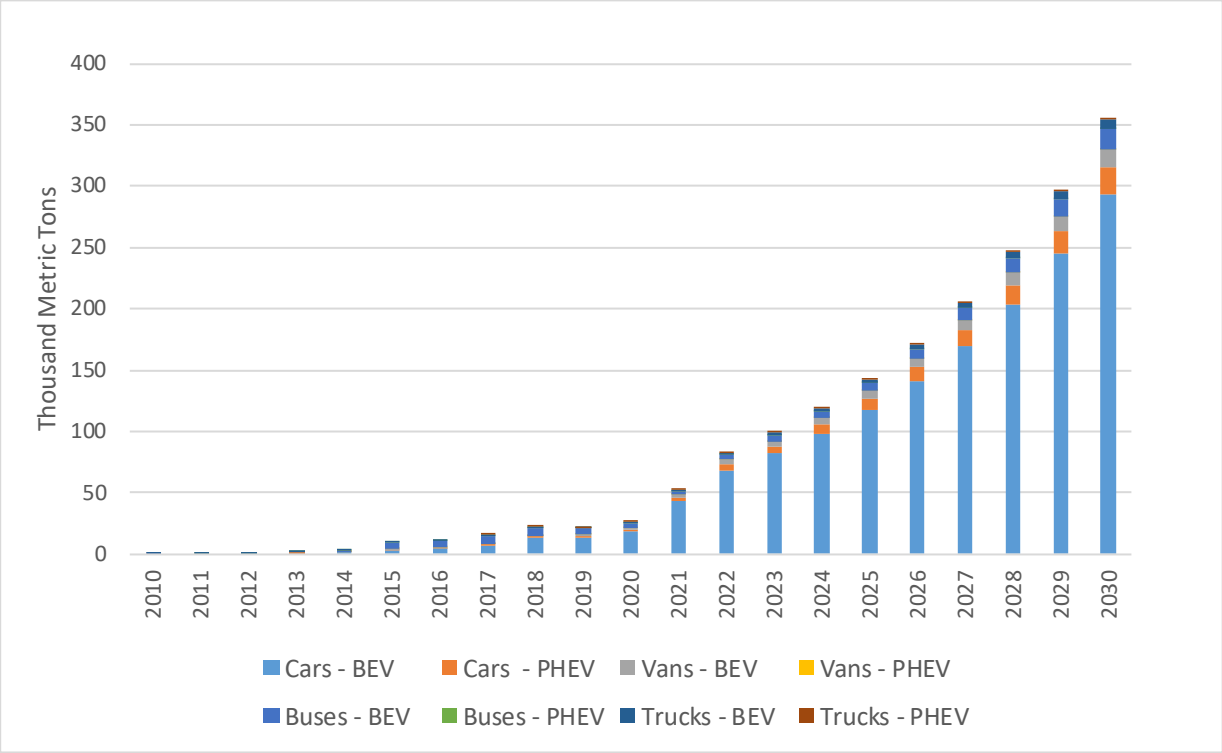
COBALT FOR BEV BATTERIES 2010-2030



Cars, primarily Battery Electric Vehicles (BEVs), account for 90% of the total market for cobalt used in batteries.

Source: International Energy Agency
Source: EV-volumes

Cobalt utilized in batteries has grown from virtually nil in 2010 to over 80,000 metric tons (mt) in 2022. Incorrys is forecasting accelerating growth with global demand reaching over 350,000 mt by 2030.

The amount of cobalt used in battery electric vehicles (BEVs) outpaced those in plug-in hybrid electric vehicles (PHEVs) across all vehicle categories.

The adoption of BEVs increased significantly, with a substantial rise in cobalt usage from 67 mt in 2010 to 294,000 mt in 2030.

The amount of cobalt used in PHEVs remained relatively low compared to BEVs, with a gradual increase from 1 mt in 2010 to 22,000 mt in 2030.

Cobalt usage in vans, buses, and trucks, both BEV and PHEV, experienced fluctuations but generally showed an upward trend over the years.

The total cobalt usage in cars consistently increased, driven by the growing popularity of EVs and the ongoing electrification of the automotive industry.

These trends indicate the growing importance of cobalt in the production of electric vehicles, reflecting the industry's shift towards more sustainable and environmentally friendly transportation solutions.

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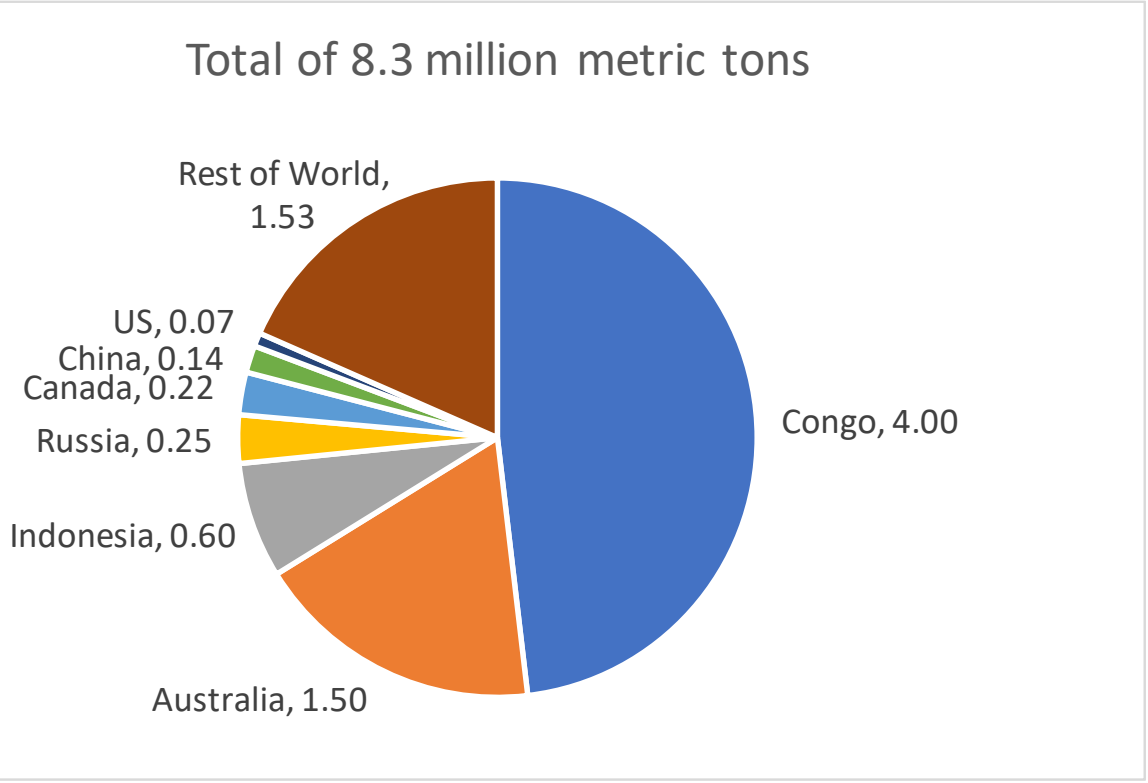
GLOBAL COBALT RESERVES



Source: US Geological Survey - Mineral Commodity Summaries 2023

Note: Reserves are a subset of resources that have been evaluated and deemed commercially viable for production.

- Total global resources of Cobalt are estimated to by about 25 million metric tons (mt). Of this total resource, there is just over 8 million mt of proven reserves.
- Almost half of proven reserves (4 million mt) are found in the Democratic Republic of the Congo. Australia has the next largest proven reserves base with almost a 20% share (1.5 million mt) followed by Indonesia with about 7% (0.6 million mt).
- Over half of the cobalt proven reserves are found in regions that are considered politically unstable (Congo) or have sanctions against them (Russia). This could impact both the supply chain and total amount of cobalt available for the growth in demand for EV batteries.
- Reserves life for cobalt in politically stable countries is around 13 years. Additional cobalt resources must be developed to meet demand after 2030-2035, which would require significant investment. Incorrys believes that limited reserve life for cobalt will lead to price increases new mine development lags demand, and new deposits are likely to have lower ore quality.

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INTRODUCTION: NICKEL

- Nickel is used in a number of applications such as coins and plating to other metals to protect them. Another key use is in the production of stainless steel which is widely used in various industries, including construction, automotive, and household appliances.
- The increasing demand for electric vehicles (EVs) and renewable energy storage systems has led to a growing need for nickel used in the production of nickel-metal hydride (NiMH) and lithium-ion batteries. Nickel plays a crucial role in enhancing the battery's energy density and overall performance, making it a key component in the transition to clean energy technologies.
- Indonesia is the largest producer of nickel accounting for almost 50% of the global total. The Philippines and Russia represent an additional 15% combined.
- On the refining and processing side, Indonesia represents about 40% of the total followed by China with a 20% market share.
- After declining over the first half of the past decade, nickel prices have been steadily increasing since 2016.
- Australia and Indonesia each account for about 20% of proven reserves followed by Brazil and Russia which represent another 23% combined.

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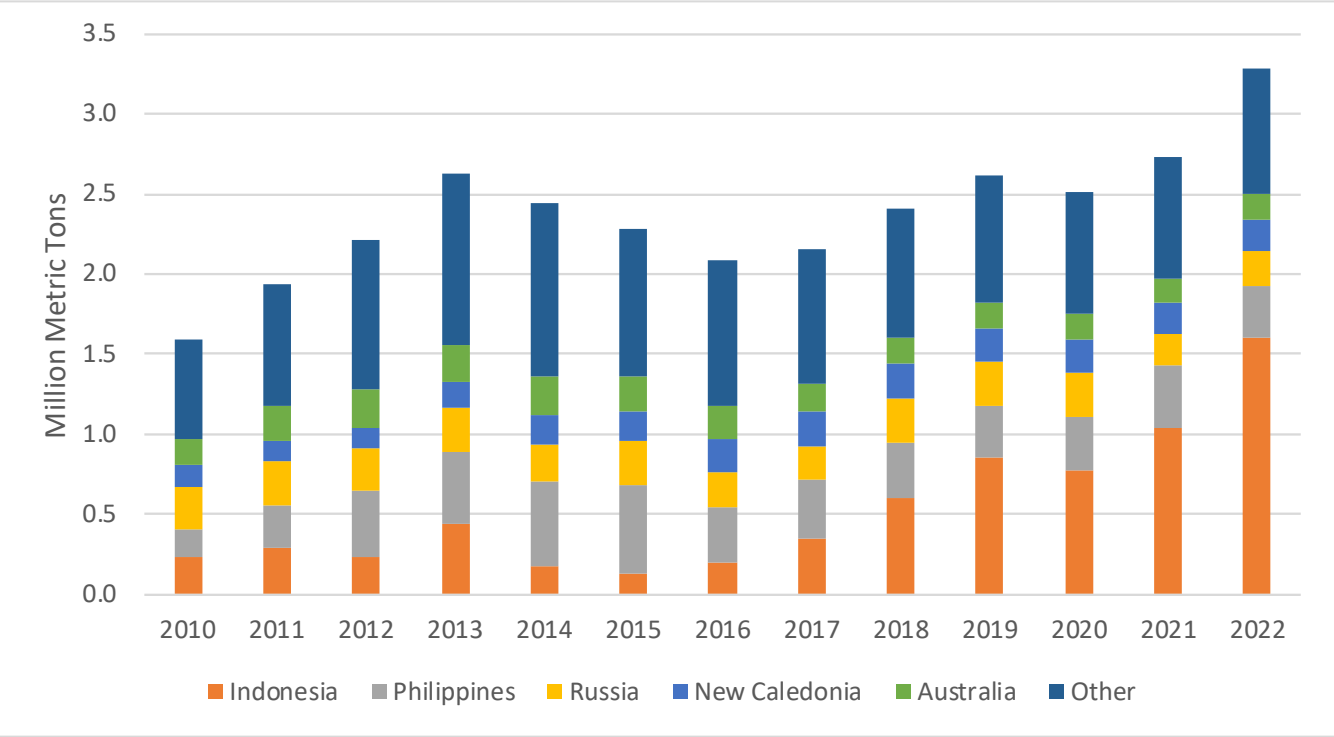
GLOBAL NICKEL PRODUCTION



Global nickel production has generally been in an upward trend growing from over 1.5 million metric tons (mt) in 2010 to 3.3 million mt in 2022.

Indonesia is currently the largest producer with production increasing from 232,000 mt in 2010 to 1.6 million mt in 2022.

The second largest producing country is the Philippines. They were the worlds leading producer from 2011-2017 before leveling off in the 350,000 mt range since then.

Russia's production has remained relatively stable in the 250,000 mt range*, while Australia and other countries have experienced slight declines.

* Note that Russian production of nickel is not under sanction.

Source: US. Geological Survey

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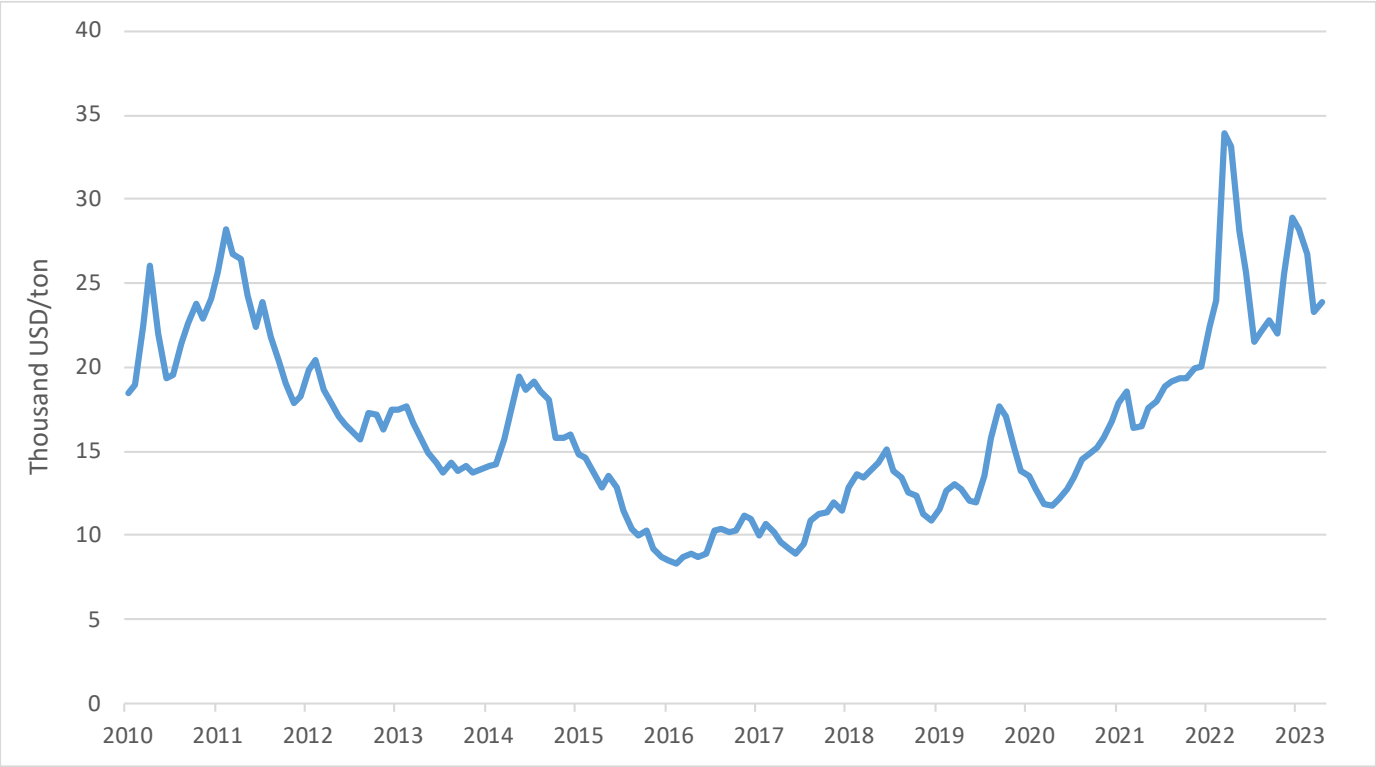
NICKEL PRICE



Annual nickel prices have exhibited varying trends between 2010 to 2023. Prices generally trended downward from 2010 through 2016 going from over USD $20,000/metric ton (mt) to about USD $10,000. Nickel hit a low of just USD $8300 in early 2016.

Nickel prices have since been generally trending upwards since 2017 recovering to the USD $20,000 price range by late 2021.

Recent prices have jumped significantly and averaged over USD $25,000 in 2022 and 2023 and peaking at over USD $33,000 early in 2022.

These fluctuations in nickel prices were influenced by a variety of factors, including global supply and demand dynamics, economic conditions, and geopolitical factors.

Like most raw materials, nickel prices are expected to increase going forward as demand for the material outpaces available supply.

Source: London Metal Exchange
Source: US. Geological Survey

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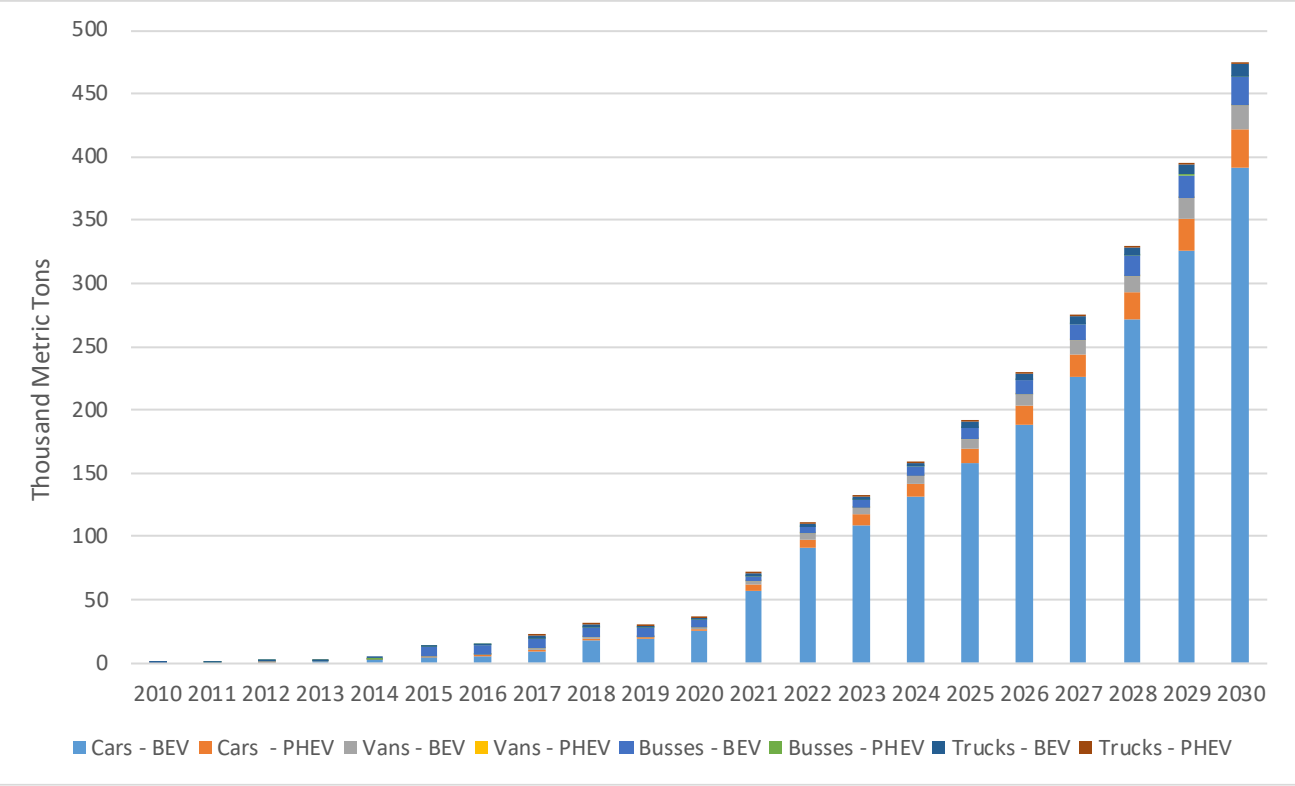
NICKEL FOR BEV BATTERIES 2010-2030



The amount of nickel used in batteries for various types of vehicles has increased from essentially nothing in 2010 to over 100,000 metric tons (mt) in 2022. This increase reveals the significant increase in the adoption of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs).

In the case of EVs, the number of battery electric cars (BEVs) has seen the most growth growing from just 90 mt in 2010 to 25,000 thousands mt by 2022. BEV vans and buses have also shown a substantial increase in numbers over the years.

Incorrys expects the amount of nickel required for EV batteries to increase from 100,000 mt in 2022 to almost 500,000 mt by 2030 with BEVs accounting for over 80%.

PHEVs, although not as prevalent as BEVs, will also experience notable growth in car, van, bus, and truck categories.

Overall, the data illustrates a shift towards greener transportation options, with a significant rise in the number of electric vehicles. This trend also highlights the increasing demand for nickel, a crucial component in the batteries used in EVs.

Source: International Energy Agency
Source: EV-volumes

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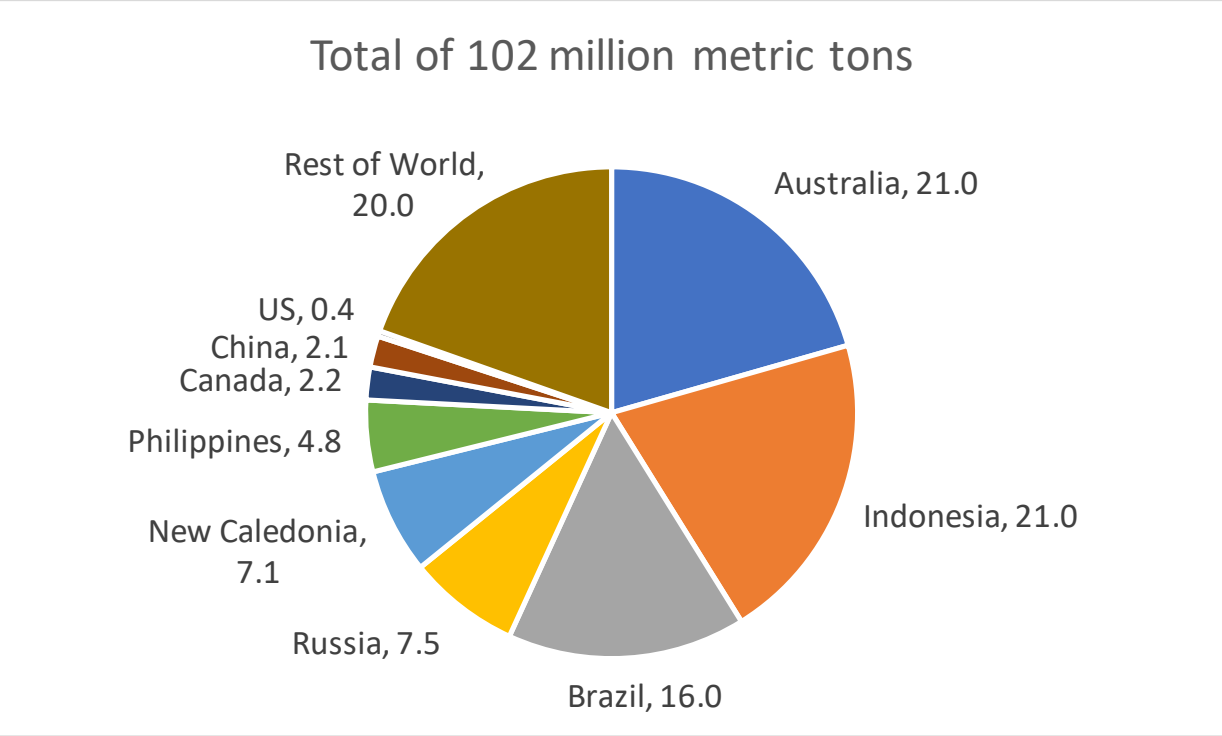
GLOBAL NICKEL RESERVES



Source: US Geological Survey - Mineral Commodity Summaries 2023

Note: Reserves are a subset of resources that have been evaluated and deemed commercially viable for production.

- Total global resources of Nickel are estimated to by about 300 million metric tons (mt). Of this total resource, there is just over 102 million mt of proven reserves.
- Australia and Indonesia each account for about 20% of the total (21 million mt each) with Brazil coming in third at 16% (16 million mt). Combined, Russia, Caledonia, and the Philippines account for a further 20%.
- Some nickel resources are found in regions that are considered politically unstable (Cuba) or under international sanction (Russia). This could impact both the supply chain and total amount of nickel available for the growth
- Nickel used in BEV batteries requires the highest Class 1 purity which is more difficult to find.
- A number of battery manufacturing companies are focused on using nickel instead of cobalt in batteries as nickel is generally cheaper plus most nickel reserves and resources are located in politically stable countries.
- Reserve life for nickel is over 25 years. More nickel resources must be developed to satisfy demand post 2035, which would require significant investments.

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INTRODUCTION: LITHIUM

- Lithium-ion batteries have revolutionized portable electronics and electric vehicles due to high energy density and long cycle life. They are commonly used in smartphones, laptops, electric cars, and renewable energy storage systems. Lithium is also used in the production of ceramics, glass, and lubricants.
- The demand for lithium has surged in recent years due to the growing popularity of electric vehicles and the increasing need for energy storage solutions. Lithium is primarily extracted from lithium-rich brine or hard rock deposits.
- Lithium is expected to play a crucial role in supporting the growth of clean technologies, however, the sustainable extraction and recycling of lithium must also be done in a manner that minimizes environmental impacts.
- Australia is the largest producer of lithium accounting for almost 50% of the total. They are followed by Chile at 30% and China at about 15%.
- China accounts for about 2/3 of global refining and processing of lithium. Chile, the second largest refiner accounts for another 30%. Combined, these two countries represent about 95% of global lithium processing.
- With a substantial increase in lithium demand, prices have quadrupled over the past 3 years and are expected to continue to increase as supply lags demand.
- Chile contains about 35% of proven lithium reserves followed by Australia at 25% and Argentina at 10%.

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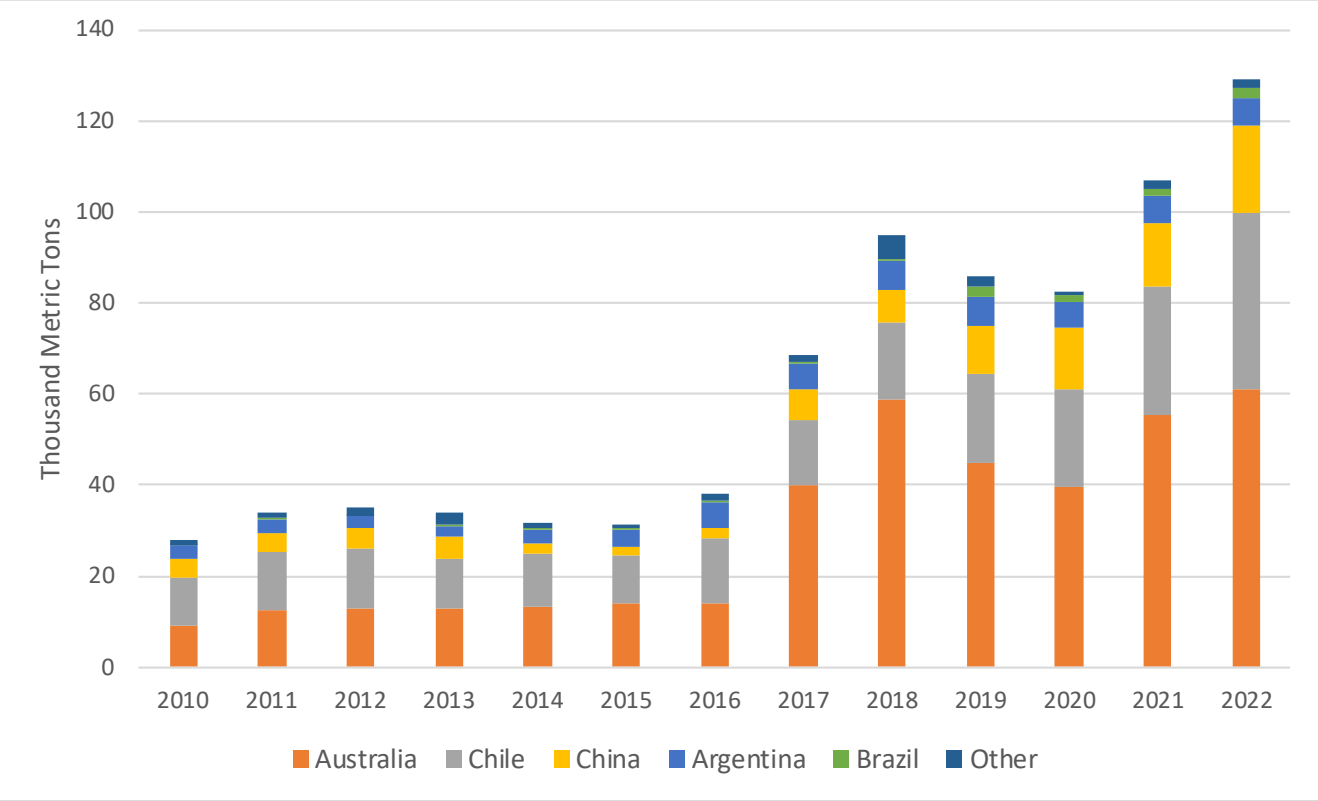
GLOBAL LITHIUM PRODUCTION



Global lithium production remained relatively flat from 2010 to 2016 averaging about 35,000 metric tons (mt). Production has since more than tripled to 130,000 mt in 2022.

Australia and Chile have remained the leading producers, while China has emerged as a significant player. Fluctuations in production levels are influenced by market demand and resource availability.

The growth in lithium production reflects the rising demand for lithium-ion batteries, particularly for the expanding electric vehicle market. Recent years have seen a surge in production as countries prioritize net-zero carbon goals.

Source: US. Geological Survey

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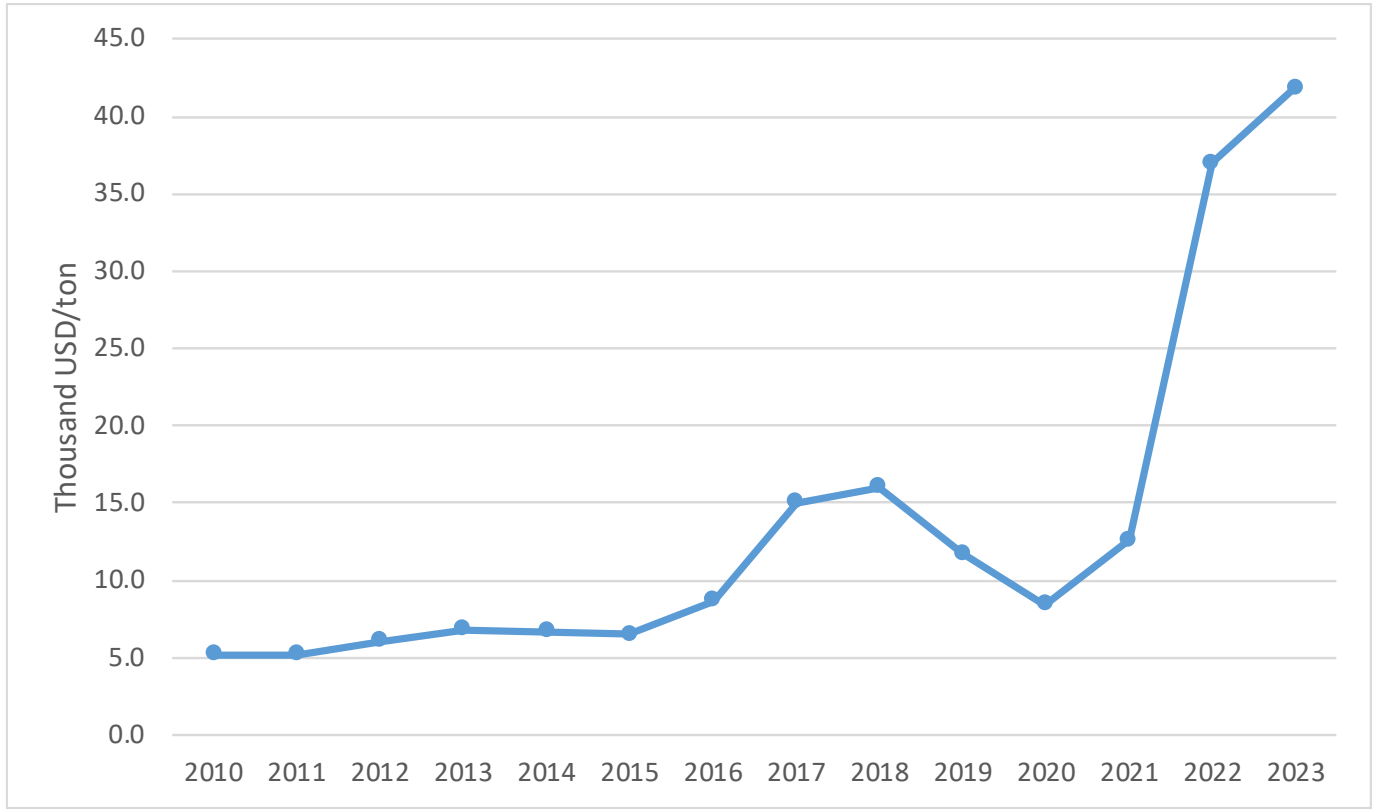
LITHIUM PRICE



Lithium prices were relatively stable from 2010-2015 ranging between $5,000 and $7000 USD/metric ton (mt). There was a notable increase starting in 2016 and reached $15,000 in 2017.

The price retreated for a few years due to the pandemic before jumping to over $35,000 in 2022. This surge in price can be attributed to the growing demand for lithium-ion batteries, driven by the increasing popularity of electric vehicles and energy storage systems.

In 2023, the price of lithium per metric ton (mt)continued to rise, reaching over $40,000. This upward trend in price reflects the limited supply of lithium compared to its increasing demand. Factors such as resource availability, production capacity, and market dynamics can influence the price of lithium.

Like most raw materials, lithium prices are forecast to increase as demand for the material outpaces available supply.

Source: US. Geological Survey
Source: Shanghai Metals Market
Source: Benchmark Minerals Intelligence

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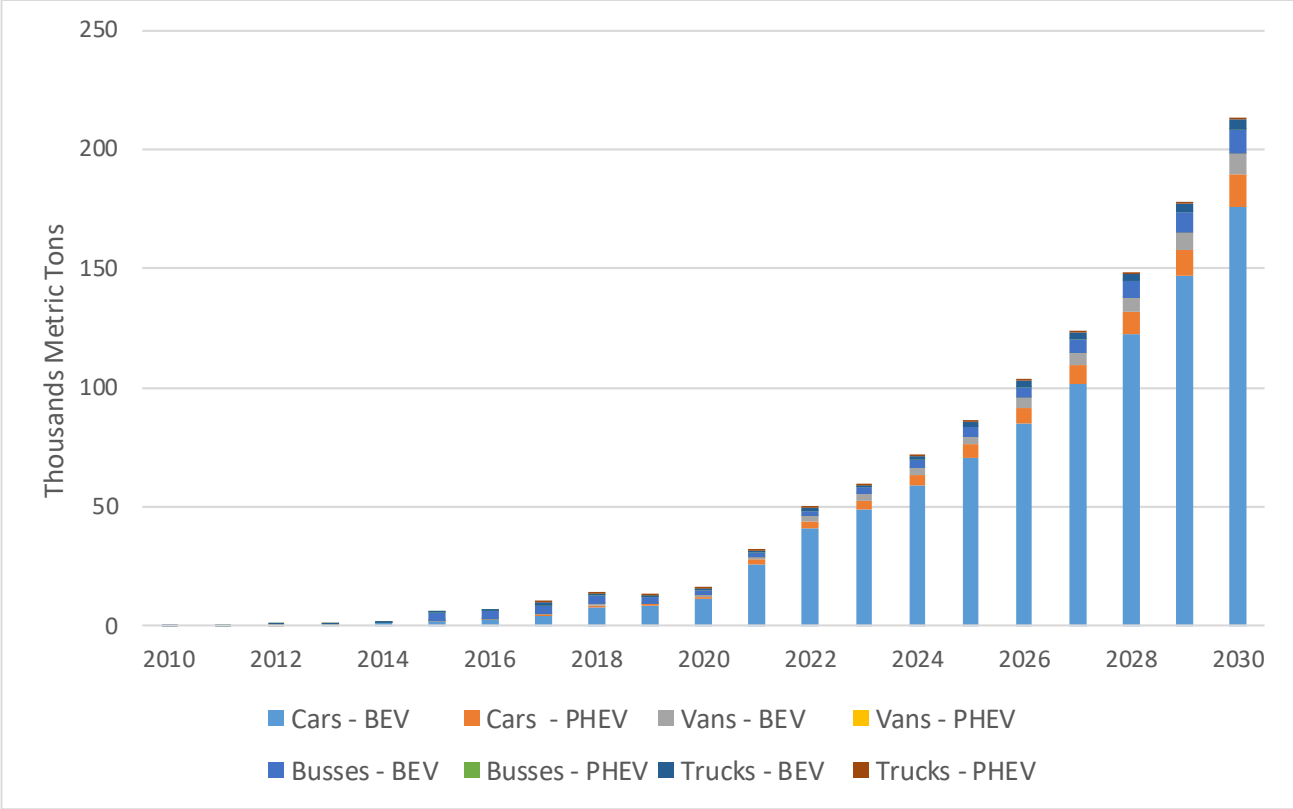
LITHIUM FOR BEV BATTERIES 2010-2030



Lithium used in BEV cars has grown from essentially nothing in 2010 to 11,000 metric tons (mt) in 2020 however, the growth is expected to accelerate through to 2030 increasing to about 175,000 mt. The number of PHEVs cars is also expected to show steady growth reaching 13,000 mt in 2030. This growth reflects the rising popularity of electric cars and the transition towards cleaner transportation options.

Similarly, the use of lithium batteries in vans, buses, and trucks witnessed strong growth. The number of BEVs in these categories increased consistently, indicating the adoption of electric drivetrains in commercial and public transportation. The number of PHEVs in vans, buses, and trucks also saw gradual growth, albeit at a smaller scale.

Source: International Energy Agency
Source: EV-volumes

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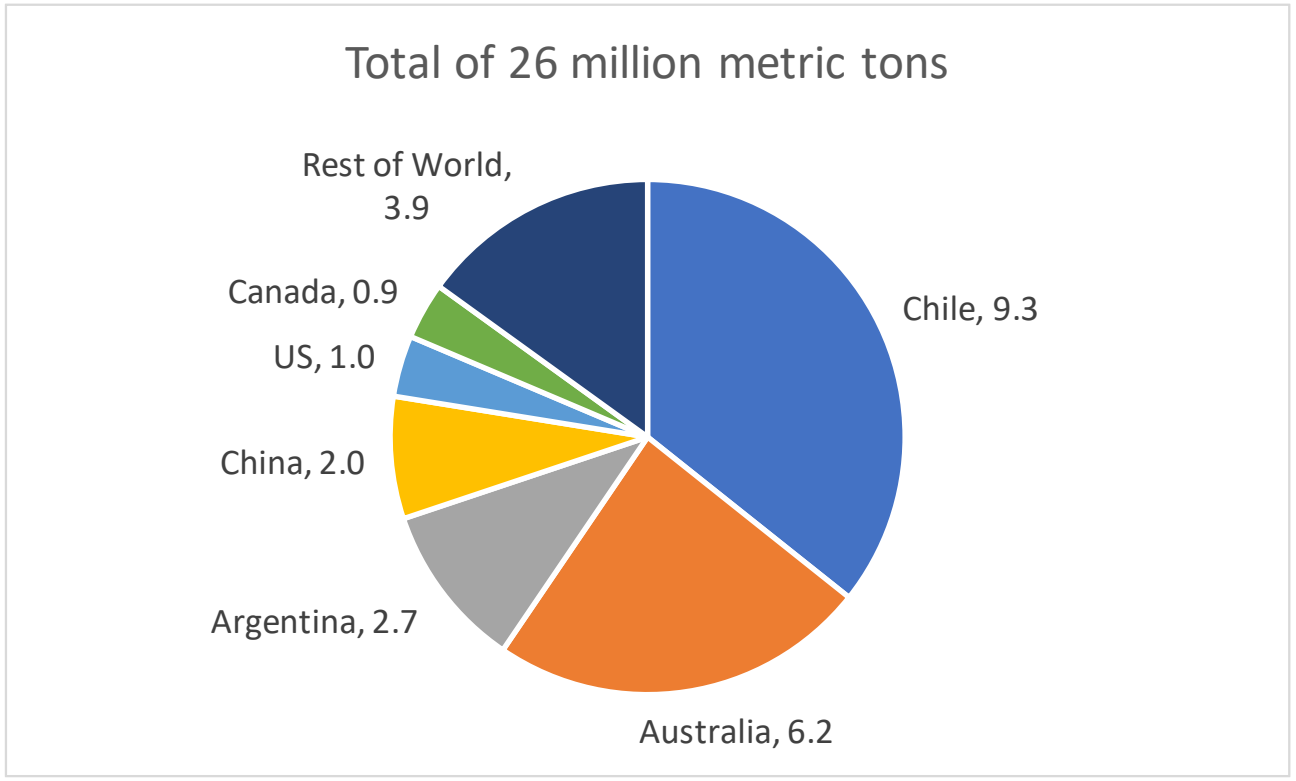
GLOBAL LITHIUM RESERVES



Source: US Geological Survey - Mineral Commodity Summaries 2023

Note: Reserves are a subset of resources that have been evaluated and deemed commercially viable for production.

- Total global resources of Lithium are estimated to be about 98 million metric tons (mt). Of this total resource, only about a quarter (26 million mt) are proven reserves.
- Chile accounts for about 1/3 of global proven reserves (9.3 million mt) followed by Australia at about 25% (6.2 million mt) and Argentina at 10% or 2.7 million mt).
- The majority of global lithium reserves are from stable, or relatively stable, regions and therefore shouldn't result in supply disruptions or shortages caused by political instability unlike other raw materials utilized in the production of EV batteries.
- Although Incorrys estimates the global reserves life for lithium is over 25 years more Lithium resources must be developed to satisfy demand for batteries. Incorrys expects Lithium refining, not mining, will be the main bottleneck in Lithium supply.
- With new refining capacities coming on market, the Lithium price is expected to remain high until at least 2030. Lower battery prices will likely require technological improvements. As a result, many battery technology applications for large trucks and large stationary energy storage are likely to be uneconomic.

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WHY INCORRYS INFORMATION SYSTEM

COMPREHENSIVE DATA

Incorrys constantly collects huge amounts of data from multiple sources world-wide

ADVANCED ANALYTICS

Incorrys performs data analysis to ensure quality and consistency among different industries and jurisdictions

ACCURATE FORECASTS

Incorrys employs proprietary forecasting methodologies to ensure accurate forecasts of trends in different industries.

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sales@incorrys.com

+1 (347) 741 8219

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