August 2023

# Inflation Reduction Act:

## Impact on North America metals and minerals market

### FINAL REPORT

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**This multi-client study offers an independent and objective assessment of the Inflation Reduction Act on the North American metals and minerals markets. S&P Global is solely responsible for the analysis and conclusions in the report. Subscribers to the report include BHP Mineral Services Ltd.; Freeport-McMoRan Inc.; Northern Dynasty Minerals Ltd.; Rio Tinto Corp.; Taseko Mines Ltd.; and Vale Canada Ltd.**

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# Preface

# Preface (1)

To what degree will the massive Inflation Reduction Act of August 2022 (IRA) achieve its goal of accelerating the US energy transition? In significant part, that hinges on minerals — will the US be able to secure sufficient supply of the minerals needed for the move toward net-zero? This new S&P Global analysis indicates that there are considerable challenges.

The IRA impacts minerals in two ways. On the demand side, it does so by providing major stimulus and subsidies for a wide range of mineral-intensive decarbonization technologies, from electric cars to off-shore wind turbines. On the supply side, it seeks to promote mineral development by imposing percentage requirements for mineral content from the United States or countries with which it has a free trade agreement ("FTA countries"). These requirements rise quickly. To qualify for IRA tax credits, 50% of the critical minerals in a vehicle's battery (by value) must meet these requirements in 2024 — rising to 80% by 2027. The IRA also seeks to reduce reliance on "foreign entities of concern."

The focus on minerals embodies widespread anxiety that insufficient supply of minerals will be a major constraint on the move to net-zero. Over the last few years, growing alarm about mineral supply has been expressed by governments and international organizations including the United States, Japanese, British and Canadian governments, as well as the EU, the International Monetary Fund, the World Bank and the International Energy Agency. As the IEA put it: "The shift to a clean energy system is set to drive a huge increase in the requirements for these minerals…. A rapid rise in demand for critical minerals — in most cases well above anything seen previously — poses huge questions about the availability and reliability of supply."

Prior to the IRA, it was already clear that the policy-driven quest for net-zero was creating new demand for minerals on top of traditional consumption, and that this rising demand could well lead to tighter markets, potential shortfalls and intensified international competition for access to both mined minerals and to the final metals that emerge as mineral rocks are processed.

The purpose of this study is to ascertain how much the IRA will add to the requirement for minerals in the United States. The conclusion can be summarized simply: a lot. With its in-depth analysis, this report aims to contribute to the national dialogue about the energy transition.

# Preface (2)

This study builds on the approach developed for S&P Global's comprehensive 2022 report, *The Future of Copper.* Copper is not currently classified by the US Geological Survey as a "critical mineral" (although the European Union and Canada have identified it as such). Regardless of its classification, copper is indeed critical because so much of the energy transition is about electrification, and copper is, as it was put in the 2022 report, "the metal of electrification."

That report concluded that world copper production would need to double by the second half of the 2030s to support achieving global 2050 net-zero ambitions. The study differed from others by taking a bottom-up, granular approach. It used 2050 goals as the starting point, and then identified the copper requirements for the different energy transition technologies to implement the 2050 target.

We described the sum of those requirements as a new category of aggregate demand: "energy transition demand," differentiated from traditional demand (such as that for construction), which increases in tandem with economic growth. We then matched up both energy transition demand and traditional demand with current mine capacity and potential new supply, taking into account the 16 to 20 years or more that it takes to bring on a major new mine. In the base case scenario, by 2035, there is a 20% shortfall in the supply of copper required to support global net-zero.

The current study uses the same approach of analyzing the mineral requirements for the energy transition technologies whose adoption the IRA aims to accelerate. This report differs, however, from the copper study in significant ways. First, it looks at three of the critical minerals around which the IRA imposes content requirements: lithium, cobalt and nickel. Given copper's fundamental importance to energy transition, it also looks at copper. Second, it is focused on US energy transition demand, not total global demand. Third, it seeks to assess how much of that demand can be met from US mining and processing and how much from FTA countries — i.e., per the IRA's content requirements.

The results indicate that post-IRA US energy transition demand for lithium will be 15% higher by 2035 than the rapidly growing volumes would have been pre-IRA, 14% higher for nickel, 13% higher for cobalt and 12% higher for copper. But the challenges of meeting these needs are considerable. This report concludes that, over time, lithium is the mineral most likely to be sufficiently supplied to the US under the IRA's content requirements. Ensuring that the supply of nickel and cobalt meets rapidly growing US demand will be more difficult. Nickel production is concentrated in non-FTA countries. Enough cobalt will be processed in FTA countries to meet US energy transition demand, but it is exported to other countries. Copper presents a substantial domestic opportunity. There is an estimated untapped copper endowment of over 70 million metric tons in the US – equivalent to about three years of global production. But lengthy and complicated regulatory and permitting processes along with litigation risks inhibit the development of this endowment and, more broadly, mineral development in the United States.

# Preface (3)

Across FTA countries, too, aboveground challenges can restrict new minerals projects. There will likely be a persisting struggle to match IRA requirements to the availability of supply. Permitting delays and litigation can create extensive roadblocks. Investors may struggle to identify and act on “actionable opportunities.” Political controversies within resource countries may impede progress. Environmental concerns and opposition to mining will likely challenge development. Labor disputes and rising costs could impede output. Government and companies will likely struggle to agree on investment terms and operational processes. International competition for constrained resources is likely to increase as governments push their 2050 goals. And, in this new era of Great Power competition, the quest for minerals will likely become entangled in the rising tensions between the United States and China, the latter of which has a predominant international position in minerals.

Some may argue that near-term fluctuations in the price of these minerals indicates less pressure coming for mineral supply, but that is not a good guide to what the future holds in the march to net-zero. For now, energy transition demand is still a relatively small part of overall demand. Current prices are much affected by traditional demand, which tracks GDP, and near-term expectations. A less vibrant post-COVID rebound in China, high interest rates, slowdowns in Europe and the United States — these all are currently impacting markets.

But the heating up of energy transition demand points to increasing pressure on supplies in the years to come. This study examines the extent to which the IRA will add to the heat — and thus to the challenges and quandaries ahead for mineral security.

- Daniel Yergin, Vice Chairman, S&P Global

# Executive summary

# Executive summary

This study analyzes the likely impact of the US Inflation Reduction Act (IRA) on US demand to 2035 for three US-listed critical minerals: cobalt, lithium and nickel. It also considers copper. Although not currently designated "critical" by the US Geological Survey, copper is fundamental to the energy transition as the "metal of electrification." In its latest draft report from May 2023, the US Department of Energy described copper as a near-critical mineral for the medium term (2025-2035).[1]

The IRA passed in August 2022.[2] It followed the Bipartisan Infrastructure Law (BIL) and the CHIPS & Science Act to become the third legislative piece of a new industrial strategy that emerged in less than 12 months. This strategy focuses on building domestic capacity in — and securing reliable supply for — the applications and industries that will advance the energy transition and give the United States a long-lasting competitive advantage. It seeks to catalyze investment in these sectors through roughly $500 billion in tax credits, mostly dispensed under the IRA, by 2032 — an unprecedented government commitment to energy transition.

Like S&P Global's report *The Future of Copper* (2022), this study takes a bottom-up approach to assessing demand for the four metals. It calculates how much of each is consumed for each major energy transition application, including power generation, transmission and distribution, and end markets such as electric vehicles (EVs). Aggregated demand is then compared with projected supply, domestic and foreign. The report then identifies key overground challenges to increasing mined supply from North America.

This study, however, differs from *The Future of Copper* in that it is focused on the United States rather than global market balances, and it assesses the change in energy transition-related demand (the demand targeted by the IRA) rather than total demand.

The overall message in our findings:

- Post-IRA US demand projections to 2035 for cobalt, lithium, nickel and copper are materially higher than pre-IRA.
- It will be very challenging to meet this demand under the IRA's sourcing requirements.

Copper, not currently listed as a critical mineral, does not qualify for IRA tax credits, but demand for it will rise as it is used alongside critical minerals in transition applications. Its supply is not subject to the IRA's sourcing requirements, but, as shown in *The Future of Copper*, the complexity and length of permitting processes presents a daunting challenge to exploiting the US's huge copper resources in coming years.

*[1] https://www.energy.gov/sites/default/files/2023-05/2023-critical-materials-assessment.pdf.*
*[2] This study is based on the provisions of the IRA as passed in August 2022. The US Treasury will continue to issue guidance that modifies these provisions for the purposes of administering IRA tax credits, for example, granting some countries "FTA-like" status via bilateral critical mineral agreements. These modifications will likely alter some of the results calculated here – but we do not expect them to affect our broad conclusions.*

# Key findings: demand requirements

- Post-IRA, US demand for lithium, cobalt, nickel and copper will be materially higher. Spurred by the IRA, energy-transition-related US demand for the critical minerals lithium, nickel and cobalt, taken together, will be 23 times higher in 2035 than it was in 2021. For copper, it will be twice as high. This is equivalent to compound annual growth rates of 25% for the three critical minerals and 4% for copper. While the upward trend was established pre-IRA with the increased cost competitiveness of renewable infrastructure and EVs, projections are materially higher post-IRA.
- Copper remains the backbone of the energy transition — what the IEA calls "the cornerstone for all electricity-related technologies." More than two-thirds of US energy transition-related volumetric demand for the four metals is for copper. Post-IRA, US demand for copper from energy transition-related infrastructure and EVs will reach nearly 2.6 million metric tons in 2035. This is energy-transition-related demand dominated by demand for copper in electric vehicles and legacy combustion engine vehicles, and electricity transmission and distribution.[1] Lithium, cobalt and nickel are critical, in the energy transition space, to battery manufacturing for EVs and energy storage systems. The 2.6 million metric tons of copper that we project will be required in 2035 in the United States compares to about 700,000 metric tons for nickel, 112,000 metric tons for lithium and 53,000 metric tons for cobalt.
- Electric vehicle batteries are the key driver of growth in the post-IRA demand outlook for critical minerals in the United States. Compared to before the IRA, US demand in 2035 is projected to be:
  - Lithium – 15% higher
  - Cobalt – 13% higher
  - Nickel – 14% higher
- Demand for copper comes from a wider range of applications, including transportation, power generation, and transmission and distribution. Post-IRA, US energy transition demand for copper is projected to be 12% higher by 2035 than our pre-IRA outlook.
- Domestic battery recycling will reduce the net demand for nickel, lithium and cobalt — but only in the longer term. The US battery recycling industry is nascent, and recycling activity will only start scaling up when electric vehicles start reaching end-of-life.
- Other countries will be competing for the same supply as countries shift toward more renewable energy capacity, EVs and electrification of their energy supply. This will further challenge the US's ability to source additional volumes from outside the country.

[1] *Offshore and onshore wind cables are considered within the wind considerations – copper intensity for onshore wind cable is more limited by technology choice (see appendix).*

# Key findings: sourcing and aboveground challenges (1)

As demand for nickel, lithium, cobalt and copper further surges post-IRA, the US will be increasingly reliant on imports. However, these will be difficult to secure per the IRA's sourcing requirements of production and/or extraction in the United States or FTA countries. The third requirement, that sourcing cannot involve a "foreign entity of concern," will be a significant constraint given Mainland China's (China's) dominant position in processing minerals. Defining "foreign entity" will have challenges of its own. Does that mean ownership, controlling interest, minority share, joint venture? Questions such as this will add to the complexity.

## NICKEL

- Indonesia, a non-FTA country, dominates global primary nickel production, and its dominance is projected to intensify by 2035. Further, Indonesia is seeking to move downstream in terms of processing. We expect that non-FTA countries together will account for 92% of production in 2035 — and the US's projected sourcing requirement will not be met by FTA countries.

- Currently, 47% of US nickel imports are from non-FTA countries, including 11% from Russia. Moreover, the US (and others) will specifically need Class 1 nickel (99% nickel content or greater) to produce EV batteries. This presents a significant challenge to fulfilling the US's sourcing requirement.

## LITHIUM

- Of the four metals considered in this study, global mined production of lithium is currently projected to grow most rapidly due to several planned capacity increases, from under 800,000 metric tons annually today to nearly 3.6 million metric tons in 2035. More than 57% will be in FTA countries, and another 5% will be in the United States.

- In refined production, China is projected to account for 52% globally in 2035. Currently, however, almost all US lithium imports are from Argentina (44%) and Chile (53%). But Argentina is not an FTA country, and much of Chile's production is exported to China, with which it has a deepening trade relationship.

# Key findings: sourcing and aboveground challenges (2)

## COBALT

- In 2035, we project that 90% of global production of cobalt will be in non-FTA countries — most of it in the Democratic Republic of Congo (DRC). Over 70% of the DRC's cobalt exports currently go to China, which in turn accounts for more than half of global refined cobalt.

- In all years to 2035, FTA countries' production of refined cobalt are projected to exceed the US's sourcing requirements. But the US currently sources 78% of its refined cobalt from non-FTA countries — including 11% from Russia. While Australia and Canada, both FTA countries, currently produce enough refined cobalt to satisfy the US sourcing requirement, only 3% and 12% of their exports, respectively, are directed to the United States.

## COPPER

- Although it is not listed in the US as a critical mineral, the US energy transition sourcing requirement for copper is higher post-IRA, and the US remains import-dependent. In 2022, 64% of the US's refined copper imports were from Chile. But only 21% of this FTA country's exports of refined copper went to the United States, compared with 43% to China.

- As with lithium, Chile has a larger trade relationship with China than with the US. It is far from guaranteed that the US will be Chile's major export destination for new capacity. In the United States itself, refined production has fallen since 2000, so mined production has been increasingly exported rather than processed in the US.

Under the IRA, at least 50% of battery components of electric vehicles seeking tax credits in the United States must be finally assembled in North America, and this rises to 100% by 2029. While policymakers in the United States, Canada and Mexico have clearly recognized the strategic importance of critical minerals and mining more generally, major aboveground challenges remain in these operating environments around permitting and post-permit litigation risks, social license to operate, and political and environmental challenges to mining.

# Key findings: summary by metal (1)

| | US-listed critical minerals | | | Not listed critical mineral |
|---|---|---|---|---|
| | **Nickel** | **Lithium** | **Cobalt** | **Copper** |
| Projected post-IRA increase in US energy transition demand in 2035 | 14% | 15% | 13% | 12% |
| US sourcing challenges | • US demand is unlikely to be met by FTA countries.<br>• Over 90% of global production is projected to be by non-FTA countries by 2035. | • Today the US sources almost all its lithium from Argentina (44%) and Chile (53%). Argentina is not an FTA country; Chile has a deepening trade relationship with Mainland China. | • In 2035, 90% of global production of cobalt is expected to be in non-FTA countries.<br>• The US currently sources 78% of its refined cobalt from non-FTA countries.<br>• In all years to 2035, FTA countries' production of refined cobalt will likely exceed the US's sourcing requirements. But the US currently sources 78% of its refined cobalt from non-FTA countries, including 11% from Russia. | • The US remains import-dependent. In 2022, 64% of the US's refined copper imports were from Chile, an FTA country.<br>• As with lithium, Chile has a larger trade relationship with China than with the US.<br>• Refining capacity in the US has fallen in recent years. |
| US sourcing opportunities | | • US domestic production is expected to grow significantly in coming years. | • Australia and Canada, both FTA countries, currently produce enough refined cobalt to satisfy the US sourcing requirement. | • While the US potentially has over 70 million metric tons of untapped copper reserves and resources, which is equivalent to three years of global primary production, it still faces the challenge of smelting and refining the ore into a usable product, most of which is done in China and other non-FTA countries. |

# Key findings: summary by metal (2)

## 13%

Post-IRA, additional projected US demand for **cobalt** for EV batteries and vehicles in 2035

## 14%

Post-IRA, additional projected US demand for **nickel** for EV batteries and vehicles in 2035

## 15%

Post-IRA, additional projected US demand for **lithium** for EV batteries and vehicles in 2035

## 12%

Post-IRA, additional projected US demand for **copper** across all energy-transition-related applications in 2035

# Introduction

Introduction

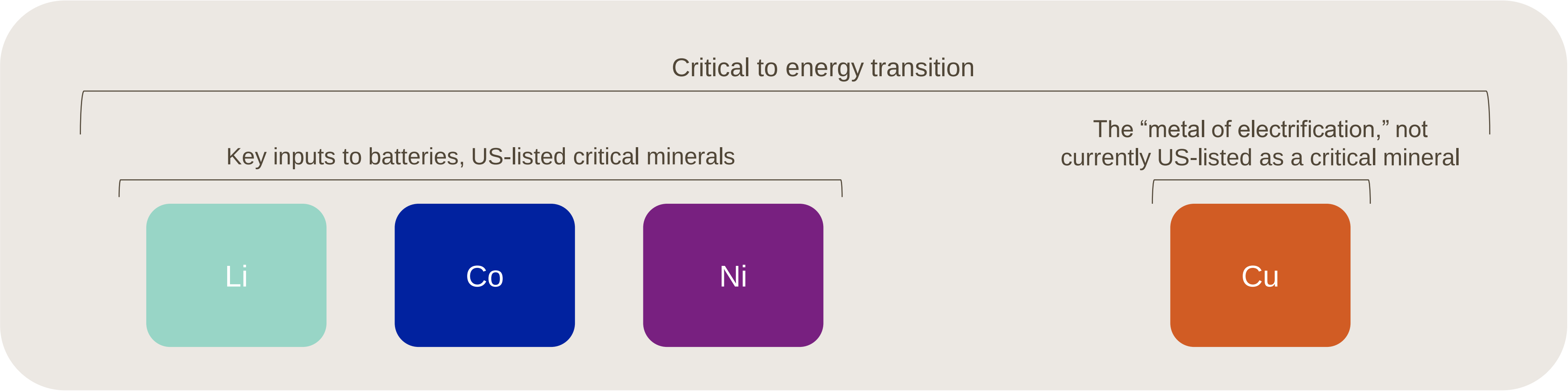
# Objectives and approach

# Introduction: lithium, cobalt, nickel — and copper

The energy transition will boost demand for a wide range of materials as new infrastructure is built and new technologies are adopted. Among these materials are several "critical minerals": currently 50 non-fuel minerals listed by the US Geological Survey as "essential to the national or economic security of the United States."[1] Reliable projections of the demand for these materials, and securing their supplies, have become core to industrial strategy. Particularly close attention has been paid to three of them: lithium, nickel and cobalt. Without these, producing efficient batteries will not be possible.

In this context, the US Inflation Reduction Act of 2022 (IRA) is a policy landmark: it dedicates substantial public funds to (i) accelerating domestic energy transition; and (ii) to "re-shoring" or "friend-shoring" production of the critical minerals on which that transition depends.

But copper, while not US-listed as a critical mineral, is arguably even more fundamental to the energy transition because it is the "metal of electrification." S&P Global's 2022 report *The Future of Copper* found that "technologies critical to the energy transition such as EVs, charging infrastructure, solar photovoltaics (PV), wind and batteries all require much more copper than conventional fossil-based counterparts." Copper imports are shielded from FTA/US sourcing restrictions, and plants using the material cannot benefit from specific IRA benefits for critical minerals.




[1]The US's Energy Act (2020) defines critical minerals as "those which are essential to the economic or national security of the United States; have a supply chain that is vulnerable to disruption; and serve an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the U.S." They exclude fuel minerals, water and common varieties of sand, gravel, stone, pumice, cinders and clay. The list is changeable and to be reviewed every three years. The most recent list was published in February 2022.

# Introduction: objectives and overview

In this high-level study, S&P Global seeks to analyze and frame the IRA's impact on demand and supply for these four metals in the United States as a contribution to the national dialogue on the implementation of the IRA. The study asks four main questions:

1 Now that the IRA has been enacted, how much demand will there be in the US for lithium, cobalt, nickel and copper to 2035?

We compare our demand projections for the four listed metals pre- and post-enactment of the IRA.

2 Which applications account for the bulk of this total demand? Which applications account for the additional demand post-IRA?

We calculate the intensity of consumption of each of the four metals for all major energy transition applications, including power generation, transmission and distribution, and end markets such as electric vehicles.

3 From where can these metals be sourced? Which of the US's free trade agreement partners produce these metals?

We estimate primary and secondary production for all countries. Estimates for the United States, FTA countries and others are compared with projected US demand for each of the four metals.

4 What are the main operational challenges to increasing production of these metals in the United States, Mexico and Canada (USMCA)?

We outline the major aboveground challenges to increasing mining production in USMCA. (Note: USMCA countries enjoy special preference in the IRA's sourcing requirements.)

# Introduction: research context

This study builds on S&P Global's work in *The Future of Copper* (2022) in analyzing the material requirements of the energy transition. *The Future of Copper* identified the coming major shortfall between the doubling in need for copper to meet 2050 goals and the actual availability of copper — the "metal of electrification." It responded to alarm raised by the US, EU and Japanese governments, the IMF, the IEA and the World Bank regarding the need for dramatic growth in minerals required to meet the energy transition demand.

That initial S&P Global research was the first to quantify the amount of *additional* copper required.

- "Energy-transition demand": Previous studies extrapolated demand from existing industrial usage. Our study was, to our knowledge, the first to quantify the amount of additional copper required to meet the energy transition demand.
- Bottom-up approach: We quantified this new component bottom-up by assessing copper consumption by application and then aggregating the implied demand.

*The Future of Copper* study concluded:

- Copper demand will likely double by 2035 to nearly 49 MMt and continue to grow to 53 MMt in 2050 — the supply response needs to come by 2035, not 2050.
- Projected shortfalls are stark, even if we assume historically high levels for mining capacity utilization and an unprecedented acceleration of recycling. In 2035, supply could be 20% less that that required by the net-zero 2050 target.
- In a highly concentrated global supply market, the United States will likely import up to 67% of its refined copper — up from 10% in the 1990s.
- Extended and uncertain timelines for permitting, in the US and around the world, are a major obstacle to bringing new supply online to narrow that shortfall.

# Introduction: our approach

This study's approach differs from *The Future of Copper* in important ways:

- US versus global. Whereas *The Future of Copper* analyzed global balances of demand and supply, this paper focuses on the United States. We do not consider rising demand for lithium, cobalt, nickel and copper in other countries — including countries from which the US will import these metals. As a result, potential shortfalls in the US's external sourcing could be even larger. US trade partners may divert some of their lithium, cobalt, nickel and copper to domestic needs or other high-growth markets and away from the US.
- Energy-transition demand versus total demand. Whereas *The Future of Copper* projected the total demand and supply of copper — including both conventional sources of demand as well as new, energy transition demand — this paper considers only energy transition demand, since that is the IRA's target. Note also that *The Future of Copper* targeted the copper required to support global net-zero by 2050. This study does not assume the world will achieve that target; the projections here are based on our baseline expectations.
- Energy-transition demand versus IRA demand. In *The Future of Copper,* demand was projected implicitly assuming no significant policy changes. Here, the target is the impact of a policy change, the enactment of legislation that explicitly seeks to boost demand by subsidizing preferred production of energy transition technologies and infrastructure.
    - Pre- versus post-IRA. It is difficult, however, to isolate the impact of the IRA on demand for the four metals. For example, automobile manufacturers in the US and around the world had already shifted production to electric vehicles in response to regulations, mandates and subsidies, and they continue to do so. General economic growth and other factors also increase total demand. This study does not address these factors. It compares projections of US demand for energy transition applications before and after enactment of the IRA ("pre-IRA" and "post-IRA"). Nonetheless, the enactment of the IRA is almost certainly a major driver of the increase in this "energy transition demand."
        - IRA original provisions. Note that calculations in this study are based on provisions in the IRA as passed in August 2022. The US Treasury is likely to continue issuing guidance that modifies these provisions for the purposes of administering IRA tax credits. For example, granting some countries "FTA-like" status via bilateral critical mineral agreements. These modifications will likely alter some of the results calculated here, but we do not expect them to affect our broad conclusions.
- Copper demand projections. *The Future of Copper* was released in July 2022, before enactment of the IRA. As a result, the increase in US energy transition demand for copper post-IRA projected in this study is above that projected in *The Future of Copper*, pre-IRA. Note that although copper is not a listed critical mineral, increased demand for IRA-subsidized applications such as electric vehicles will also boost demand for copper, as it is the metal of electrification.

## Introduction

# The IRA as new industrial strategy

# New industrial strategy: substantive support for US energy transition (1)

The US Inflation Reduction Act of August 2022 (IRA) is the third part of a new industrial strategy that emerged in less than 12 months. The first was the Infrastructure Investment and Jobs Act in November 2021, commonly known as the Bipartisan Infrastructure Law, which allocated $550 billion in new federal funding for US transport and digital infrastructure. The second was the CHIPS & Science Act, also in August 2022, which allocated $280 billion to investment in domestic semiconductor research, fabrication and development of science, technology, engineering and mathematics skills, among other things.

Together, the three pieces of legislation represent a major focus on building domestic capacity, and securing reliable supply, for the technologies and industries that are required for a successful energy transition and to give the United States long-term competitive advantage.

## Selected climate and energy spending in IRA 2022 (1)

### Production tax credits

**Clean electricity**
Up to 1.5 cents per kWh of renewable or zero-carbon electricity

**Advanced manufacturing**
Variable unit credits for solar components, wind turbine and offshore wind components, inverters, certain battery components, critical minerals

**Clean hydrogen**
Up to $3 per kilogram of clean hydrogen produced*

**Nuclear power**
Up to 1.5 cents per kWh of electricity produced from nuclear energy

### Investment tax credits

**Clean electricity and energy projects**
Up to 30% of investment in certain renewable or low-carbon energy projects

**Geothermal heating**
Up to 30% of investment in geothermal heat pump projects

**Advanced energy projects**
Up to 30% of investment in industrial heat, carbon capture, recycling, waste reduction and energy efficiency and other projects

### Production, investment tax credit bonuses

**American-made**
Up to 10% bonus for meeting certain domestic manufacturing requirements

**Energy communities**
Up to 10% bonus for projects located in brownfields or communities in fossil fuel industry

**Low-income communities**
Up to 10% bonus for projects located in low-income communities or on tribal lands; up to 20% for projects in low-income residential buildings

As accessed Aug. 8, 2022.
*Clean hydrogen is defined as releasing less than 4 kg of carbon dioxide equivalent ($CO_2e$) per kilogram of hydrogen produced.
Sources: U.S. Senate; Capitol Tax Partners LLP; Bipartisan Policy Center; S&P Global.

# New industrial strategy: substantive support for US energy transition (2)

The IRA is wide-ranging. Among its provisions are a mix of subsidies, discounted credit and tax incentives to catalyze investment in clean energy generation, alternative fuels, and carbon capture and storage. Tax credits are also extended directly to households for qualifying electric vehicles (EVs) to accelerate transition to EV fleets and attract further investment in the US market. The IRA is expected to stimulate supply, boost demand and accelerate adoption of energy transition applications to meet the US's 2050 net-zero goals.

## Selected climate and energy spending in IRA 2022 (2)

### Carbon capture tax credits

**Industrial facilities and power plants**
Up to $85 per metric ton of $CO_2$ captured and stored; up to $60 per metric ton of $CO_2$ utilized

**Direct air capture facilities**
Up to $180 per metric ton of $CO_2$ captured and stored; up to $130 per metric ton of $CO_2$ utilized

### Offshore wind

**Fossil fuel tie**
A year prior to offshore wind lease issuance, at least 60 million acres must be offered in oil and gas lease sale

### Fuel tax credits

**Clean fuels**
Up to $1 per gallon of low-carbon transportation fuel produced

**Sustainable aviation fuel**
Up to $1.75 per gallon of sustainable aviation fuel produced

### Residential tax credits

**Clean energy**
Up to 30% of investment in residential solar, wind, geothermal, biomass and battery storage projects

**Energy efficiency**
Up to 30% of investment in projects that improve energy efficiency

### Clean vehicle tax credits

**Consumer vehicles**
Up to $7,500 for purchase of electric vehicle, plug-in hybrid or hydrogen fuel cell vehicle

**Used vehicles**
Up to $4,000 for purchase of used EV or plug-in hybrid

**Commercial vehicles**
Up to $40,000 for purchase of clean vehicle weighing over 14,000 pounds; Up to $7,500 for vehicle weighing less than 14,000 pounds

**Charging stations**
Up to 30% of cost of charging station or alternative fuel refueling station

### Electric transmission

**Financing**
$2 billion to Department of Energy (DOE) for loans financing transmission lines determined to be in the national interest

**Siting**
$760 million to DOE for grants to states to help with siting transmission lines

**Planning**
$100 million to DOE through Sept. 30, 2031, for planning and modeling interregional and offshore wind transmission

As accessed Aug. 8, 2022
Sources: U.S. Senate; Capitol Tax Partners LLP; Bipartisan Policy Center; S&P Global.

# New industrial strategy: supply chain resilience (3)

The new industrial strategy comes in the context of growing concerns regarding strategically important supply chains' vulnerability to geopolitical rivalries. The IRA, therefore, also imposes three requirements on the sourcing of critical minerals contained in newly purchased vehicles qualifying for tax credits. These requirements set the percentages of these minerals (by value) that must be extracted or processed in: (i) the US; or (ii) in a country with which the US has a free trade agreement ("FTA countries"); and (iii) not a "foreign entity of concern." The percentages increase annually: (i) 50% for a vehicle in service before 2024; (ii) 60% for a vehicle coming into service in 2024 or 2025; (iii) 70% in 2026; and (iv) 80% after 2026.

The requirements present a significant challenge. Production of key minerals is currently dominated by non-FTA countries, and the United States relies on these to meet its needs. For example, Norway and Japan, both non-FTA countries, together account for almost half of US refined cobalt imports. Chile and Australia, FTA countries, together account for almost three-quarters of globally mined lithium, but this is mostly exported to China. Indeed, 41% of global refined lithium production is by China-based entities, which are potential "foreign entities of concern."

| Metal | Percentage of global production by non-FTA countries[1] | | Percentage of US imports from non-FTA countries |
|---|---|---|---|
| | Mined | Refined | |
| Lithium | 10.4 | 53.7 | 46.6 |
| Nickel[2] | 75.1 | 86.9 | 46.4 |
| Cobalt | 86.8 | 85.5 | 77.3 |
| Copper[3] | 31.7 | 68.5 | 2.2 |

[1] Non-FTA countries include China and Russia. While Chinese and Russian entities are major producers, they are very likely to be designated "foreign entities of concern," and processing by them may disqualify input materials from IRA tax credits.
[2] Refined production for nickel relates to primary production.
[3] Copper is not designated a "critical mineral" by the US Geological Survey, so will not qualify for IRA tax credits. It is, however, the "metal of electrification" and key to energy transition.

2023 production estimates; 2022 US import estimates. Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

# Coordinated policy: competition vs. collaboration

The US Inflation Reduction Act is a landmark: a substantial fiscal transfer to accelerate the energy transition. However, it will not unfold in a vacuum. US allies and competitors alike are responding with their own critical minerals strategies. The success of the IRA, and the global energy transition, is likely to depend on collaboration. In April 2023, the G7 foreign ministers' communique stated: "We will work to strengthen secure, resilient, sustainable, responsible, transparent, and diverse critical minerals supply chains essential for net-zero economies and clean technologies."

But even with close allies, collaborative initiatives vie with potentially competitive ones. For example, between the US and the EU:

**US and EU: collaboration and competition**

| Collaborative | Competitive |
|---|---|
| • The US Department of Treasury has published guidance for practical application of the IRA rules, including on qualifying sourcing. Per that guidance, "critical mineral agreements" negotiated with allies will be recognized as having FTA-equivalent status. Such an agreement is likely to be finalized with the EU in 2023. (An agreement has already been established with Japan, although this is meeting Congressional criticism on grounds of overstepping presidential authority.)<br><br>• The Minerals Security Partnership (MSP), which includes the US and several EU member states, is engaging several African and Latin American countries to secure supplies. The MSP's stated goal is to "catalyze public and private enterprise investment in critical minerals supply chains globally… diversifying supply chains." | • The EU proposed its Critical Raw Materials Act in mid-March. That will require at least 10% of the EU's annual consumption of extracted "critical raw materials" — which for the EU includes copper — to be within the EU. Similarly, 40% of processing consumption must be within the EU. This could compete with sourcing to the US.[1]<br><br>• Without the equivalent of federal taxation, the EU cannot currently offer, centrally, the scale of subsidies that the US federal government can. While EU manufacturers are already demonstrating eagerness to capture IRA support via US-based operations and shifting investment in that direction, the EU itself has expressed strong concern about EU companies' capital, time and skills being diverted from the EU's energy transition to the US.<br><br>• The EU is seeking skill-sharing and research agreements with several sub-Saharan African and Latin American governments to secure supplies of its listed critical raw materials — including the Democratic Republic of Congo, Argentina and Chile. |

[1]The EU's 2023 list of critical raw materials (CRMs) effectively includes **copper**. The list contains 34 CRMs. Materials qualify as CRMs based on criteria for (i) economic importance; and (ii) supply risk. While copper, lithium and nickel do not meet these criteria, the EU's Critical Raw Materials Act provides for their inclusion as strategic raw materials. Cobalt qualifies as a CRM.

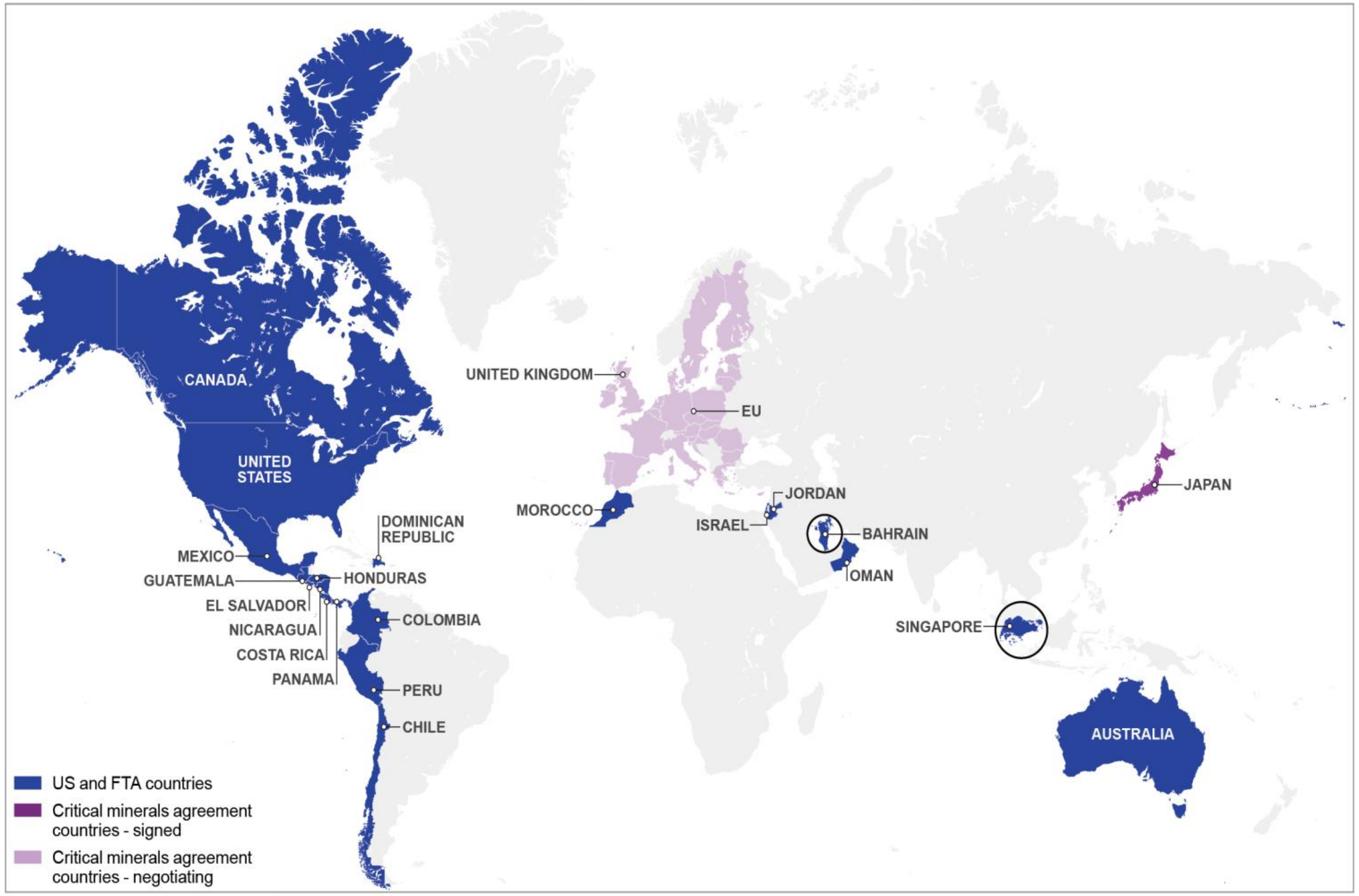
# Sourcing: free trade agreement countries and "foreign entities of concern"

The US has free trade agreements with 20 countries: Australia, Bahrain, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Jordan, South Korea, Morocco, Nicaragua, Oman, Panama, Peru, Singapore, Mexico and Canada — the final two as a trading bloc under the US-Mexico-Canada Agreement (USMCA).

Defining foreign entities of concern is less straightforward. It covers several categories of designated entities, including foreign terrorist organizations, specially designated nationals and blocked persons, and "covered nations." These include the Democratic Republic of (North) Korea, the Islamic Republic of Iran, the Russian Federation and the People's Republic of China. Products manufactured in these countries are potentially disqualified from the IRA's tax credits. (The Inflation Reduction Act [section 13401] defined these with reference to the Bipartisan Infrastructure Law [section 40207], which in turn refers to the United States Code, Armed Forces chapter.)

However, the US Treasury will continue to publish guidance on the application of the IRA in the coming months. This may *de facto* narrow the definition of foreign entities of concern and/or expand the number of countries granted limited FTA status through critical minerals agreements, for the sake of administering IRA tax credits. The US Treasury will continue to feel pressure to balance facilitating the energy transition with addressing congressional criticism of the way the guidance is formulated.

**Free Trade Agreement countries and prospective critical minerals partners**




Data compiled Aug. 8, 2023.
Source: S&P Global Market Intelligence: 2010495.

# Supply chain and trade: estimating vulnerabilities with three-part analysis

**How much supply of key metals and minerals will North America produce?**

## Supply: North America

Bottom-up analysis of existing and forecast supply between expansions and capacity additions in the United States, Mexico and Canada.

**How much supply will countries with a free trade agreement produce?**

## Supply: FTA countries

Bottom-up analysis of existing and forecast supply between expansions and capacity additions in countries with a free trade agreement with the United States, Mexico and Canada.

**What other countries do FTA countries trade with?**

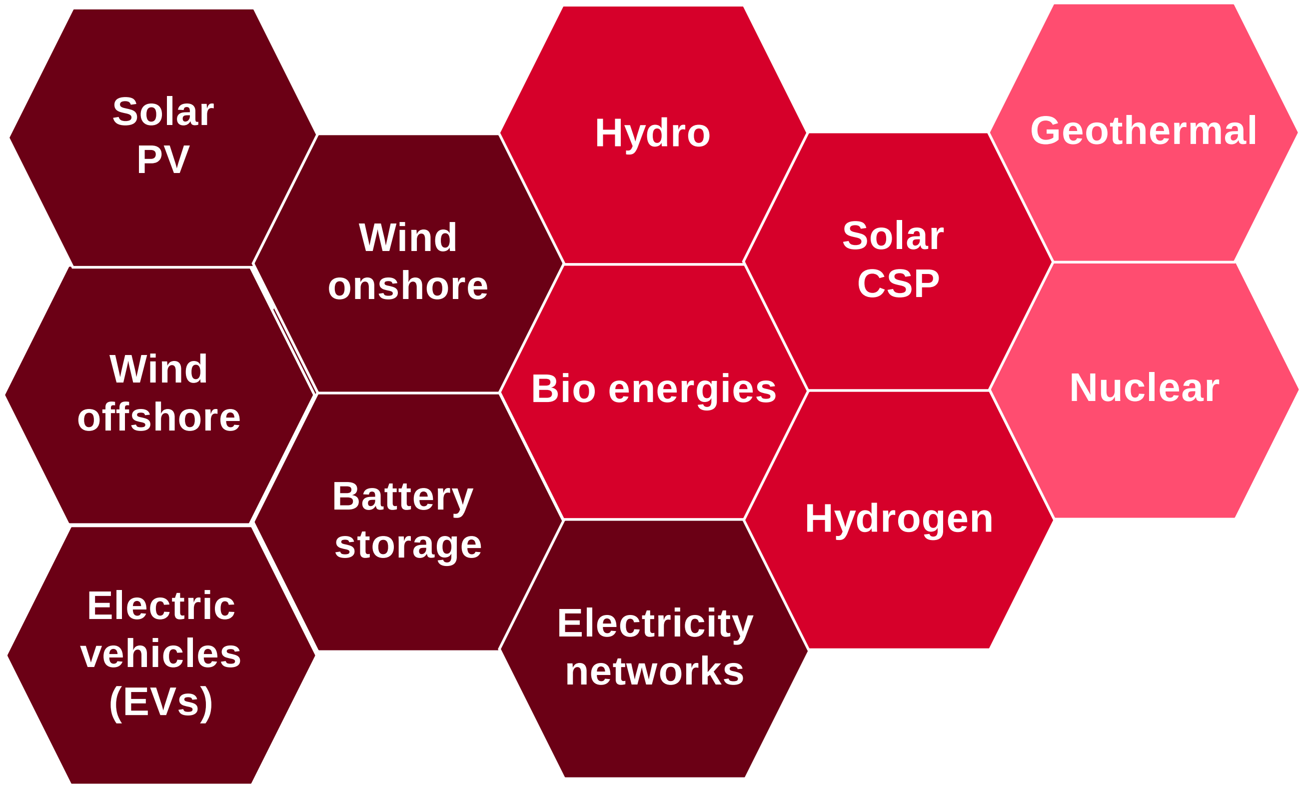
## Trade: Bilateral

Analysis of bilateral trade flows over time for the United States, Mexico and Canada, and FTA countries.

# Demand requirements of the Inflation Reduction Act

# S&P Global analyzed the role of copper and critical battery raw materials in key sectors of the energy transition and the associated impact of IRA

- Copper is nearly unrivaled as an efficient electrical and thermal conductor. It lowers the amount of energy needed to produce electricity and helps reduce $CO_2$ emissions.
- Nickel, lithium and cobalt are the main battery cathode components used for EV-related battery manufacturing.
- To evaluate the impact of the IRA on demand for energy transition metals, the S&P Global base case outlooks were compared for the main energy transition sectors both pre- and post-IRA announcement.
  - IRA economic assumptions and tax-incentive assumptions were embedded in our investment outlooks for energy transition infrastructure.
  - On a bottom-up basis and using metal intensity, recycling assumption and substitution risks, metals demand assumptions were applied to the two scenarios (pre-IRA and post-IRA) to evaluate the impact of the IRA on energy transition metals.
  - Note that non-energy-transition demand has been excluded from this specific analysis.




Presence of copper and critical minerals in clean energy technologies

● High ● Moderate ● Low

Nickel is used in hydrogen electrolyzers and not nuclear or geothermal, hence the “moderate” assessment of hydro.

# IRA and BIL collectively allocate ~$502 billion to new climate & energy spending

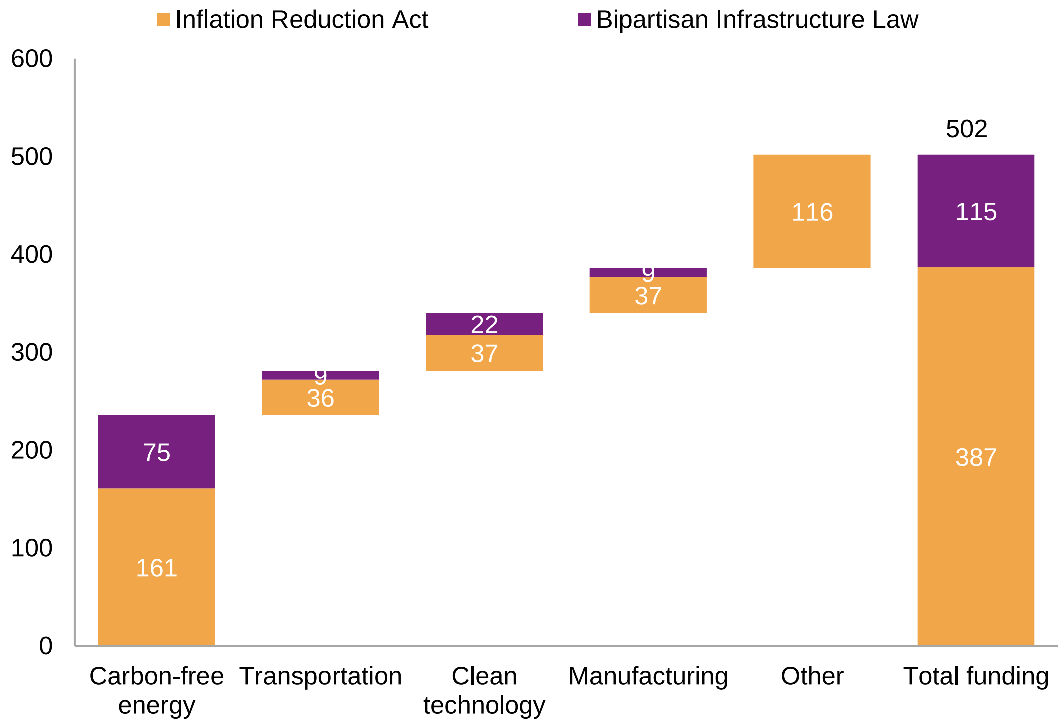
## But some institutions estimate that the $387 billion allocated to the IRA could cost up to $1.2 trillion

| | |
|---|---|
| Carbon-free energy | • Tax credits for investment in solar and storage<br>• Tax credits for wind and nuclear energy production<br>• Tax credits for clean energy transmission<br>• Funding for energy efficiency |
| Transportation | • Tax incentive for purchases of EVs<br>• Funding for EV charging infrastructure |
| Clean technology | • Tax credit for carbon capture (CCUS & DAC)<br>• Tax credit for production of clean hydrogen (45V)<br>• Funding for hydrogen and DAC hubs<br>• Funding for sustainable aviation fuels (SAF) |
| Manufacturing | • Funding for advanced manufacturing/support domestic manufacturing<br>• Investment for advanced industrial facilities |
| Other | • Methane emissions charge (revenue-generating)<br>• Greenhouse gas reduction funds, etc. |

CCUS = carbon capture utilization and storage; DAC = direct air capture.
Source: S&P Global, FACT SHEET: Historic Bipartisan Infrastructure Deal, The White House, public domain.

**Collective funding for climate and energy investment**

Approximate figures in US$ billion




Data compiled February 2023.
Source: FACT SHEET: Historic Bipartisan Infrastructure Deal; The White House, public domain.

# Tax credits will reduce the levelized costs for wind and solar

## US renewable energy tax credit availability

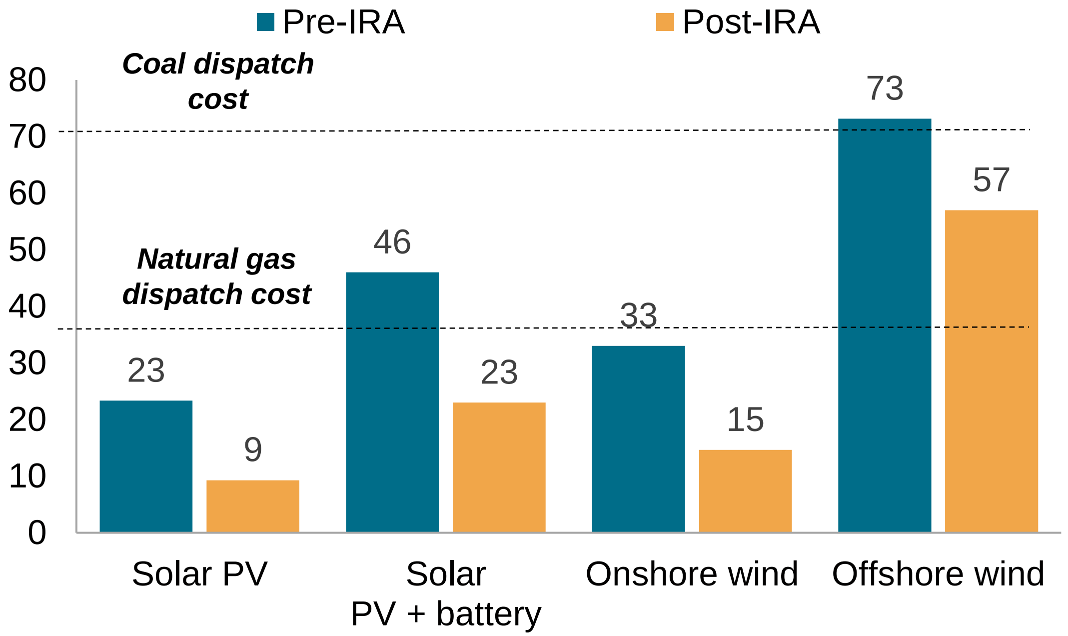
%, 2021 US$/MWh

| | | | 2023-33 | Post 2034 |
|---|---|---|---|---|
| ITC | Base credit | Base credit | 6% | Phase out starting 2034 or first year when annual GHG emissions fall under 75% below 2022 levels. Tax credits decline to 75% of their full value in the first year, 50% in the second year, and 0% in the third year. |
| | | Domestic content | +2% | |
| | | Energy community | +2% | |
| | Full rate | Base credit | 30% | |
| | | Domestic content | +10% | |
| | | Energy community | +10% | |
| PTC | Base credit | Base credit | $5 | |
| | | Domestic content | +$1 | |
| | | Energy community | +$1 | |
| | Full rate | Base credit | $25.5 | |
| | | Domestic content | +$3 | |
| | | Energy community | +$3 | |

Data compiled February 2023.
ITC = investment tax credit; PTC = production tax credit.
The most valuable tax credit is modelled for each technology. PV benchmark includes full PTC, full ITC for battery storage, full PTC for onshore wind and full ITC for offshore wind.
Source: S&P Global Commodity Insights; FACT SHEET: Historic Bipartisan Infrastructure Deal; The White House, Public Domain.

## 2030 levelized cost of electricity (LCOE) for US power supply

2021 US$/MWh



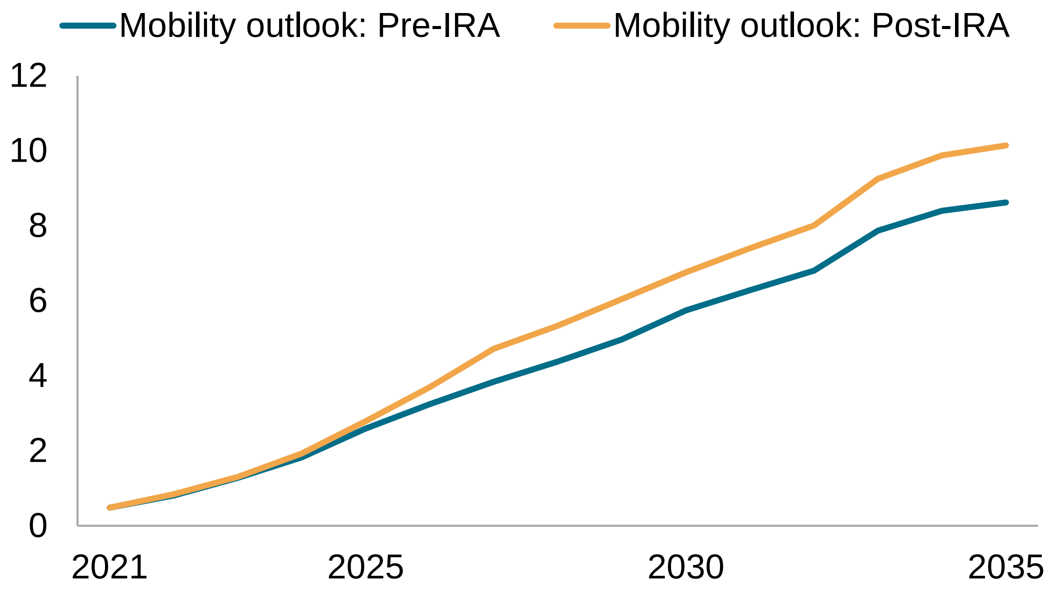

Data compiled February 2023.
Source: S&P Global Commodity Insights; FACT SHEET: Historic Bipartisan Infrastructure Deal; The White House, Public Domain.

# The IRA will accelerate the US transition to renewables and EVs with extension of tax credits, with an expected boost of 30 GW of wind and solar by 2030

| Share of new EV & fuel cell vehicles sales | 2022 | 2025 | 2030 | 2035 |
|---|---|---|---|---|
| Pre-IRA | 6% | 15% | 35% | 52% |
| Post-IRA | 6% | 17% | 41% | 58% |

## US EV sales (new vehicle sales)

Gross capacity additions in millions

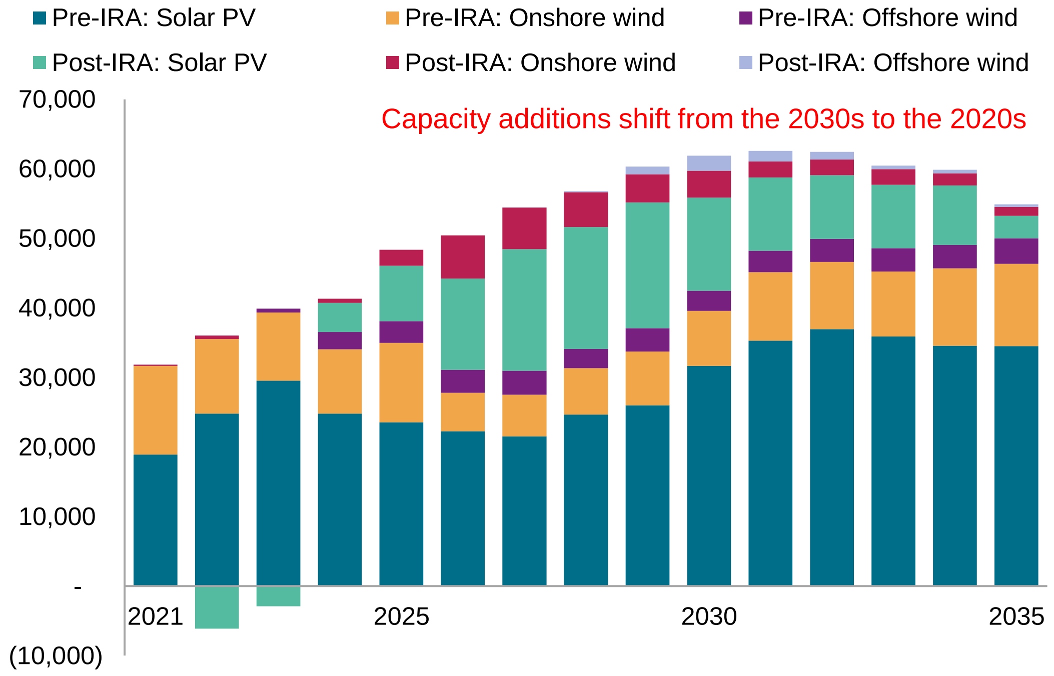



Data compiled February 2023.
Includes light commercial vehicle and medium/heavy vehicle sales in the United States.
Source: S&P Global Mobility.

| Share of solar and wind in power generation | 2022 | 2025 | 2030 | 2035 |
|---|---|---|---|---|
| Pre-IRA | 19% | 21% | 30% | 41% |
| Post-IRA | 19% | 24% | 38% | 51% |

## US renewable power capacity additions by type

Gross capacity additions in MW

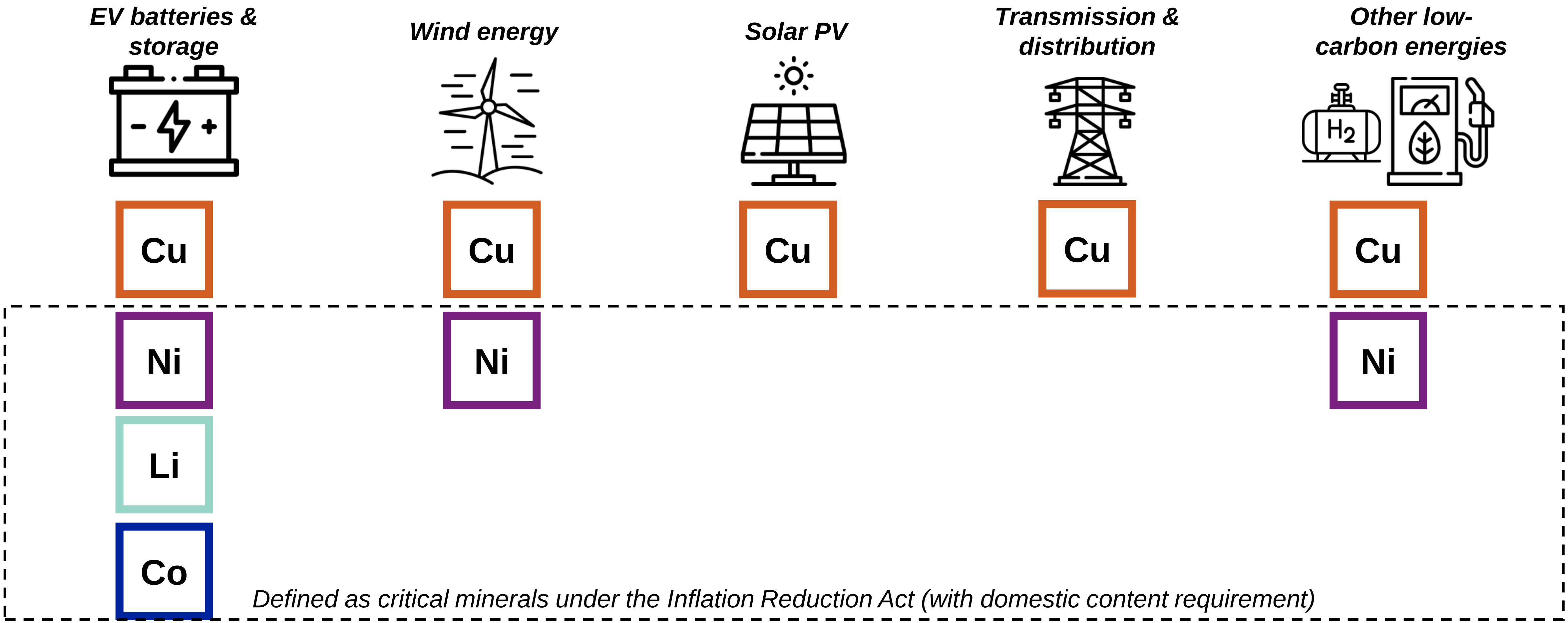



Data compiled February 2023.

The IRA results in a roughly 10% increase in expected additions this decade, mostly between 2025 and 2030, leading to doubling of power generation from renewables by 2030. Negative values in 2022 and 2023 reflect delays in our post-IRA forecast due to ADCDV consultations.

Source: S&P Global Commodity Insights - represents S&P Global Commodity Insights power capacity additions outlook in June 2022 vs. February 2023 to reflect changes to the outlook.

# Clean energy technologies require a wide range of metals




Other elements such as rare earth elements, chromium, PGMs, aluminum, zinc and steel are also used in these applications but have been excluded from this specific analysis.
Source: S&P Global.

# IRA impact on energy transition demand: IRA is expected to accelerate renewable capacity additions and contribute to increased US electric vehicle sales

- **The IRA and BIL collectively allocate ~$502 billion to new climate and energy spending.** Most of the allocation centers on tax credits for new investments, with close to 50% of the allocation destined to the green electrification of the United States.
- **Associated investment and production tax credits increase the competitiveness of renewable electricity sources against fossil fuels.** With the associated tax credits, solar, onshore wind and offshore wind are projected to become relatively more competitive than natural gas and coal power generation.
- **The IRA makes renewable generation more competitive sooner.** Renewable capacity additions, previously modeled to come online in the 2030s, are expected to become competitive in the 2020s, leading to a strong push in renewable generation in the near term.
- **The IRA provides sales credits for electric vehicles.** These EV credits, along with a strong push from automotive manufacturers to shift their production to electric vehicles, will likely contribute to strong EV sales growth between now and 2035.
- **These demand shifts will require significant volumes of base and critical metals.** Energy infrastructure investments and the vehicle shift to EVs are metal-intensive — their growth will automatically lead to additional demand for the key raw materials in batteries: copper, nickel, cobalt and lithium, among others.

**Bottom line: The IRA is a large contributor to increased investments in energy infrastructure, which will require more metals.**

# Critical minerals (lithium, cobalt and nickel) market analysis

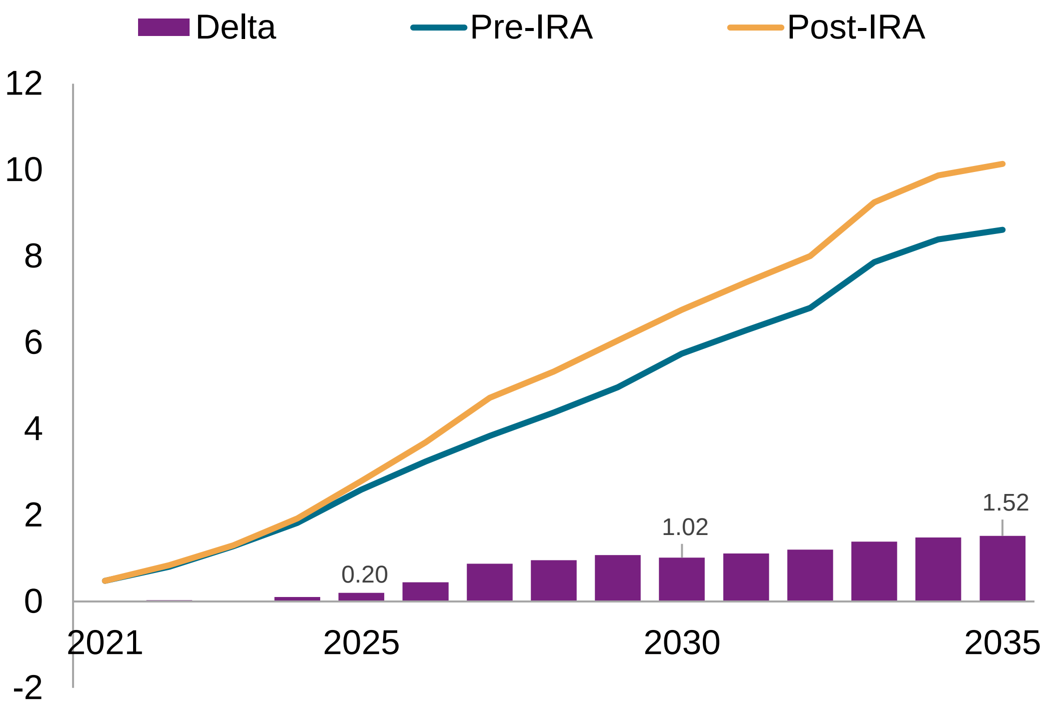
## Demand requirements

# Critical minerals: lithium, cobalt, nickel

# Absolute new EV sales and battery chemistry drive local raw material requirements

## New EV sales: United States

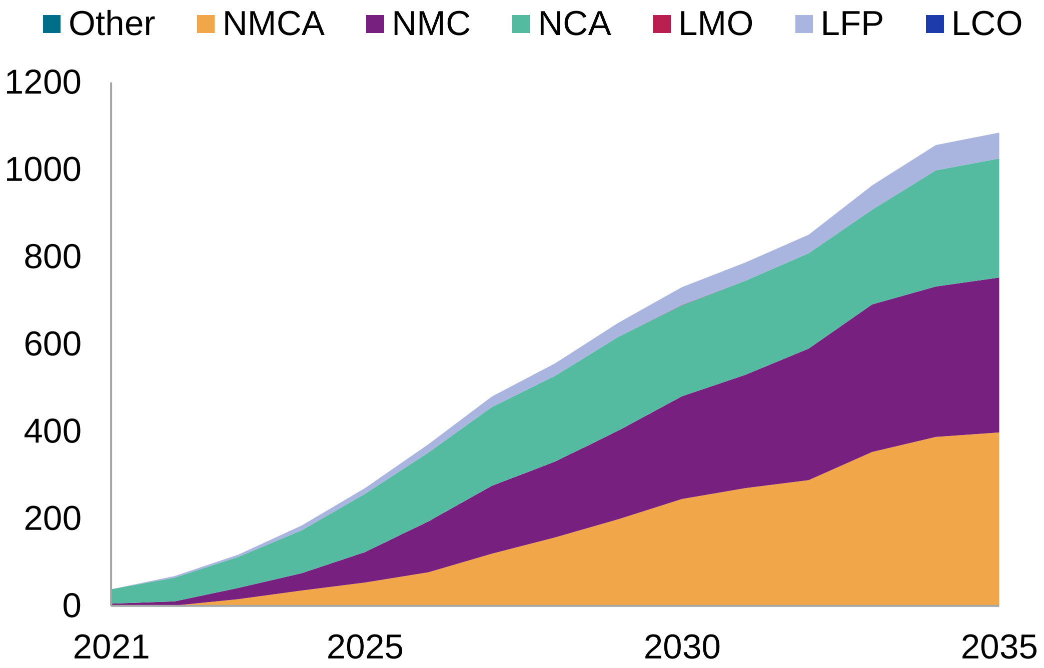
Million vehicles




Data compiled February 2023.
Source: S&P Global Commodity Insights; S&P Global Mobility.

## US EV battery demand by cathode

GWh



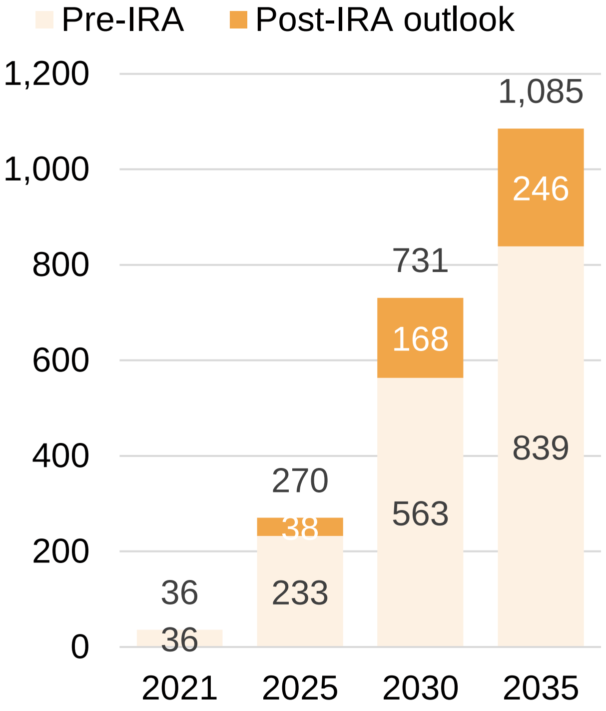

Data compiled February 2023.

LCO = lithium cobalt oxide; LFP = lithium iron phosphate; LMO = lithium manganese oxide; NCA = nickel cobalt aluminum; NMC = nickel manganese cobalt; NMCA = nickel manganese cobalt aluminum.
Excludes PHEV and HEV.
Source: S&P Global Commodity Insights; S&P Global Mobility.

Ni Li Co

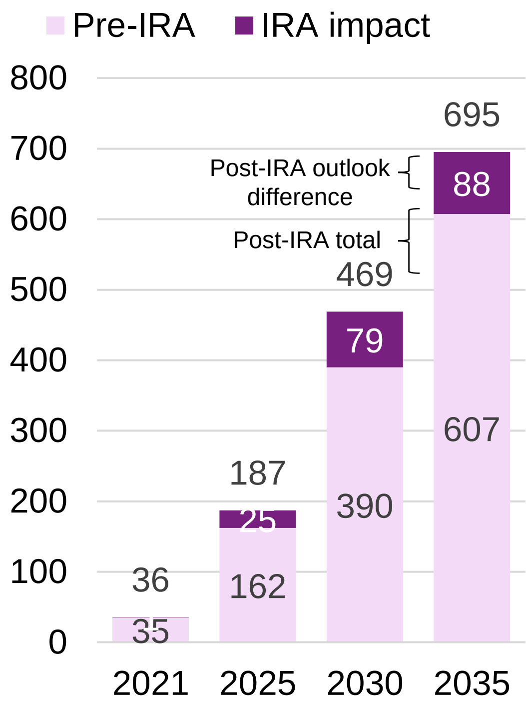
# Metal requirement for EV batteries will grow by 28% annually following IRA credits

## EV battery capacity
Gross capacity GWh



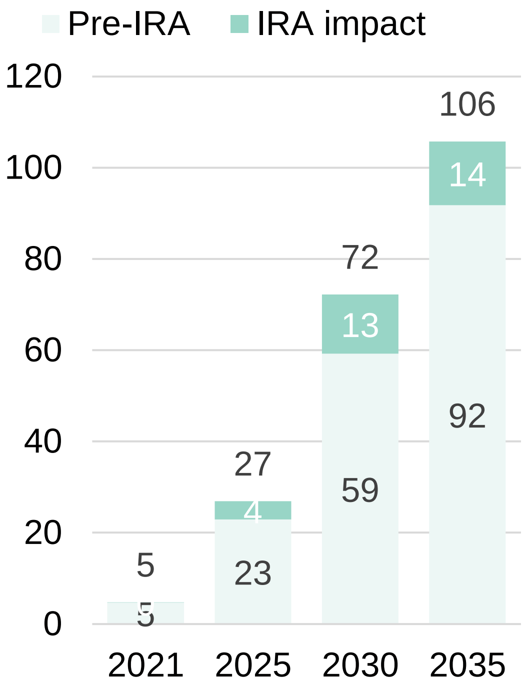

Data compiled February 2023.
Source: S&P Global Commodity Insights.

## Metal requirement for EV batteries in sold vehicles in the United States
Thousand metric tons



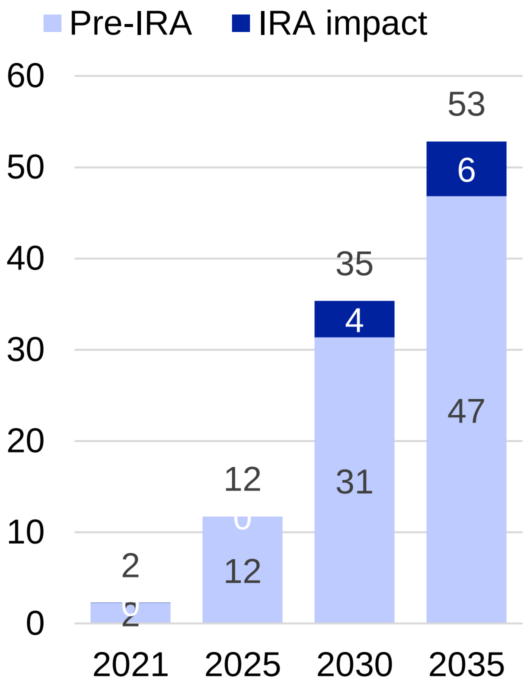

Data compiled February 2023.
Source: S&P Global Commodity Insights.

Ni




Data compiled February 2023.
Source: S&P Global Commodity Insights.

Li



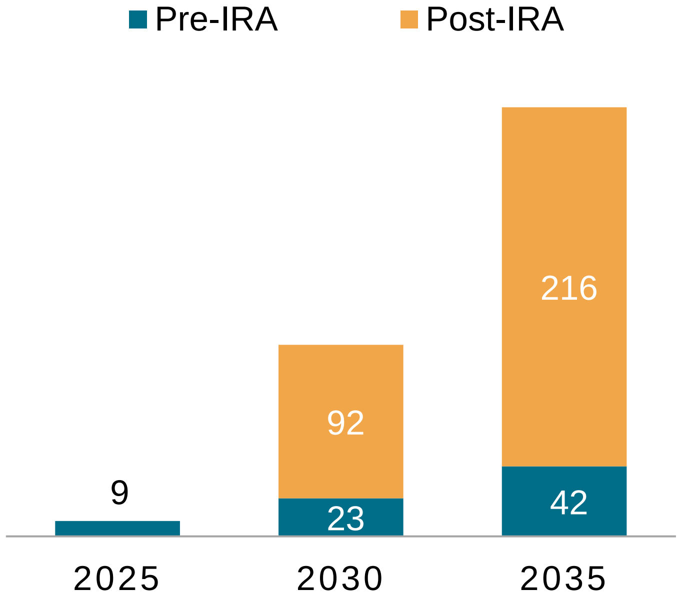

Data compiled February 2023.
Source: S&P Global Commodity Insights.

Co

Battery capacity requirement based on estimated US vehicle sales and vehicle demand; battery chemistry assumed similar with US manufacturing assumptions.

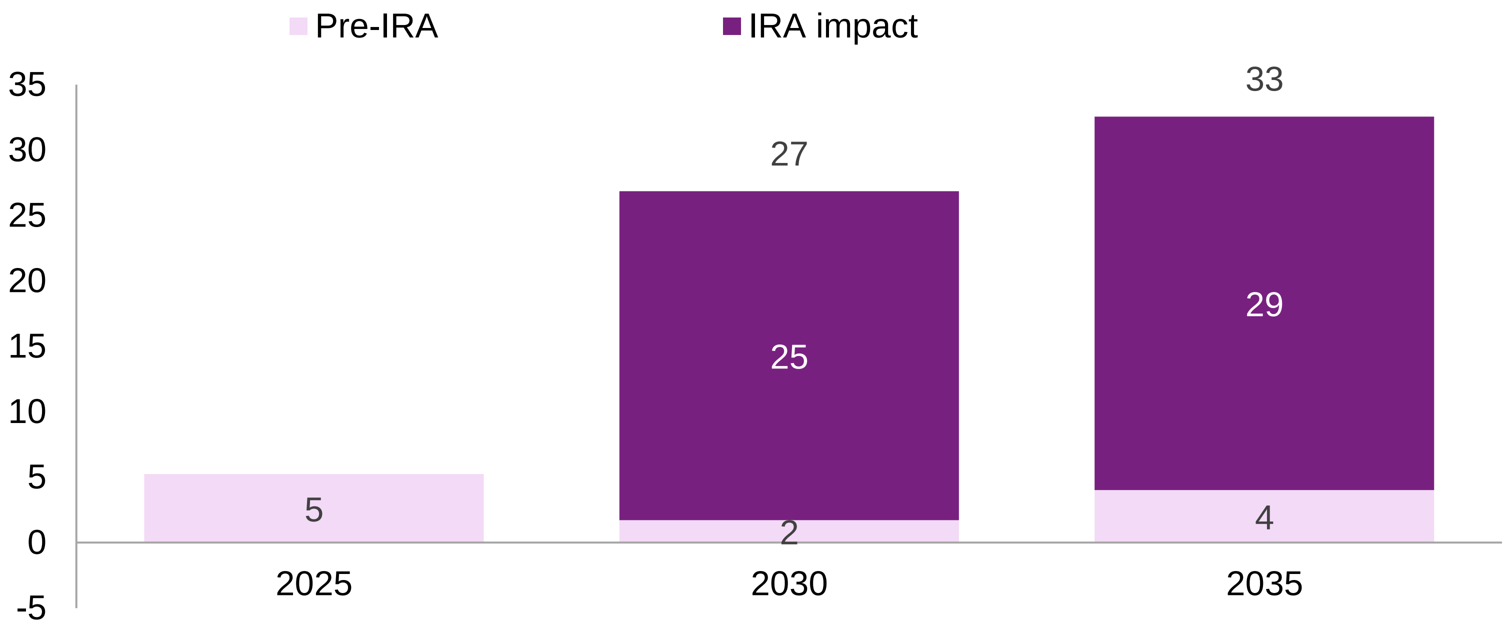
# Hydrogen-related tax credits to drive green and blue $H_2$ capacity growth 5x by 2035

**US cumulative installed electrolysis capacity**
GWh




Data compiled February 2023.
Power generation requirement and T&D assumptions are included in capacity additions and T&D analysis above. 1 Mt H2 = 33-39 MWh of energy.
Source: S&P Global Commodity Insights.

**US nickel and copper requirements for electrolysis manufacturing**
Thousand metric tons



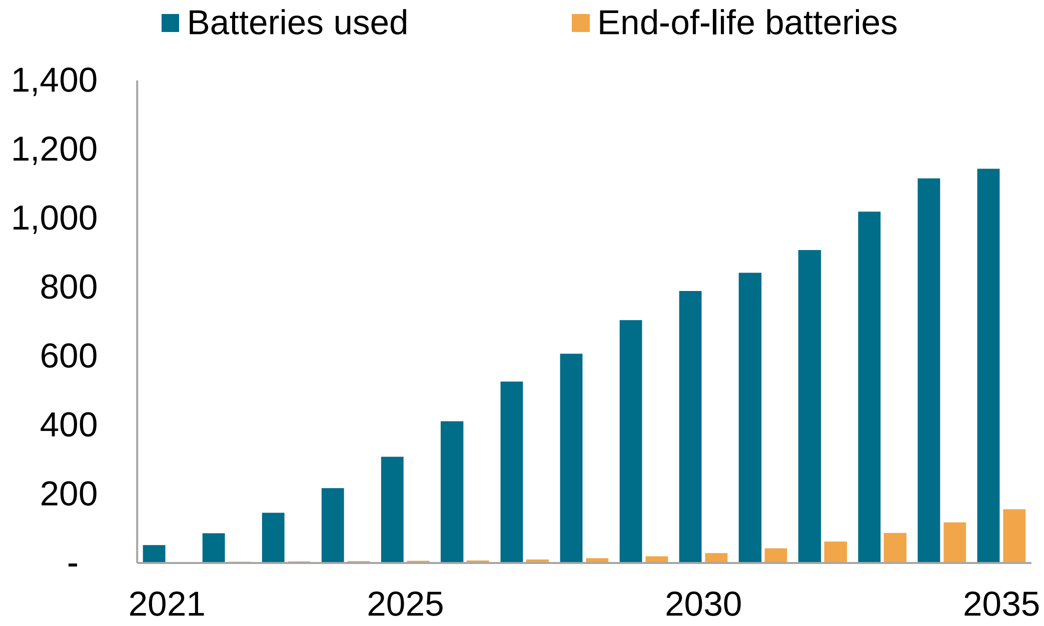

Data compiled February 2023.
Each electrolyzer technology deferrers in metals usage. For alkaline electrolyzer, assuming ~2.1 metric tons of Ni per MW and 0.3 metric tons of Cu per MW. For PEM assuming ~4.5kg per MW. For SOEC ~0.2 metric tons of Ni per MW. Split between technologies is based on the global announced manufacturing capacity – copper demand for hydrogen is centered on need for wires and new generation capacity to feed into electrolyzer. Current use of hydrogen is primarily in petroleum refining and fertilizer production.
Some of the projects in the pre-IRA outlook have been delayed and will only be operating between 2026 and 2030 – they are included in the 25 thousand metric tons for 2030.
Source: S&P Global Commodity Insights.

Long-term uses of hydrogen: transport of heavy goods (trucks), shipping, intermediate fuels (e-fuels), heavy industry (steelmaking) and feedstocks (fertilizers).

# Increased local battery manufacturing and EV end-of-life will increase recycling

Ni Li Co

**Battery use versus end-of-life batteries**
GWh

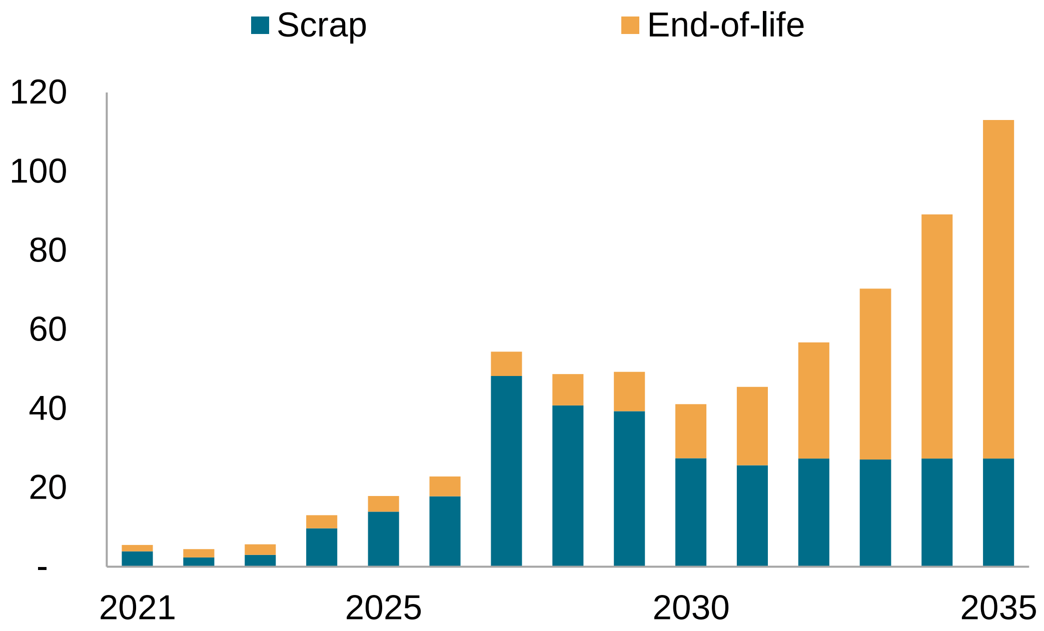



Data compiled February 2023.

Batteries used includes EV sales and ESS; material here is lithium, cobalt and nickel only. S&P Global assumes an average battery life of 12 years in 2022, increasing to 14.5 years in 2030 and reducing to 12.2 years in 2035. Reduction in battery life assumption is driven by lower ownership, higher use of batteries through vehicle to grid (V2G), mobility as a service (MaaS) and greater vehicle sharing.

Source: S&P Global Commodity Insights.

**Recycled critical minerals by process**
Thousand metric tons material




Data compiled February 2023.

Estimates material recovery of 95% by 2035, up from ~76% in 2022.
This chart shows battery-related scrap (both secondary and post-consumer (which we define as end-of-life)) – the large increase in the next 5 years reflects the high increase in battery manufacturing capacity along with the low material recovery in the first few years, which improves going forward, leading to lower scrap recycling and higher end-of-life recycling.
Assumes up to 20% (by 2035) of end-of-life batteries are reused and repurposed for ESS (for duration of 5 years).

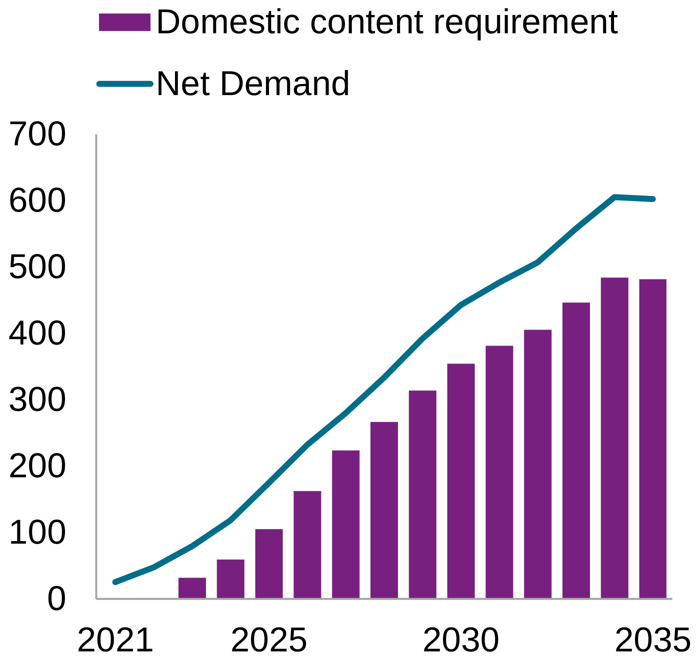
Source: S&P Global Commodity Insights.

Ni Li Co

# IRA sourcing requirements show that local sourcing of Ni, Li and Co is necessary

## Nickel demand vs. domestic

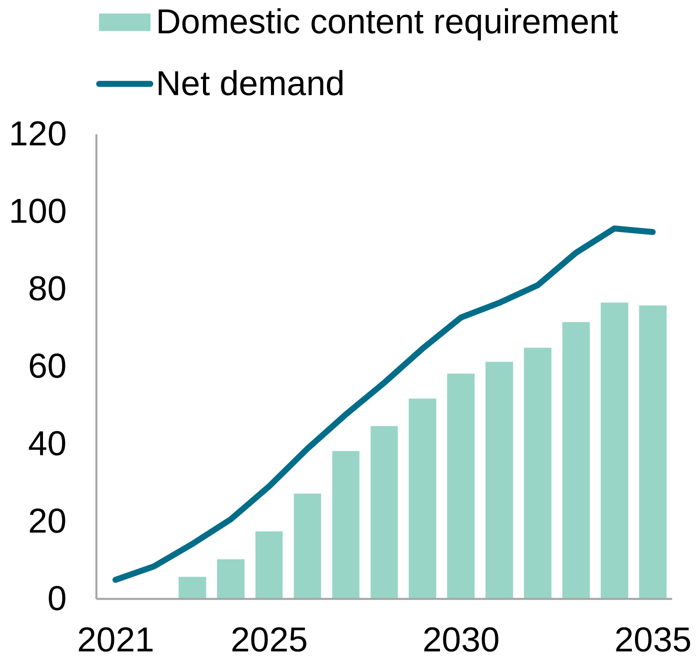
Thousand metric tons




Data compiled February 2023.
Source: S&P Global Commodity Insights; IRS Report.

## Lithium demand vs. domestic

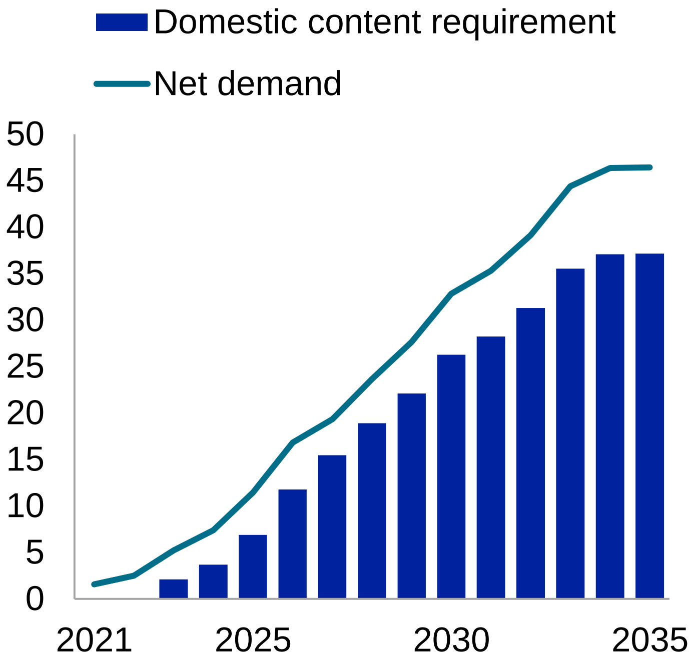
Thousand metric tons




Data compiled February 2023.
Source: S&P Global Commodity Insights; IRS Report.

## Cobalt demand vs. domestic

Thousand metric tons




Data compiled February 2023.
Source: S&P Global Commodity Insights.

# Critical battery raw materials: The IRA increases demand for metals and domestic/FTA supply requirements, which adds to challenges

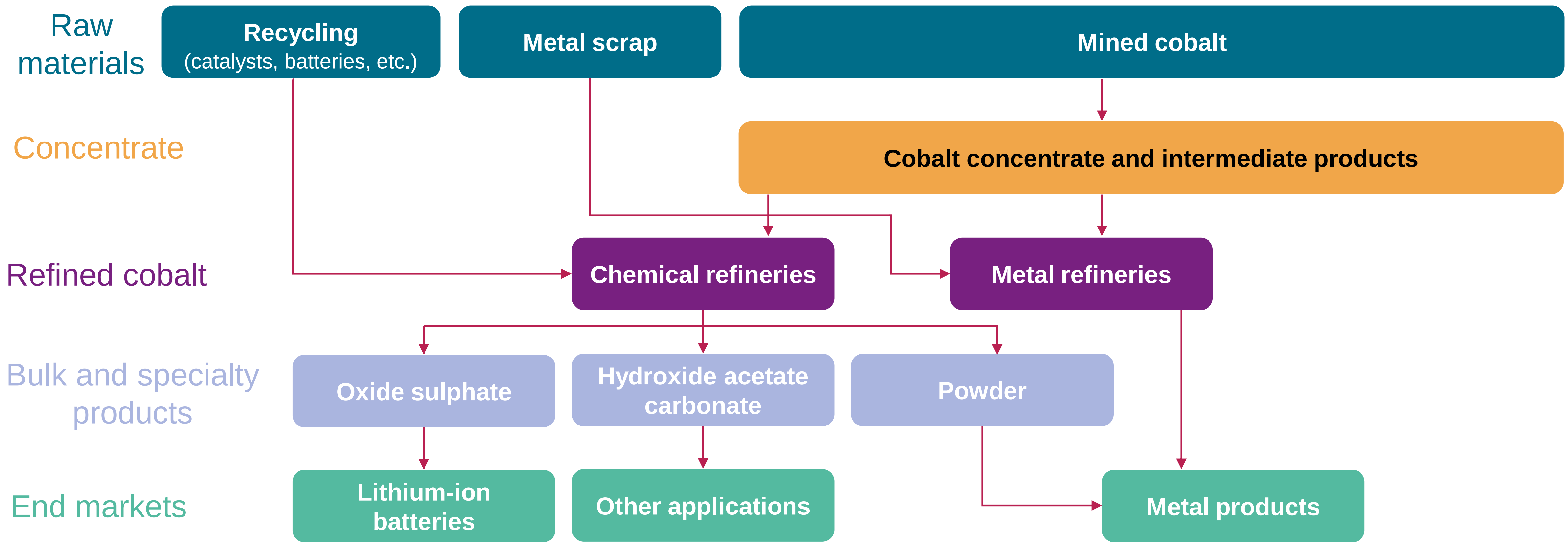
- **Battery raw material demand will follow growth in EV sales:** Automotive manufacturers' increased development of EVs, as well as IRA tax credits, contribute to expected strong growth in EV sales in the United States. This leads to projected growth in EV battery demand of 24% year over year between 2021 and 2035.
- **EV batteries have different chemistries with various levels of specific metal content:** The main battery chemistries used in EVs are nickel-intensive lithium-ion batteries (NMC, NMCA, NCA).
- **The IRA impact on EV sales adds a layer of requirements for metals for EV manufacturing:** Overall critical mineral requirements are expected to increase by 28% year over year post-IRA announcement to 2035 (previous growth prospects were ~17% year over year).
- **Investments in hydrogen electrolysis will also lead to additional requirements for nickel:** IRA hydrogen incentives will significantly decrease $H_2$ production costs, driving green hydrogen additions and increased demand for nickel.
- **Demand for battery raw materials will only be slightly mitigated by increased recycling capability:** The battery recycling industry is nascent, and by 2035 could recover up to 100 kt of raw material when new electric vehicles start reaching end-of-life (~12% of 2035 end-use demand). Before then, only manufacturing scrap batteries will be recycled.
- **The domestic manufacturing industry will be challenged by the IRA domestic content requirement incentives to kick-start local manufacturing:** Raw materials demand is increasing quickly, but meeting demand with local or FTA-sourced supply will likely be a major challenge for manufacturers looking to maximize IRA incentives.

**Bottom line: Battery demand for EVs is booming, but IRA incentives are tagged to meeting growing demand for critical minerals from domestic sources or FTA countries, which adds to the challenges.**

## Sourcing

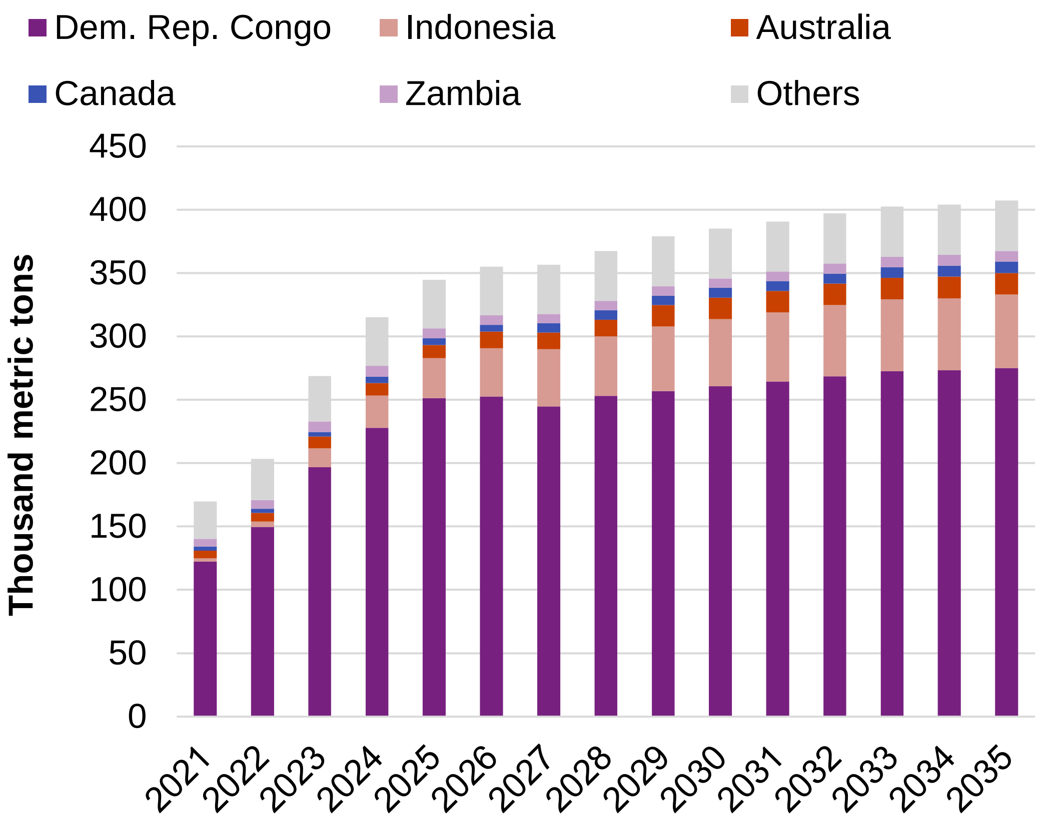
# Cobalt

# Cobalt: from mined to refined



# Mined cobalt production is dominated by the Democratic Republic of Congo (DRC), though Indonesia is ramping up production

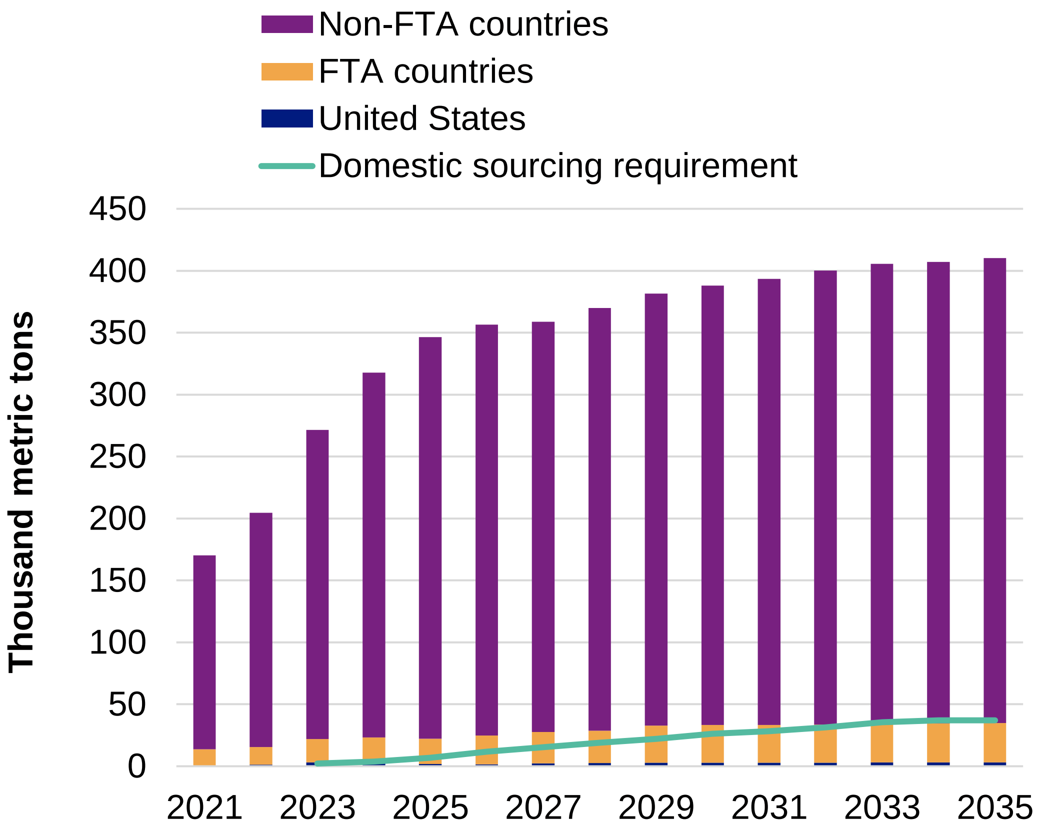
## Top countries for mined cobalt production




Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

## Mined cobalt production by country grouping

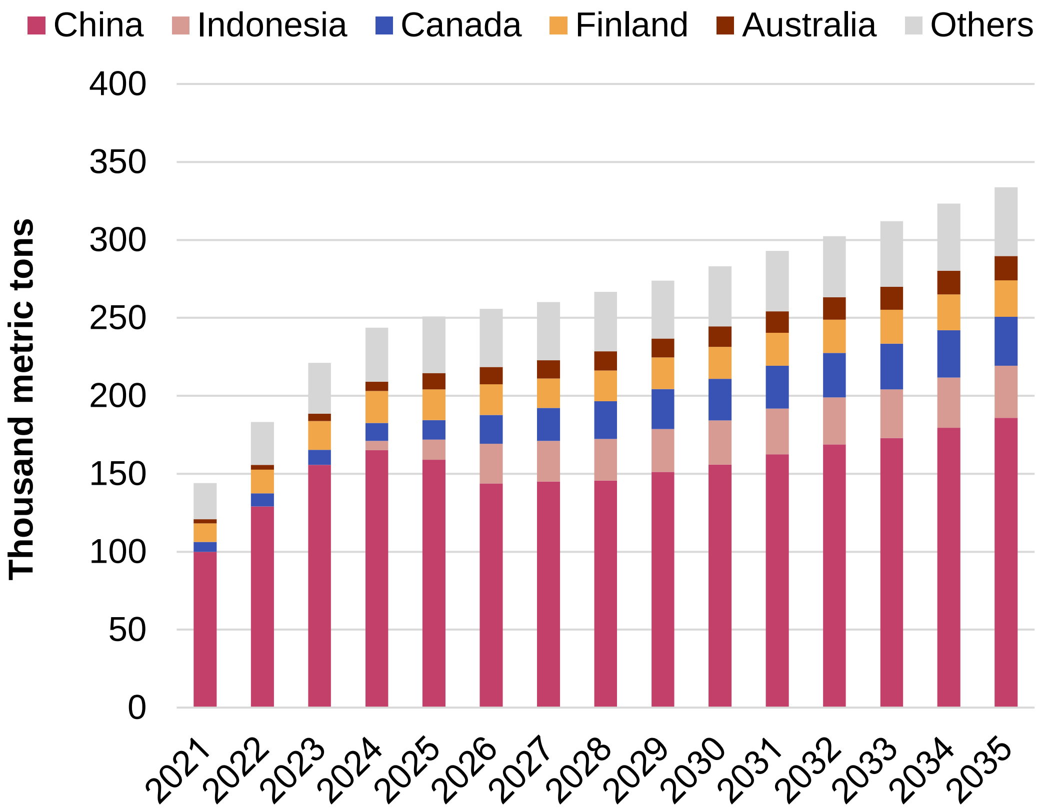



Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

# Meanwhile, China controls more than half of global refined cobalt supply and accounts for over 70% of mined cobalt exports from the DRC

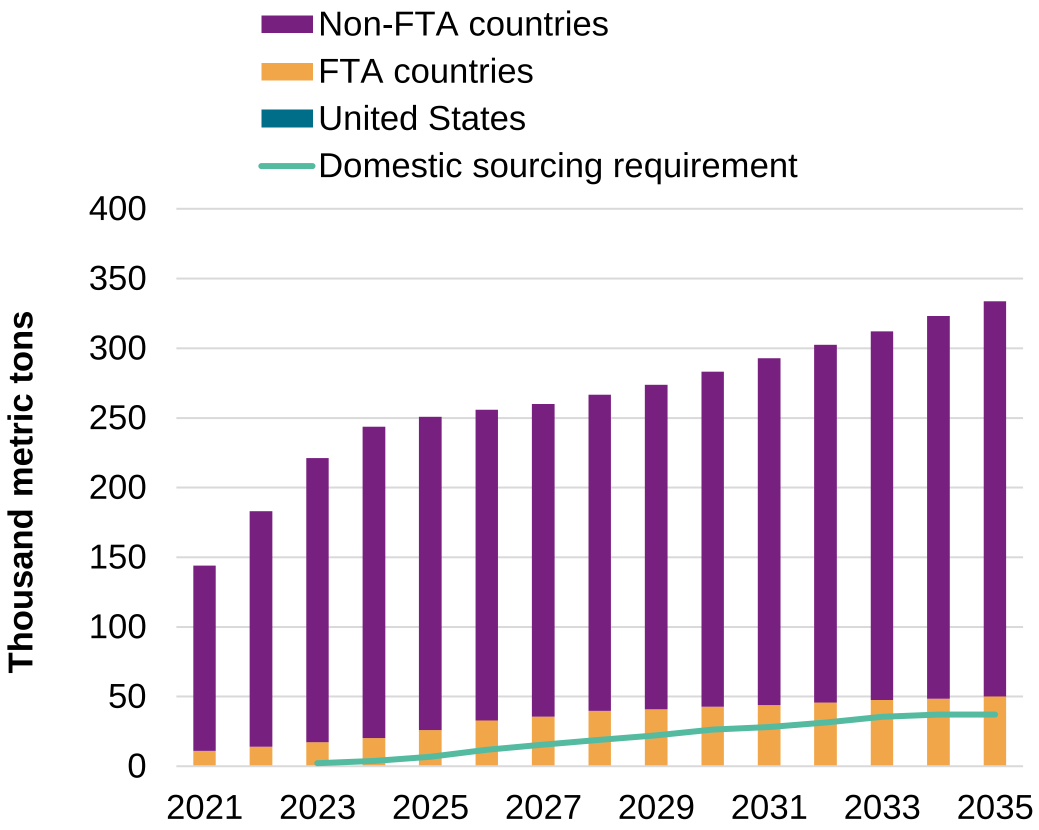
## Top countries for refined cobalt production




Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

## Refined cobalt production by country grouping

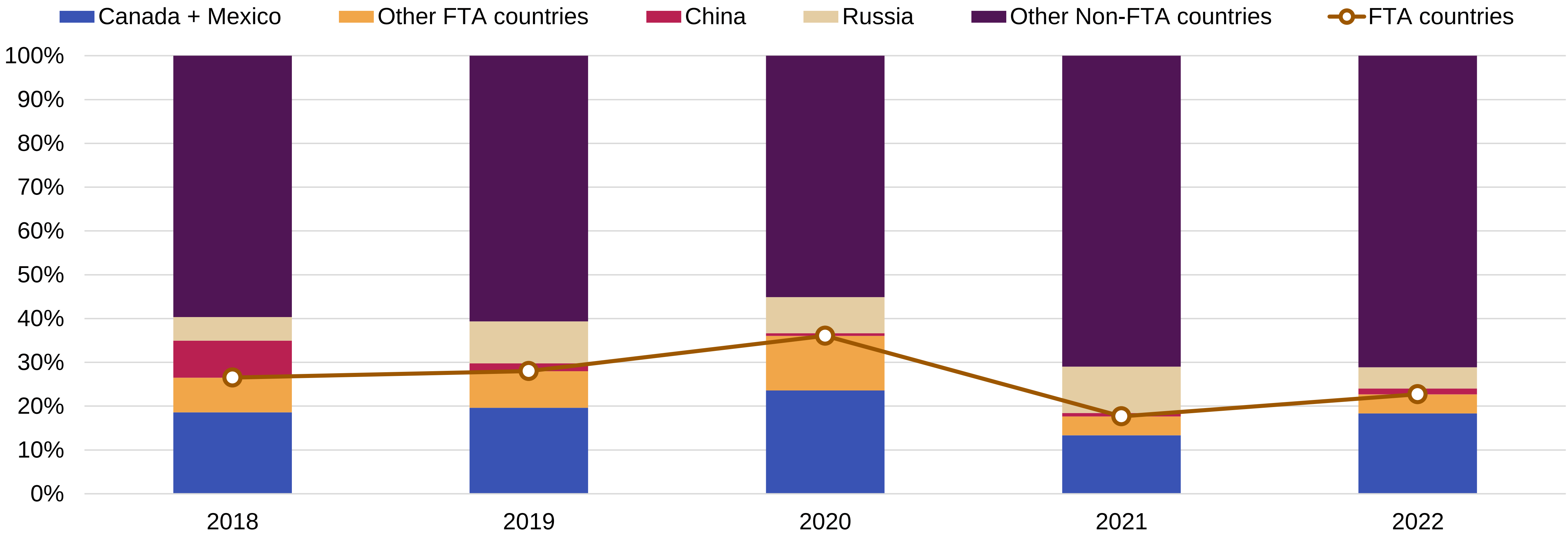



Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

# The US must rely on imports to meet domestic sourcing requirements — while there is enough refined cobalt supply in FTA countries to meet these requirements, most US imports come from non-FTA countries

**Breakdown of US cobalt imports by source country**

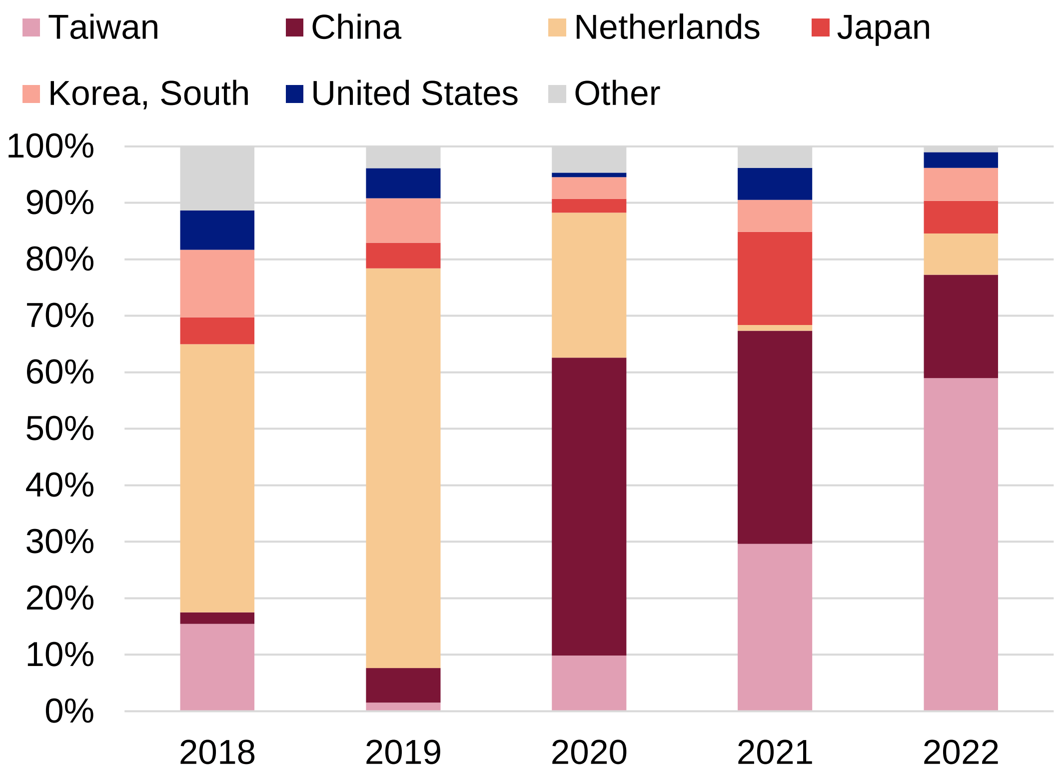



Data compiled Feb. 23, 2023.

Source: S&P Global Market Intelligence.

# Australia and Canada produce enough refined cobalt to supply the US energy transition, but most of their supply goes to non-FTA countries

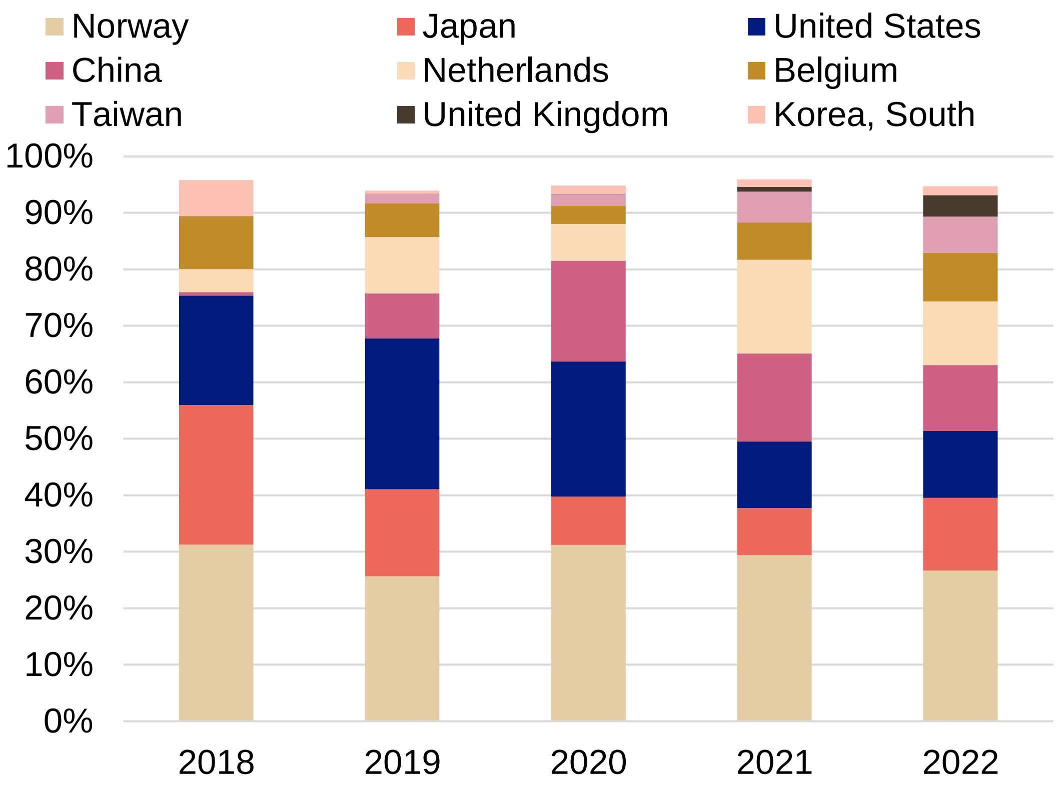
## Breakdown of Australia refined cobalt exports by destination country




Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

## Breakdown of Canada refined cobalt exports by destination country




Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

Note**:** Some refined cobalt from Canada faces separate trade restrictions to the United States, as the cobalt Sherritt International refines originates in Cuba.

# Cobalt: Existing trade patterns would make it difficult to meet local sourcing requirements

- **Both mined and refined production are dominated by non-FTA countries.** Most cobalt is mined in the DRC and refined in Mainland China, solidifying more than half of global cobalt production.
- **Canada and Australia produce enough cobalt to support US energy-transition-related demand.** Despite limited access to over half of the global cobalt supply, FTA countries — primarily Australia and Canada — produce enough cobalt to meet the domestic sourcing requirement.
- **But currently, the US mostly imports from non-FTA countries.** In 2022, 77% of US refined cobalt imports were from non-FTA countries, with Japan and Norway accounting for roughly half of US imports.
- **To meet domestic sourcing requirements, the US would need to increase imports from Canada and Australia.** Additionally, metal cobalt is more expensive than cobalt hydroxide, creating a cost disadvantage.
- **However, there is substantial trade competition for Canadian and Australian refined cobalt.** Mainland China and Taiwan accounted for over 75% of Australian refined cobalt exports in 2022, with only 3% going to the United States. About 40% of Canadian exports went to Norway or Japan, with China and the US each accounting for 12%.

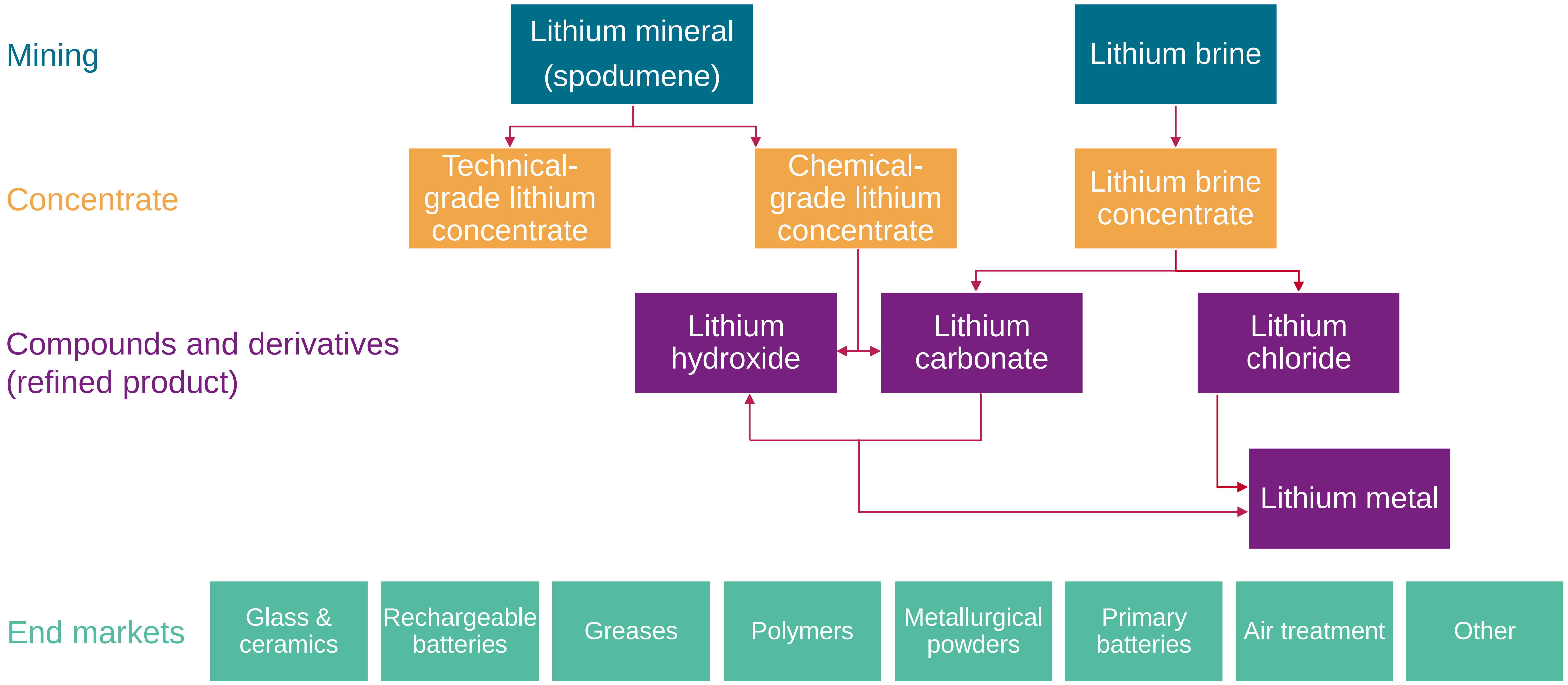
**Under existing trade patterns, the US will not meet domestic sourcing requirements for cobalt. While there will likely be enough cobalt production in FTA countries to meet these requirements, current trade patterns and resource distribution will make the shifting of trade patterns difficult.**

**Bottom line: The required reorientation of trade patterns makes meeting the domestic sourcing requirements for cobalt unlikely.**

Sourcing

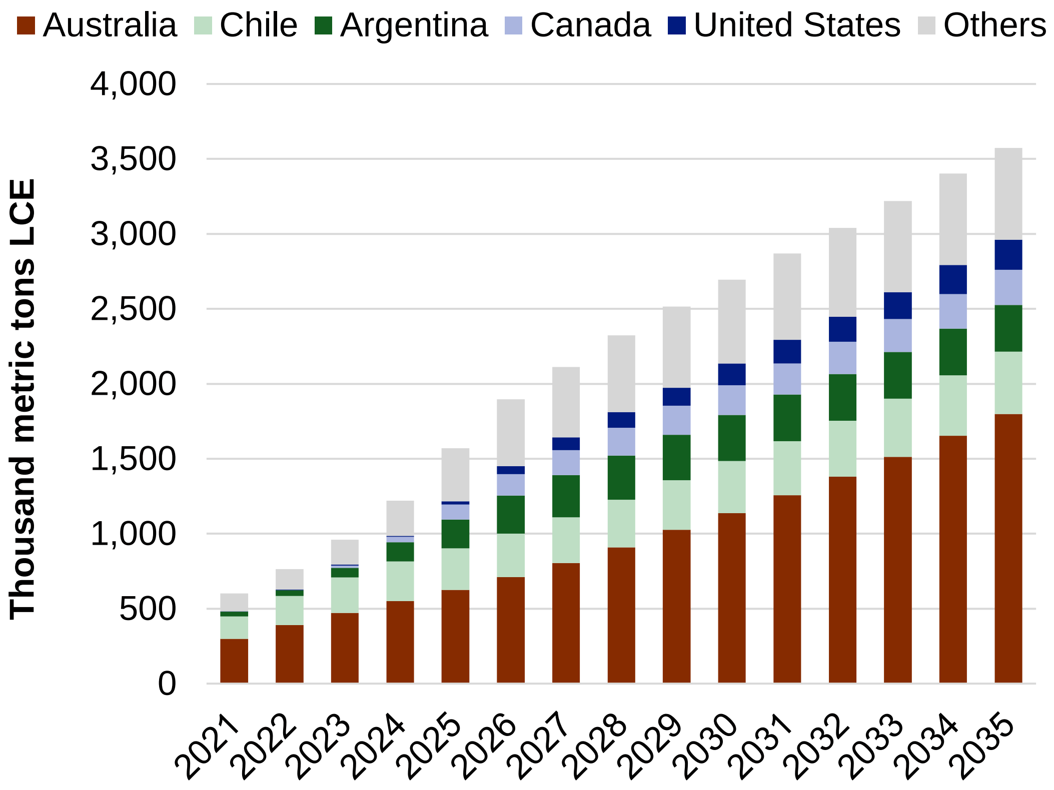
# Lithium

# Lithium supply: from mined to refined



# Aggressive mine capacity additions are planned globally and in the United States to meet growing lithium demand from increasing EV sales

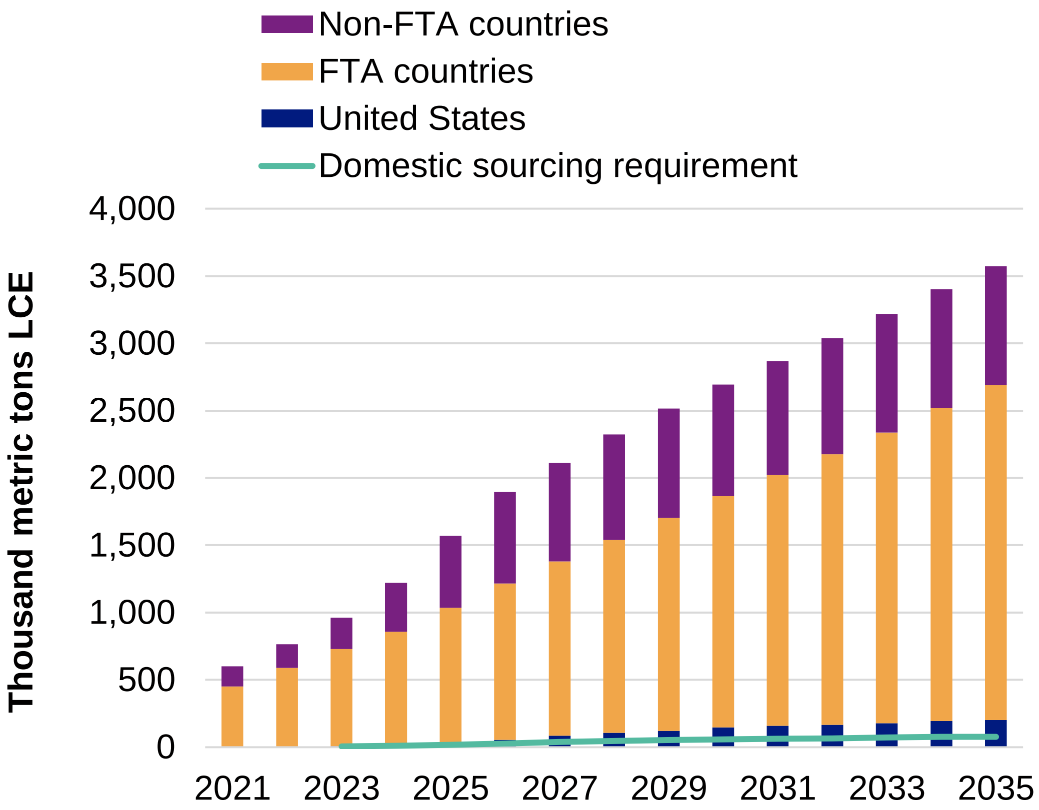
## Top countries for mined lithium production




Data compiled Feb. 24, 2023.

LCE = lithium carbonate equivalent.
Source: S&P Global Market Intelligence.

## Mined lithium production by country grouping

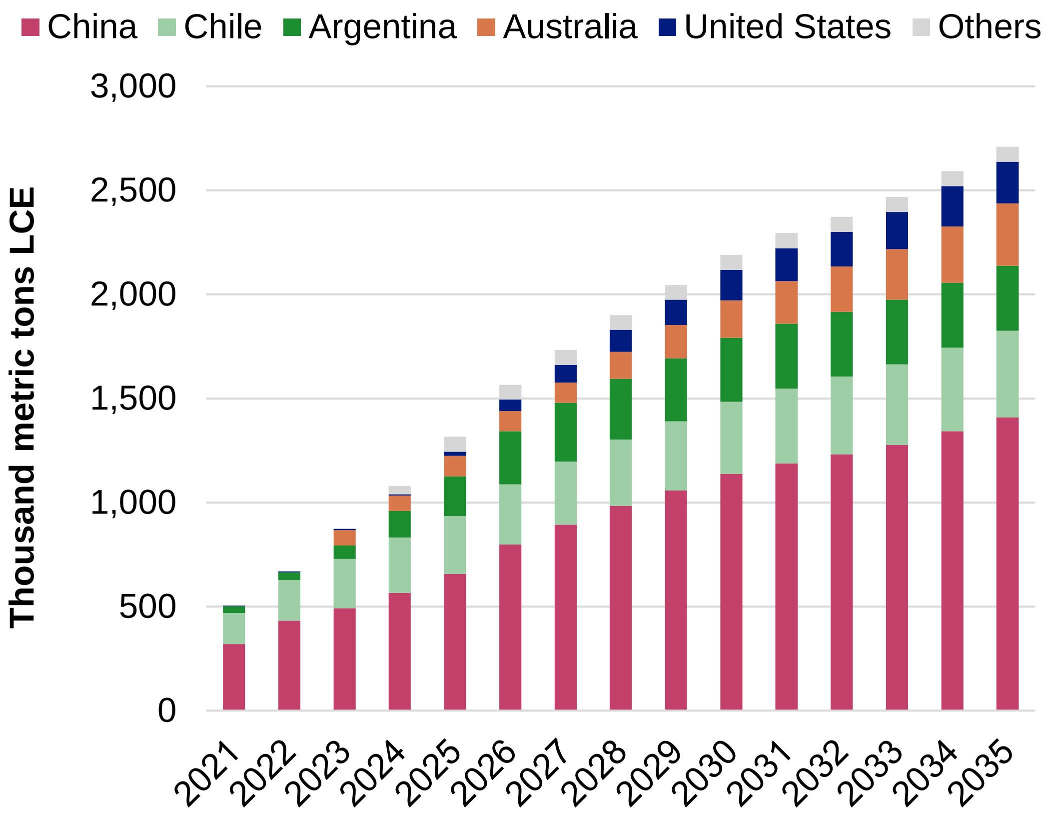



Data compiled Feb. 24, 2023.

LCE = lithium carbonate equivalent.
Source: S&P Global Market Intelligence.

# While China is projected to remain the largest refiner of lithium, the US and FTA countries such as Chile and Australia have substantial capacity increases planned

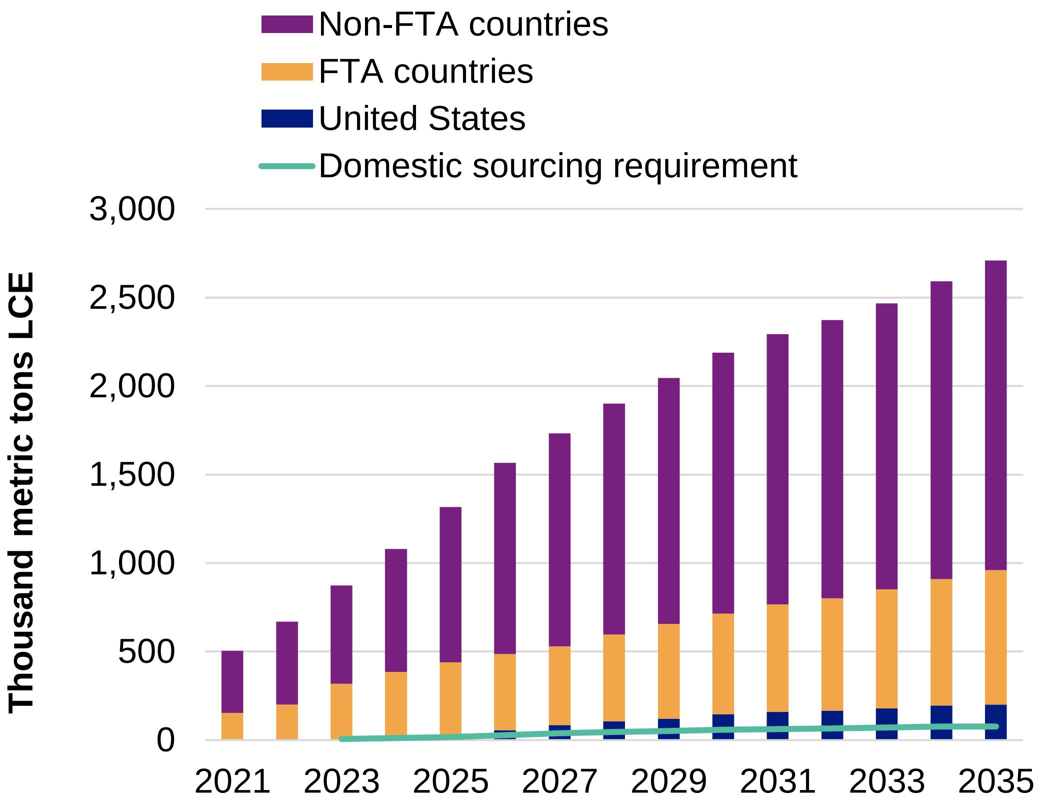
## Top countries for refined lithium production




Data compiled Feb. 24, 2023.

LCE = lithium carbonate equivalent.
Source: S&P Global Market Intelligence.

## Refined lithium production by country grouping

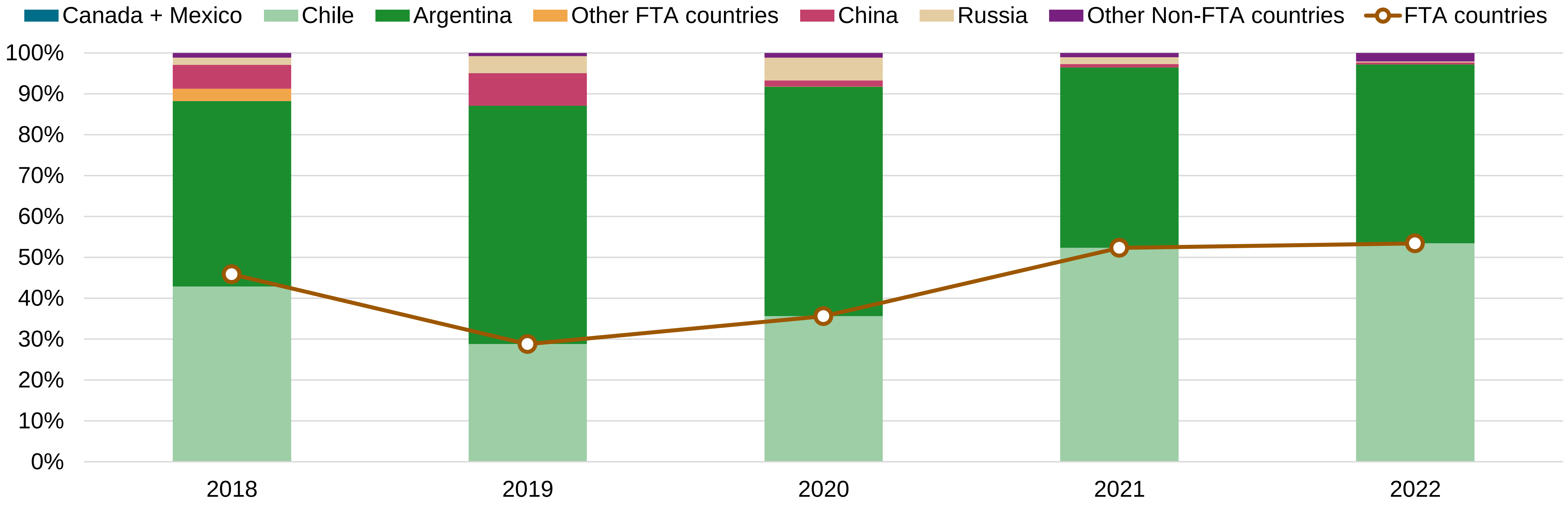



Data compiled Feb. 24, 2023.

LCE = lithium carbonate equivalent.
Source: S&P Global Market Intelligence.

# Over 90% of recent US lithium imports were from Argentina and Chile; if planned US capacity additions fail to come online, trade patterns would need to shift

**Breakdown of US lithium imports by source country**




Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

# Lithium: Planned capacity additions mean the US would be self-sufficient — but social license and permitting challenges could delay self-sufficiency

- **Planned supply additions in the United States will meet domestic sourcing requirements.** The aggressive planned increases in lithium supply in the United States will be enough to meet projected domestic sourcing requirements. Robust capacity increases are also planned internationally. In particular, strong supply additions are forecast in Chile, Australia and Argentina — both for mined and refined lithium.
- **Plans can be delayed.** Challenges such as permitting and social licensing have plagued mining and refining projects in the United States. These pose a serious risk to planned US capacity additions coming online as scheduled.
- **US trade patterns may need to shift.** Chile and Argentina currently account for more than 90% of US refined lithium imports. While China's and Russia's footprints in US refined lithium imports have shrunk to less than 1% each, Argentina does not have a free trade agreement with the United States.

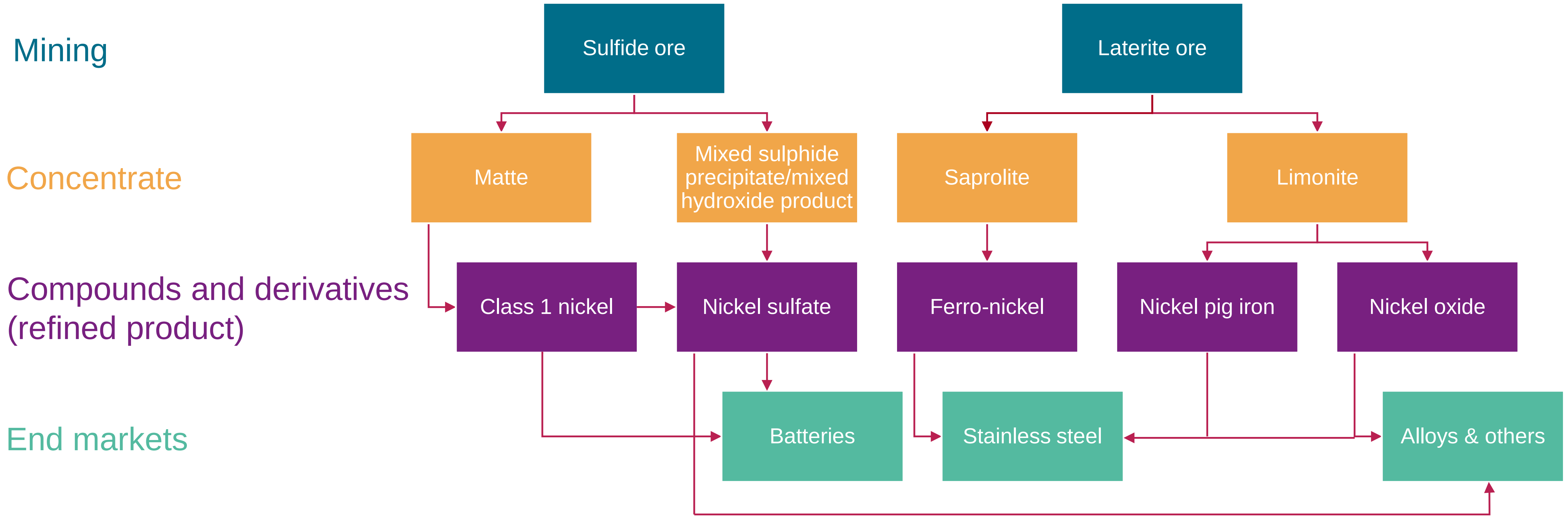
**If capacity additions come online as projected in the United States and in other FTA countries such as Chile, Canada and Australia, the United States could easily meet domestic sourcing requirements. However, if US production does not come online as quickly as anticipated, the United States may still need to rely on imports to meet the requirements.**

**Bottom line: While planned US capacity additions mean domestic sourcing requirements could be met just through US production, project delays could cause the United States to rely on sourcing from other FTA countries such as Chile.**

## Sourcing

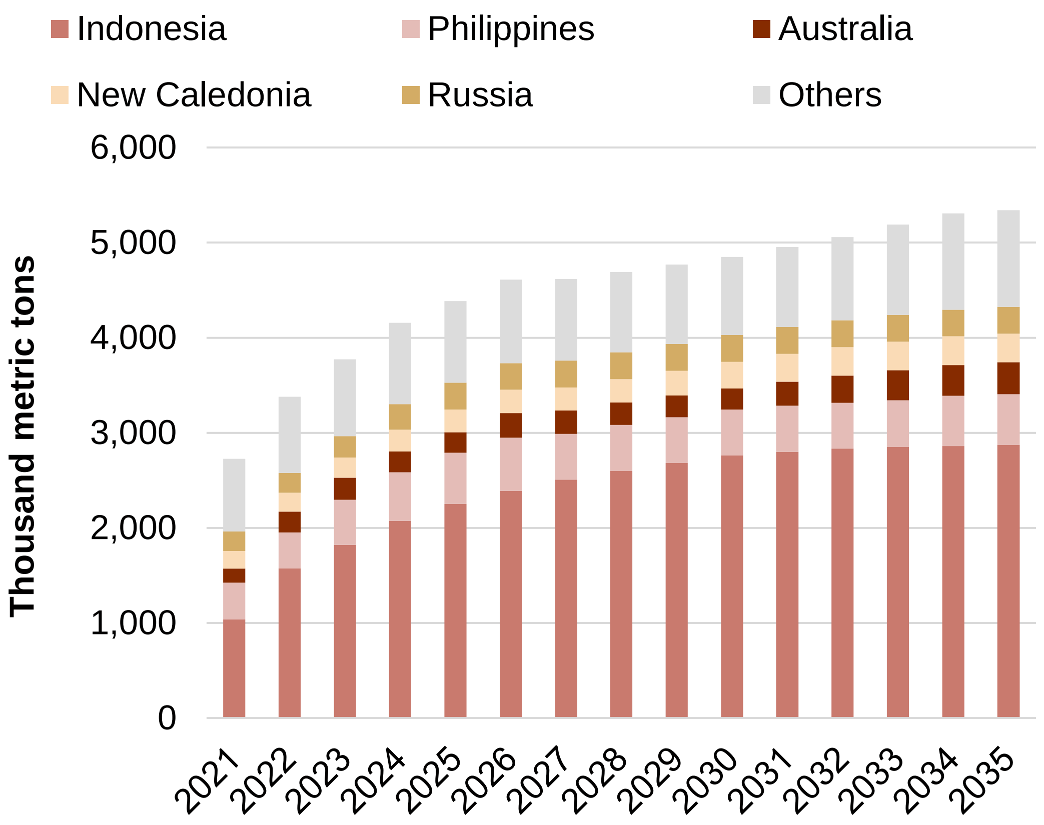
# Nickel

# Nickel supply: from mined to refined



# Nickel mining is dominated by the Eastern hemisphere, with Indonesia's share of the global market expected to grow

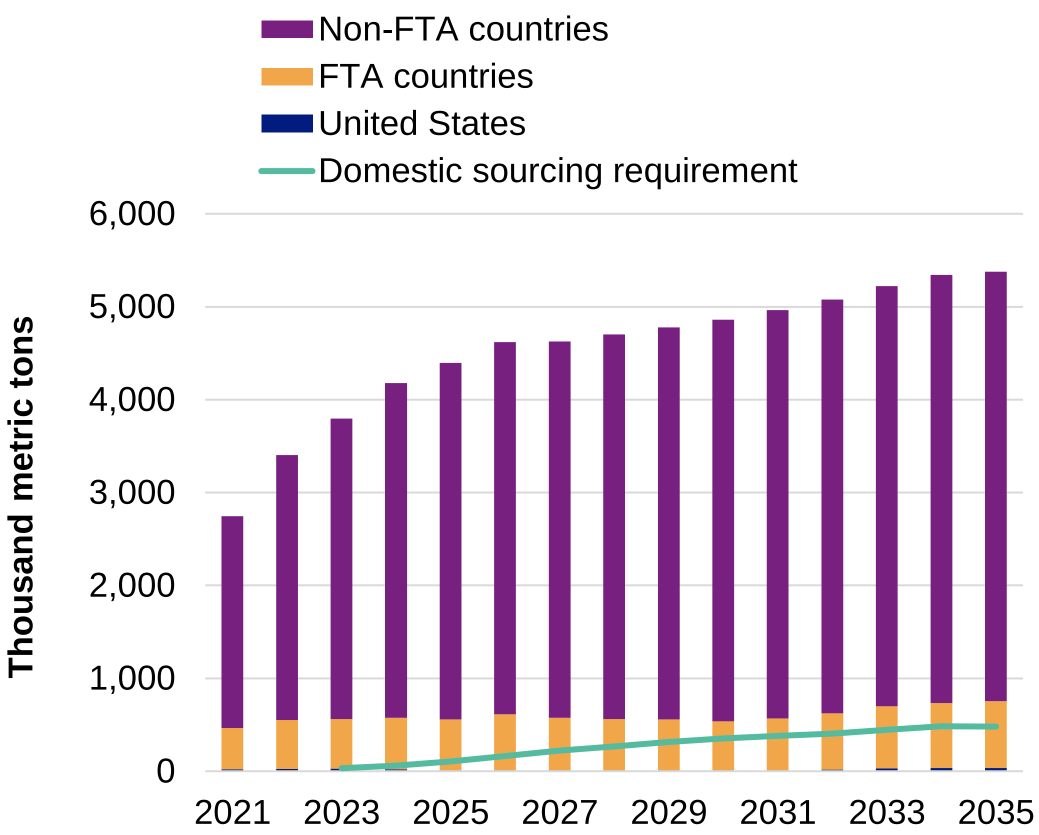
## Top countries for mined nickel production




Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

## Mined nickel production by country grouping

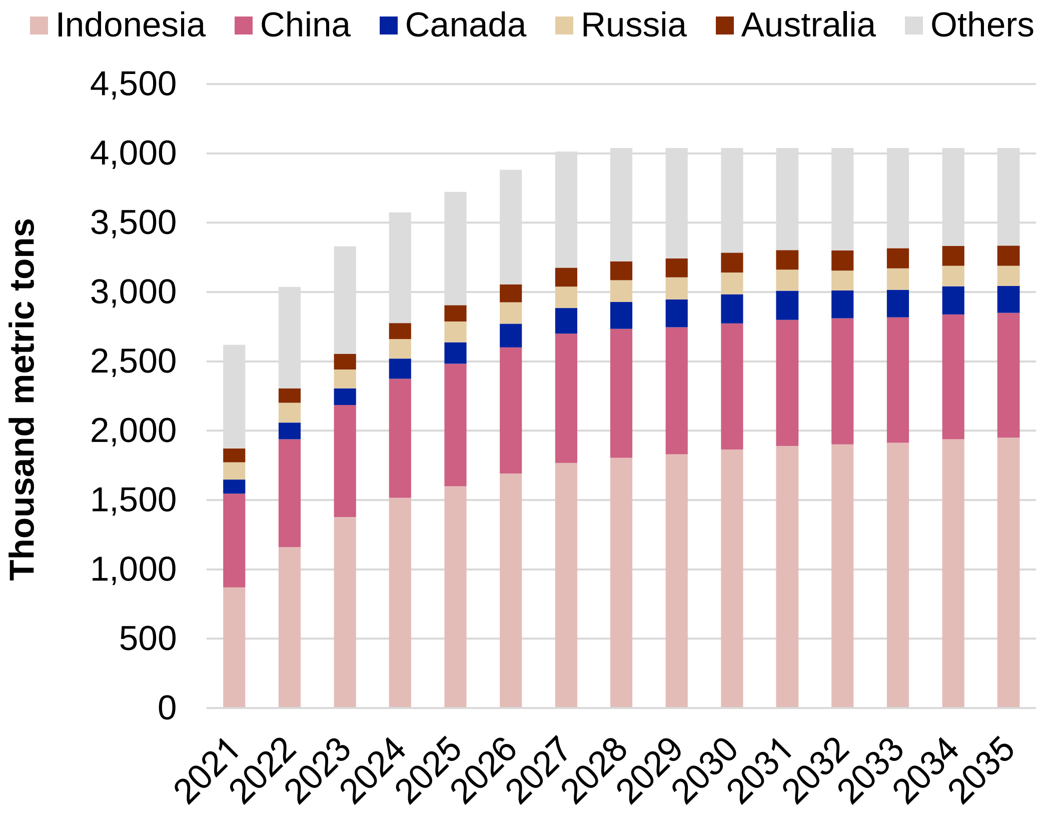



Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence.

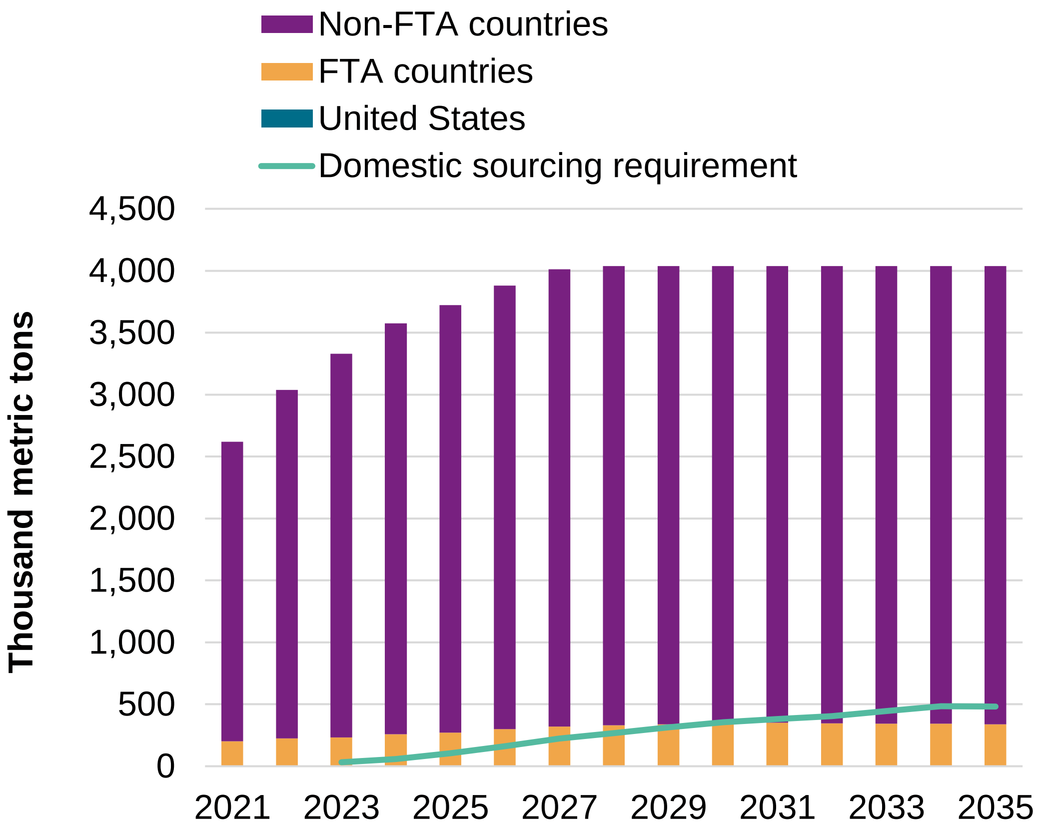
# Beginning around 2030, the United States' domestic requirement will likely surpass total primary nickel production in FTA countries

## Top countries for primary nickel production




Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

## Primary nickel production by country grouping

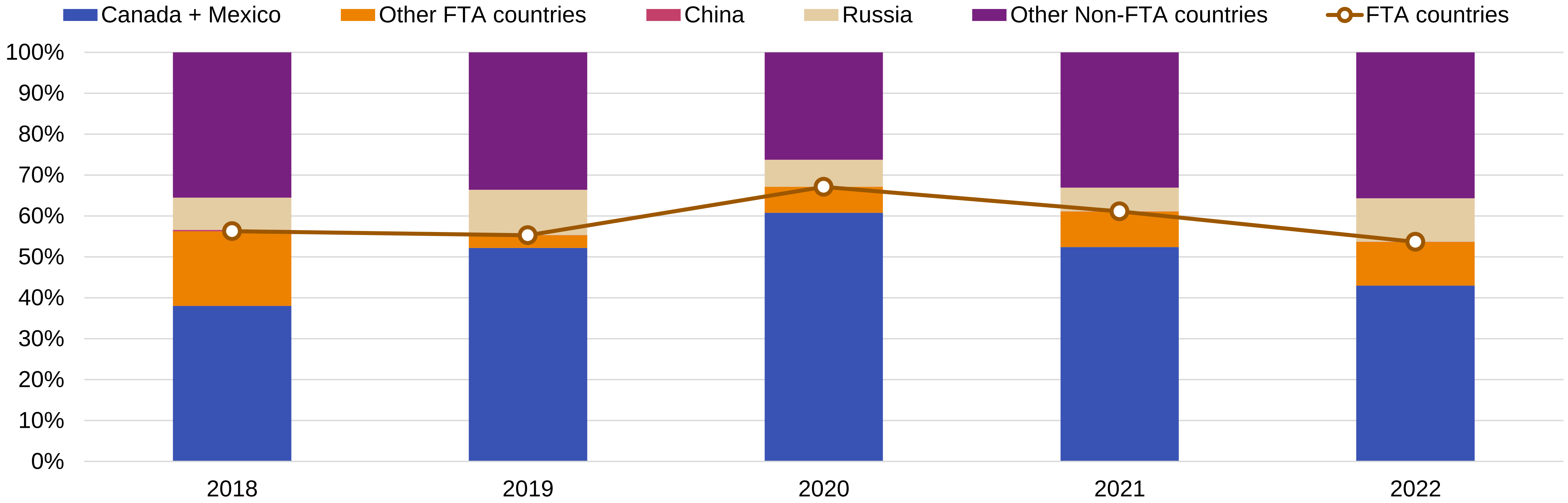



Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

Even if **100%** of primary nickel production from FTA countries went to the United States, domestic sourcing requirements would still not be met in the latter years of the forecast.

# More than 40% of US nickel imports come from non-FTA countries, with Russia supplying 11% of US imports in 2022

## Breakdown of US nickel imports by source country



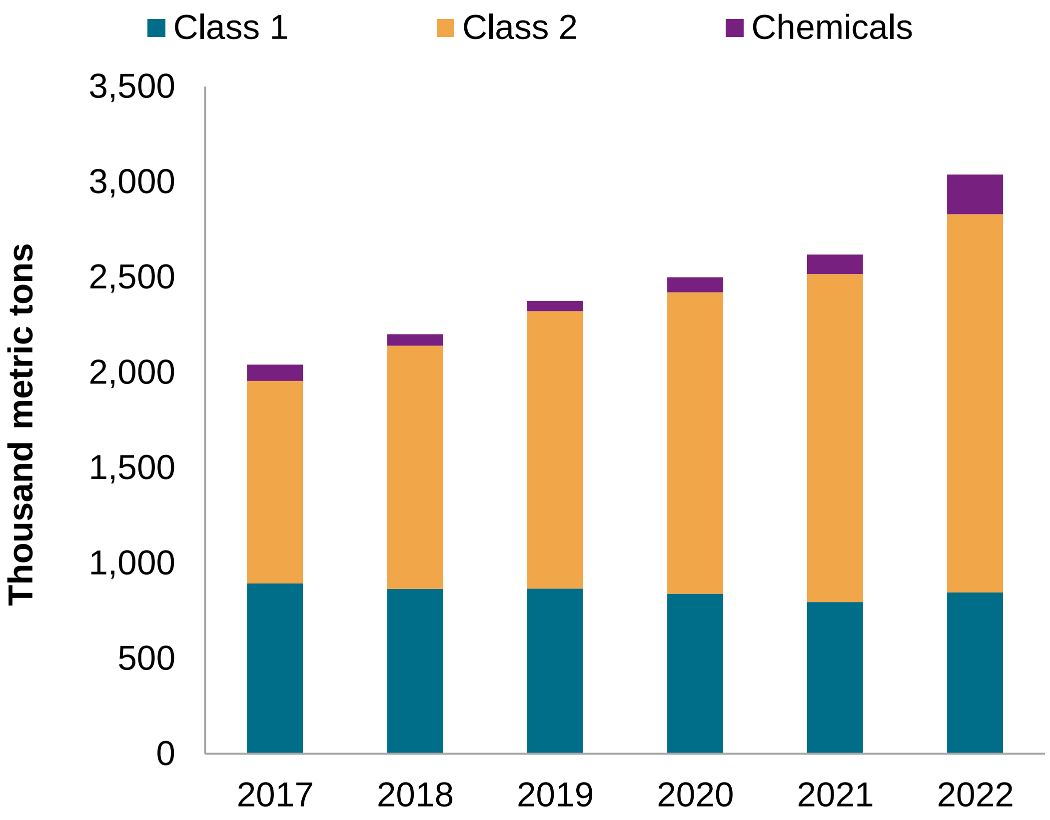

Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

Russia is the dominant producer of high-grade nickel used in batteries, and the Ukraine invasion has led to strong sanctions that limit Russia's trade with the West. Meanwhile, Russia is increasingly economically dependent on China.

# Nickel industry product mix will further widen the gap between supply and demand ambitions

- There are two classes of primary nickel:
  - **Class 1:** Nickel content of 99% or higher, e.g., briquettes
  - **Class 2:** Nickel content of less than 99%, e.g., nickel pig iron or ferronickel
- Class 1 nickel is typically used for battery production because it is the most cost-effective means to produce nickel sulfate ($NiSO_4$).
- Even without this distinction, there will not be enough nickel production in FTA countries for the United States to meet domestic sourcing requirements.
- Class 1 production represented less than 30% of global primary nickel production in 2022, and its share of total production has been shrinking during the last five years.
- Absent any change in the cost-effectiveness of nickel sulfate production, more primary production will need to shift to Class 1 production to support growing global EV demand.
- This distinction makes meeting domestic sourcing requirements for nickel **even more difficult.**

**Breakdown of global primary nickel production**




Data compiled Feb. 24, 2023.

Source: S&P Global Market Intelligence, Antaike, International Nickel Study Group, Shanghai Metals Market.

# Nickel: There is unlikely to be enough supply in FTA countries to meet US domestic sourcing requirements, especially given the growing importance of Class 1 nickel

- **There is not enough primary nickel production in FTA countries.** Even if all primary nickel production in FTA countries was exported to the United States, there would not be enough supply to meet domestic sourcing requirements.
- **Trade patterns would need to shift.** More than 45% of US nickel imports in 2022 came from non-FTA countries, including 11% from Russia.
- **The gap between demand ambitions and available supply is likely to widen further.** The widening gap is influenced by two main factors:
  - **Competing end uses:** Stainless steel is currently the most dominant end use of nickel, making up over 85% of current US nickel usage.
  - **Class 1 versus Class 2 production:** Class 1 primary nickel is typically used for battery production, but less than 30% of primary nickel production in 2022 was Class 1.

**Meeting domestic sourcing requirements would require (1) a substantial increase in $NiSO_4$ capacity, which typically comes from Class 1 production in the United States and FTA countries, and (2) that 100% of that supply go to the United States.**

**Bottom line: Unless there is a significant change in investment, there will not be enough nickel production in FTA countries to meet US domestic sourcing requirements for energy-transition-related technologies, let alone other end-market demand or demand in other FTA countries.**

# Copper market analysis

# Demand requirements

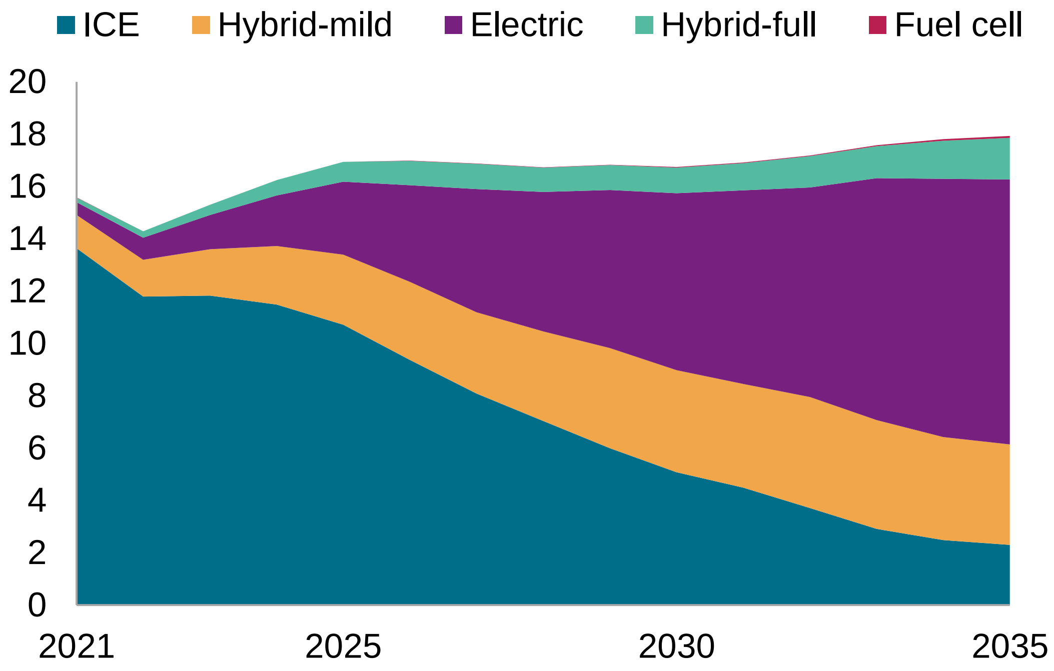
## Copper

# Copper use in battery and non-battery car components is expected to increase

Cu

## US new vehicle sales by type

Millions of vehicles




Data compiled February 2023.

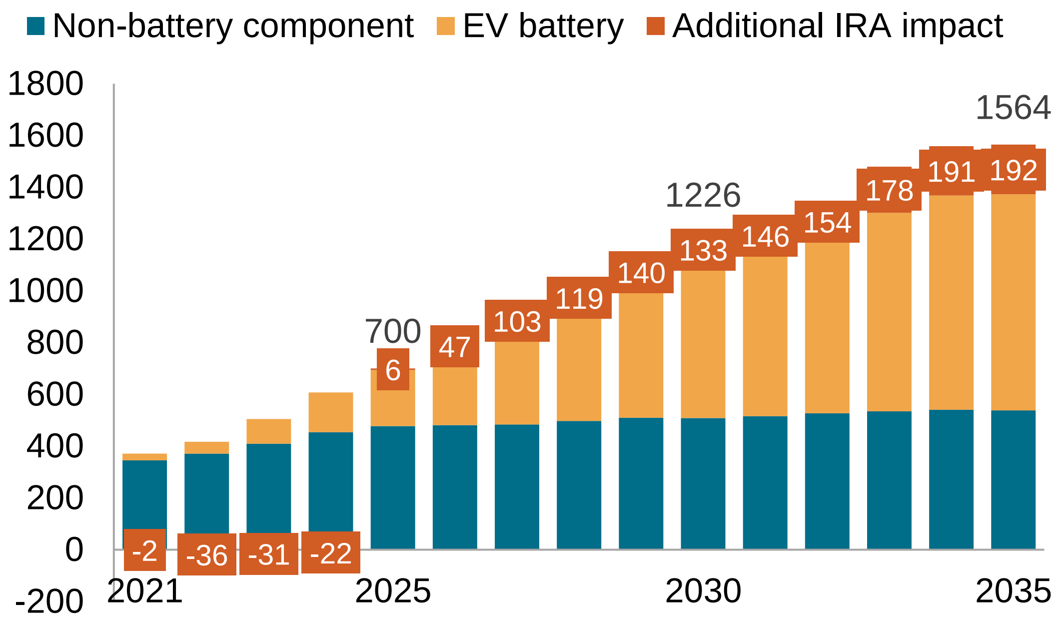
ICE = internal combustion engine.

Hybrid-mild cannot drive on pure battery alone, while hybrid-full can; fuel-cell vehicles are powered by hydrogen.

Source: S&P Global Mobility.

## US copper end-use[1] demand in transport

Thousand metric tons




Data compiled February 2023.

[1] This represents end-use demand (excludes recycling assumptions).

Non-battery components include harnesses and other electrical wires. Some levels of copper substitutions were assumed and are available in the appendix. Short-term negative "additional IRA impact" reflects slowdown in sales observed due to other macroeconomic factors in our latest outlook vs. the pre-IRA outlook.

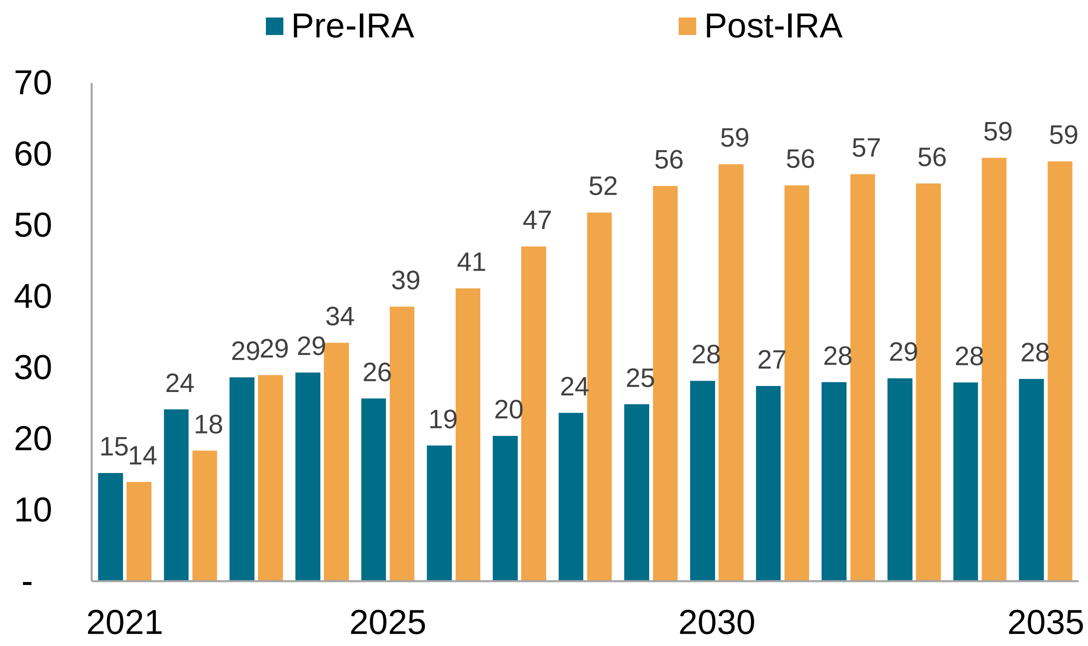
Source: S&P Global Commodity Insights.

# Growth in energy storage capacity will also drive metals demand up

Cu

### Energy storage systems (ESS) demand (United States)

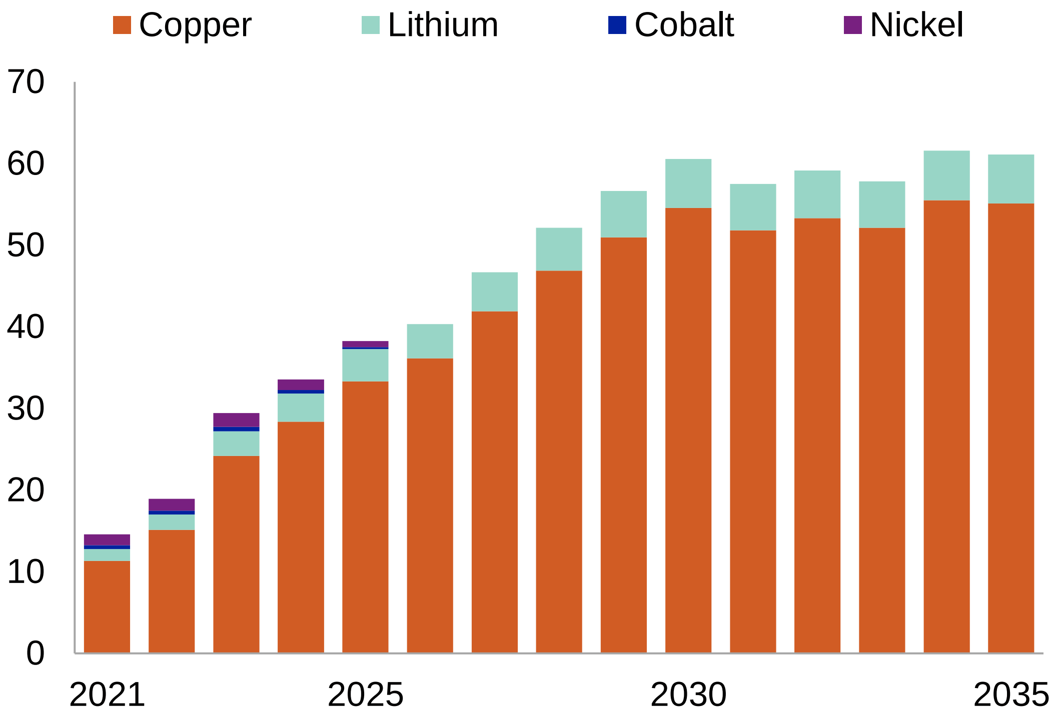
GWh




Data compiled February 2023.
Pre- and post-IRA represent S&P Global Commodity Insights' outlook published before and after the IRA was announced.
Source: S&P Global Commodity Insights.

### Metals demand for ESS (post-IRA)

Thousand metric tons

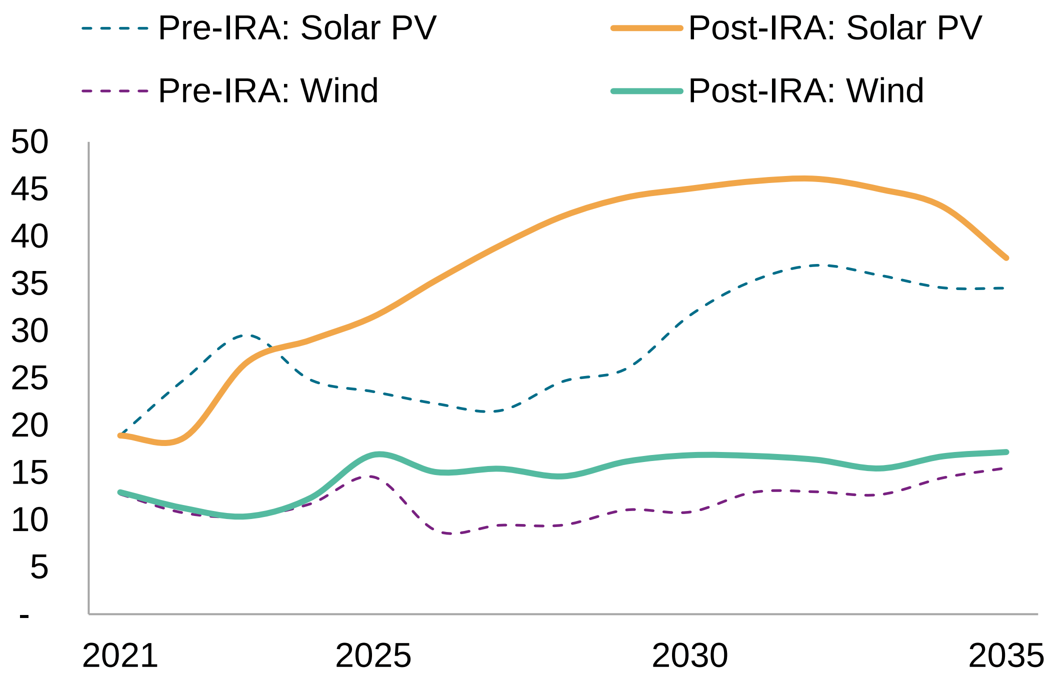



Data compiled February 2023.
Source: S&P Global Commodity Insights.

# The IRA will contribute to the acceleration of capacity additions in wind and solar

## US power capacity additions by energy source

GW



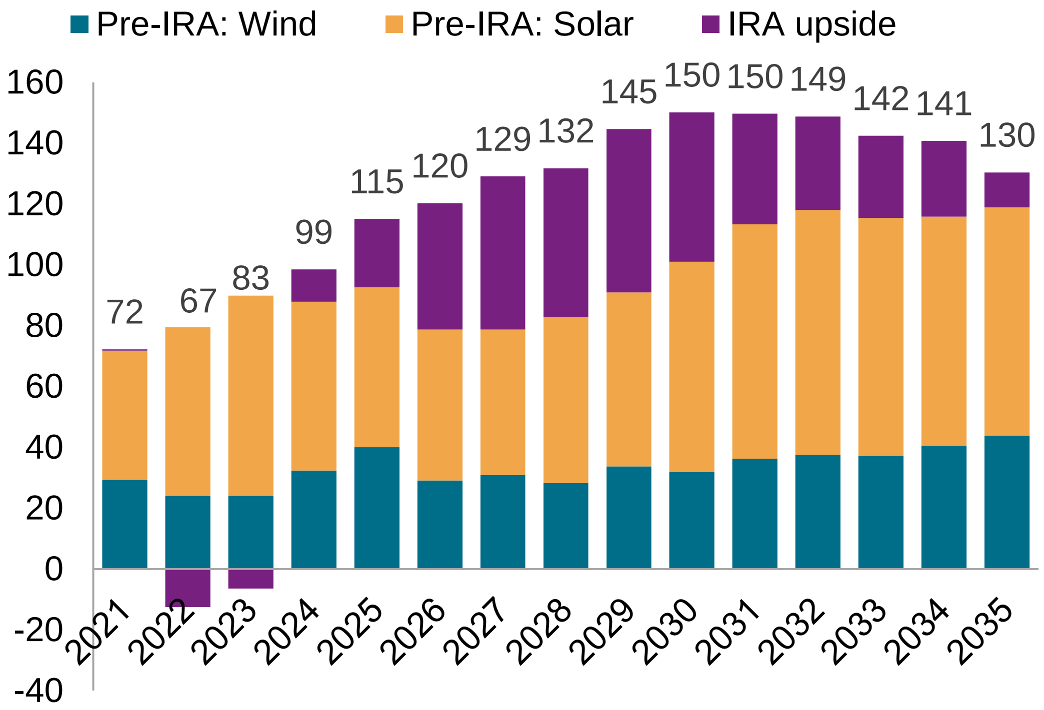

Data compiled February 2023.

Copper intensity in power generation is calculated for capacity additions (renewable capacity). Retirement of coal power plants has not been considered in the analysis (and subsequent reuse or recycling of copper wires in coal plants).

Source: S&P Global Commodity Insights.

## US copper end-use demand for power generation

Thousand metric tons




Data compiled February 2023.

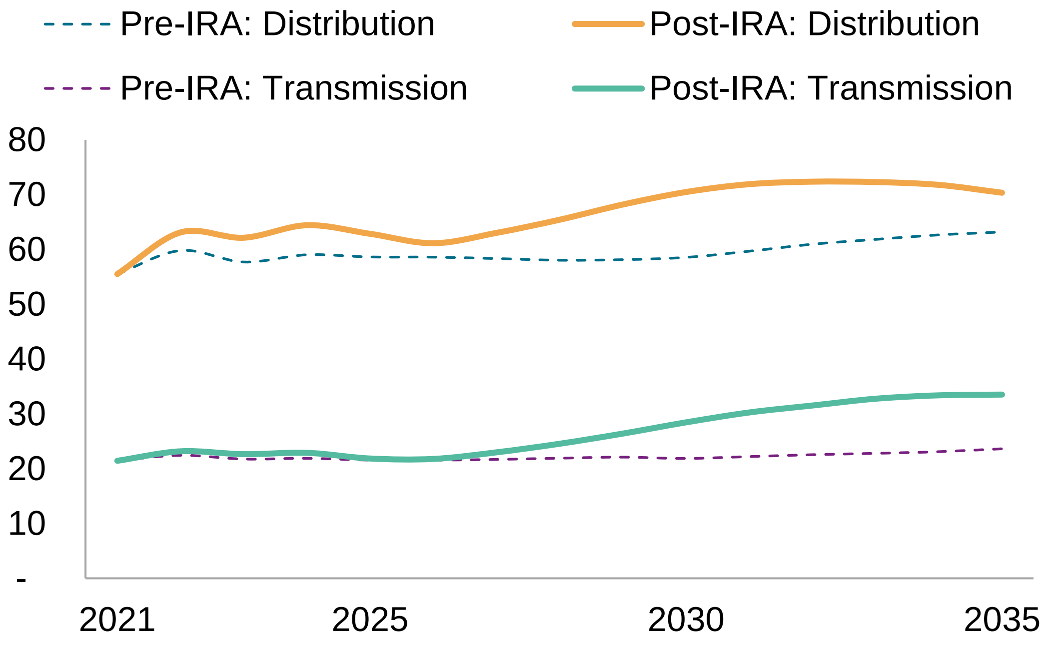
Source: S&P Global Commodity Insights.

# Electricity grid investments continue to increase to meet power demand

Cu

### US annual investment in transmission and distribution (T&D) power systems

2020 US$ million



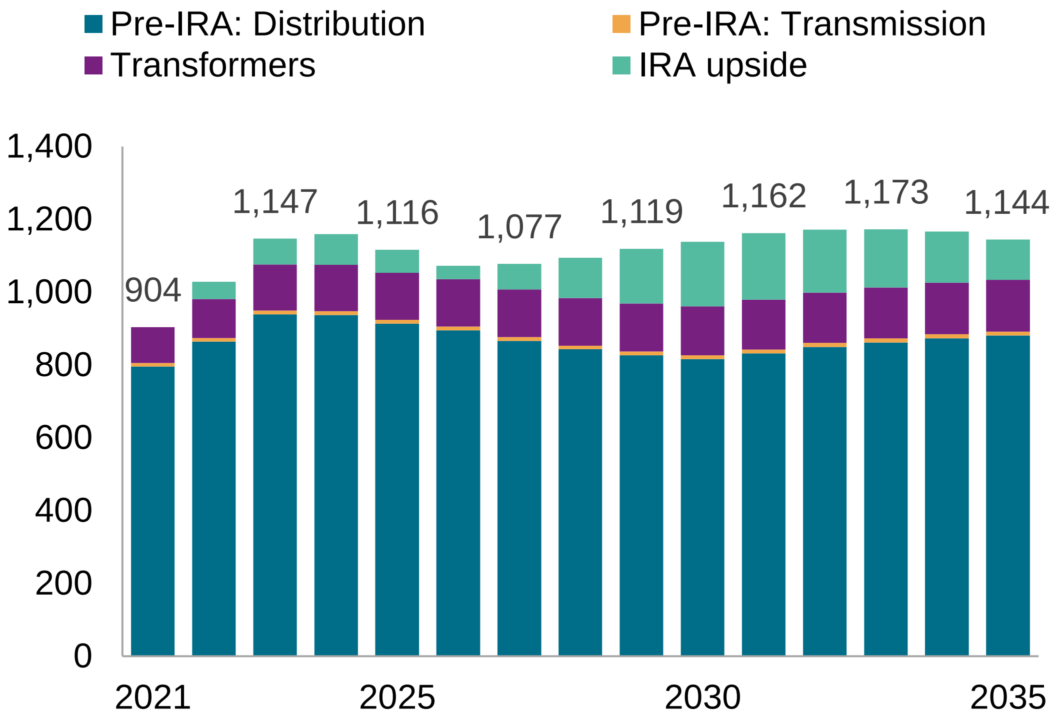

Data compiled February 2023.

Post-IRA distribution represents required investment in T&D lines under a green rules scenario (with heavy capacity additions in wind and solar generation).

Source: S&P Global Commodity Insights.

### US copper end-use demand for T&D

Thousand metric tons



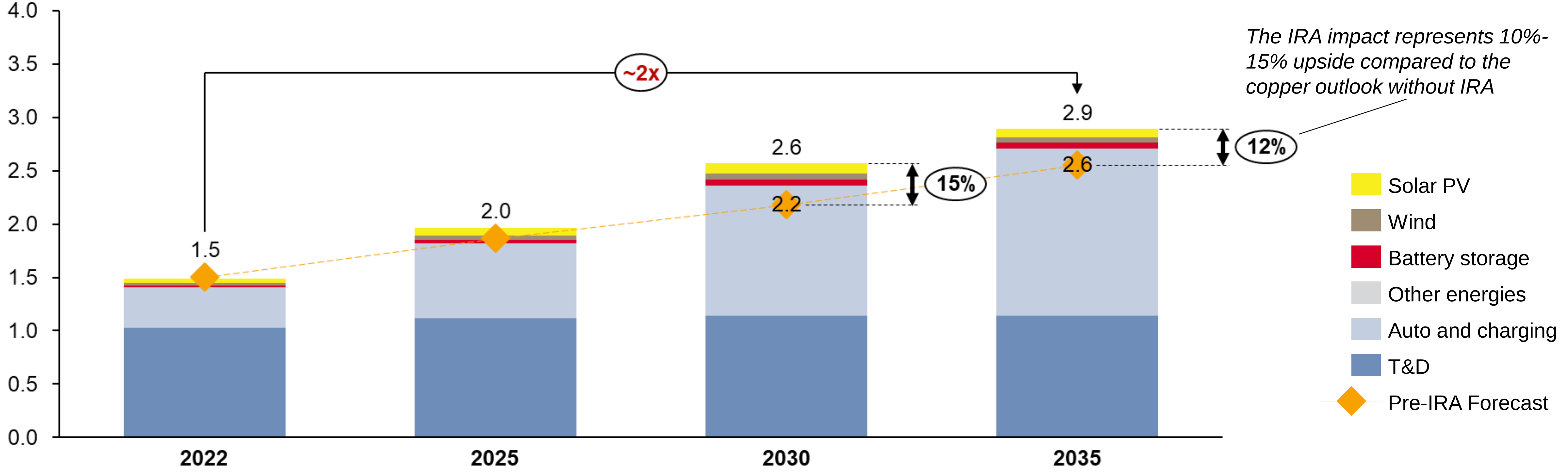

Data compiled February 2023.

Source: S&P Global Commodity Insights.

Cu

# Overall energy transition demand for copper will double by 2035, spurred by heavy investment in renewable infrastructure and electric vehicles

**US gross (end-use) copper demand by energy transition application**
*(Million metric tons Cu)*




Source: S&P Global Commodity Insights.
Because copper is not defined as a "critical mineral," IRA-driven upside will not necessarily mean upside for domestic copper supply.

# Copper: a key component of energy-transition-related infrastructure

- **With EV sales expected to increase, demand for copper from the automotive industry will grow at a faster rate.** Copper intensity in EVs can be up to three times that of ICE vehicles. The accelerated shift toward EVs will drive copper requirements in transport — projected to rise 12% year over year in 2035 relative to 2022.
- **The associated IRA impact on EV sales also applies to copper demand.** In 2035, copper requirement from vehicles sold is expected reach 1.6 Mt Cu — up 165 kt from a no-IRA outlook (~11% upside).
- **The IRA is also driving increased investments in stationary energy storage systems (ESS).** S&P Global's post-IRA ESS capacity outlook forecasts more than double the growth of its pre-IRA forecast, with 59 GWh of ESS demand by 2035, leading to copper requirements of more than 50 kt by 2035, up from 18 kt in 2022.
- **Additional wind and solar capacity additions in the 2020s are likely to drive up medium-term copper demand.** With additional wind and solar capacity expected between 2025 and 2035, copper demand for wind and solar is expected to grow by 4.4% annually between 2022 and 2035.
- **Increased wind and solar capacity additions will also require heavy investment in T&D infrastructure, which requires sizable volumes of aluminum and copper.** S&P global expects an annual average of 112 kt more copper required for T&D following the IRA announcements.

**Bottom line: Copper demand growth is indirectly supported by the IRA, which will accelerate renewable energy infrastructure investments. Energy-transition-related copper demand is projected to double between now and 2035.**

## Sourcing

# Copper

# Copper: the “metal of electrification”

This study is premised on the tax credits and sourcing requirements applied to US-listed critical minerals in the IRA. Copper is not currently listed as a critical mineral. However, we include it in our study for three reasons:

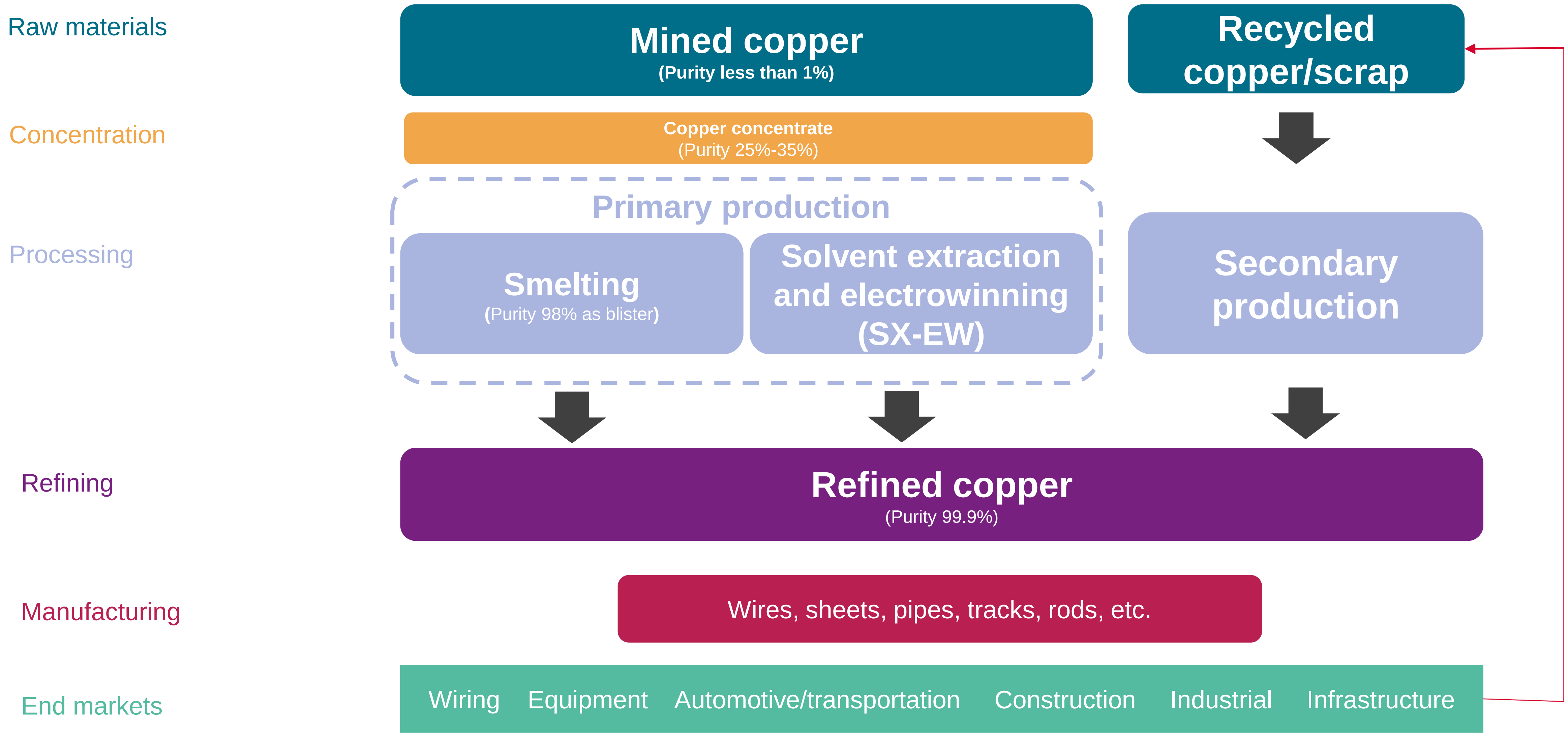
- Copper, the “metal of electrification,” is arguably more fundamental to the energy transition than any critical mineral. S&P Global’s study *The Future of Copper* (2022) calculated, bottom-up, the unprecedented annual quantities of copper required to achieve global net-zero carbon emissions by 2050. By boosting US demand for energy transition applications such as EVs and energy storage systems, the IRA will also boost demand for refined copper.

- More than two-thirds of US energy transition-related demand for the four metals considered in this paper is for copper. In 2035, we project that post-IRA, the US energy transition-related demand for copper will be more than three times that for nickel, lithium and cobalt combined.

- Beyond energy transition applications, copper is already one of the most widely used metals in industry. Post-IRA total US demand for refined copper in 2035, including traditional and energy transition-related demand, will likely be almost twice (1.8 times) that of copper demand for energy-transition-related applications. Yet copper refining capacity in the United States has fallen since 2000, meaning the United States is becoming increasingly reliant on imports for its refined copper.

To assess potential sources of mined copper through 2035, this analysis leveraged S&P Global Market Intelligence’s mining asset database and supply estimates to identify mined supply trends, particularly in the United States and FTA countries.

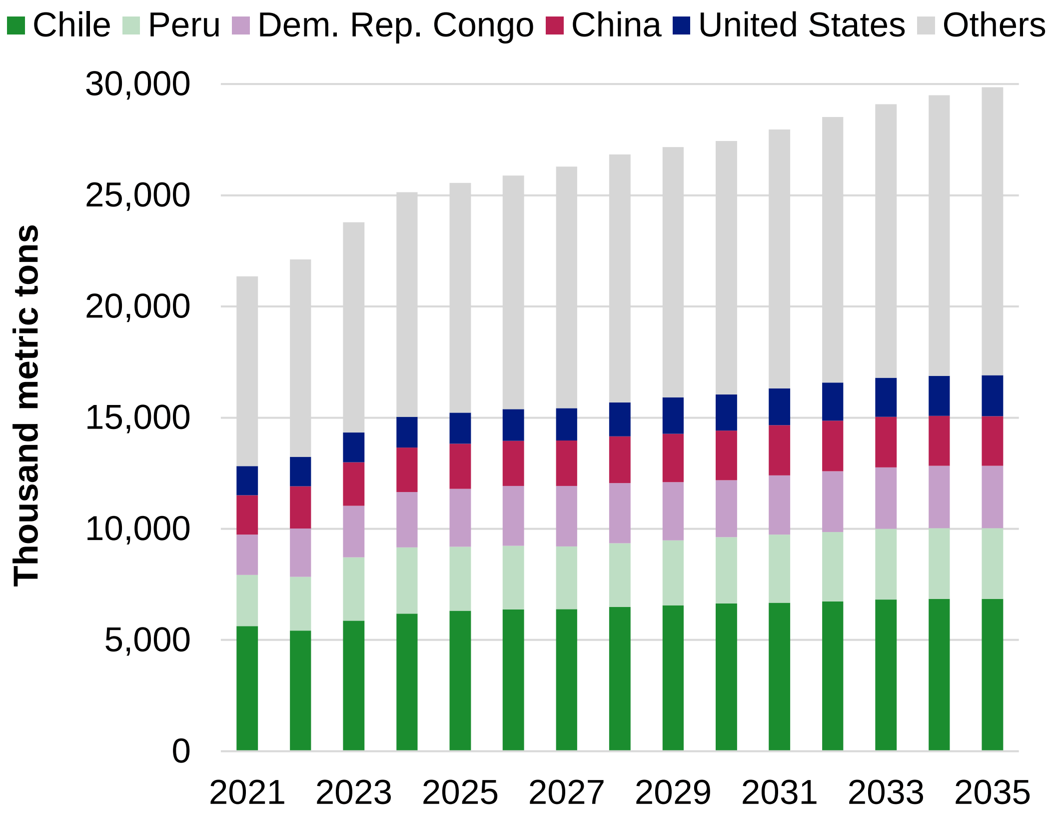
# Copper: from mined to refined




Some scrap is used directly (direct-use) at the fabrication and semi-fabrication stage.

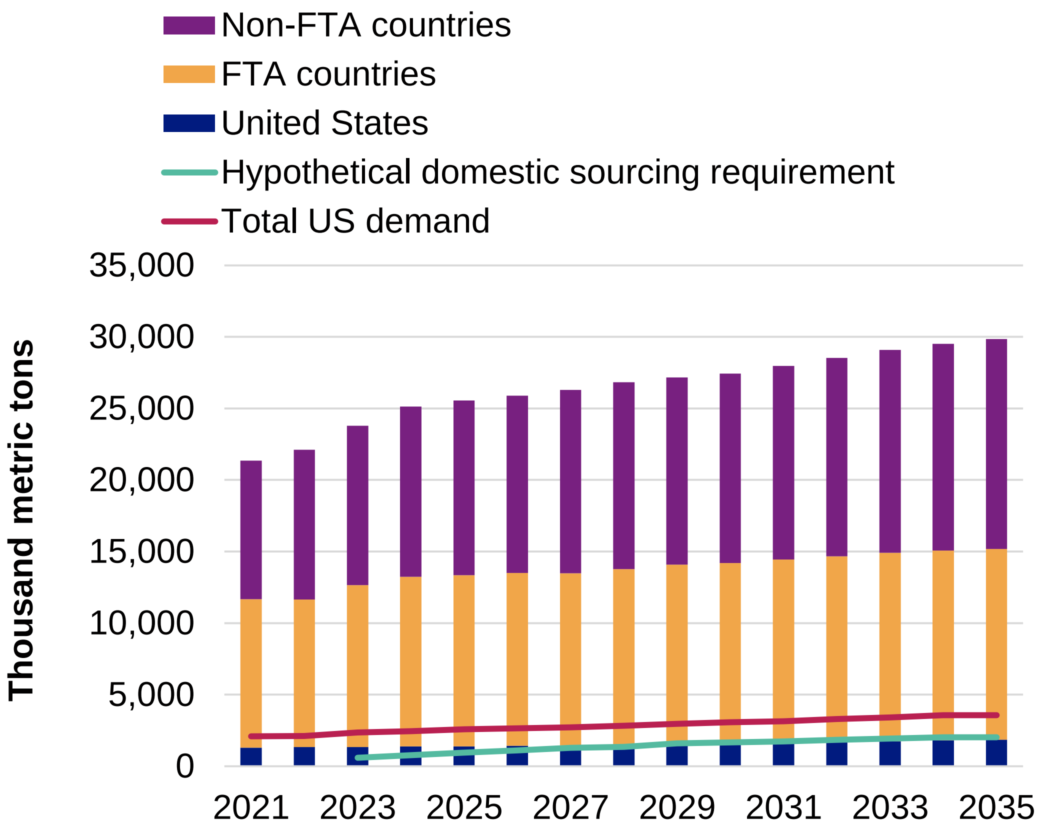
# While copper does not have a domestic sourcing requirement per the IRA, the United States must rely on imports to meet demand ambitions

## Top countries for mined copper production




Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

## Mined copper production by country grouping



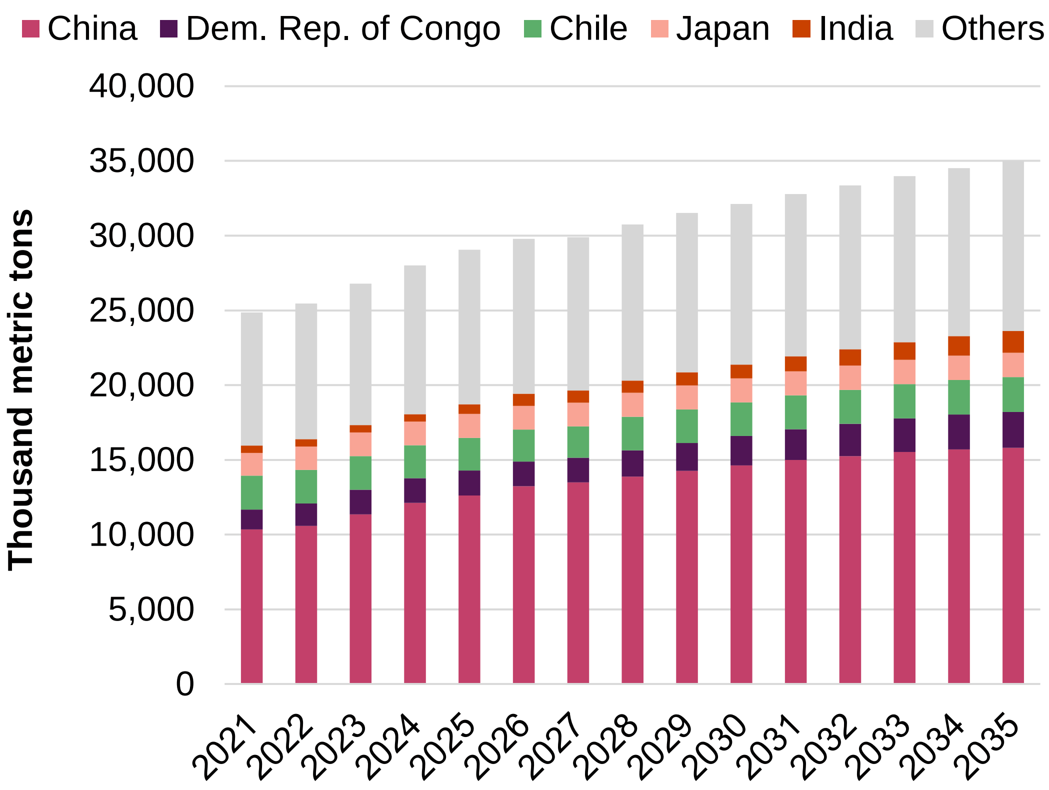

Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

Much of this FTA-produced mined copper goes to China and other parts of Asia.

Note: Hypothetical domestic sourcing requirement for copper is calculated using the same domestic sourcing requirement percentages used for lithium, cobalt and nickel as stipulated in the IRA. Energy-transition-related copper demand is projected to double by 2035, but overall copper demand is projected to increase 71% during that period.

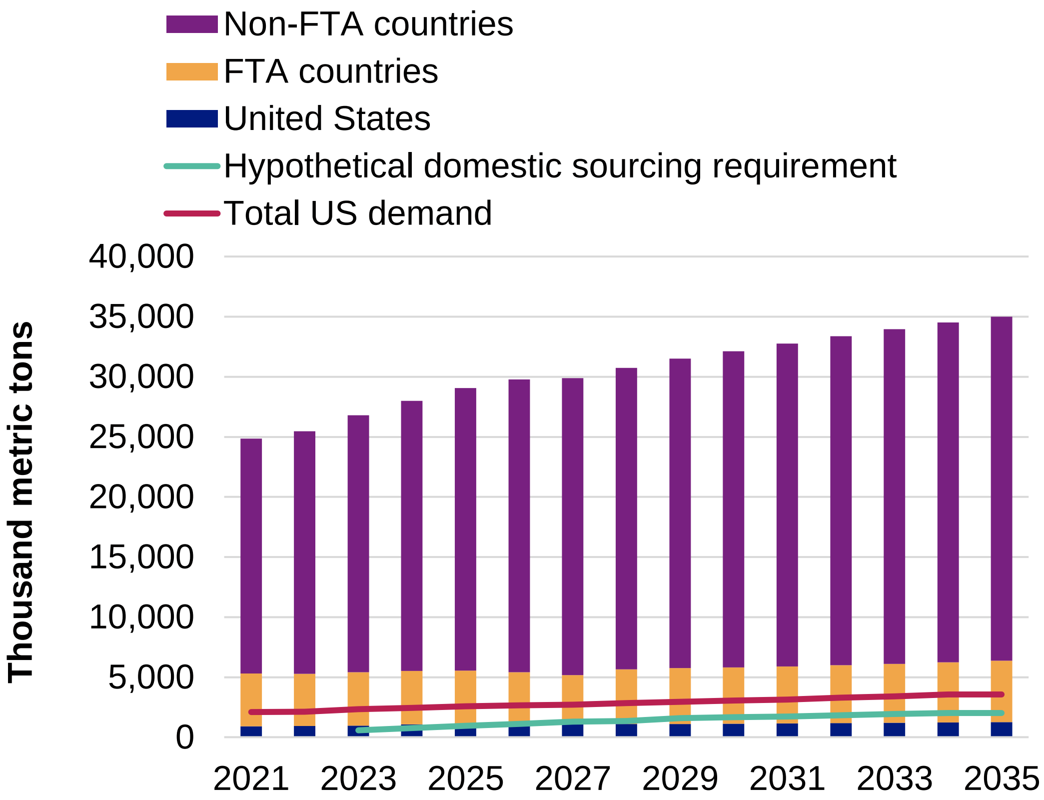
# While Chile and Peru are the key drivers of mined copper, China controls nearly half of refined copper supply

## Top countries for refined copper production




Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

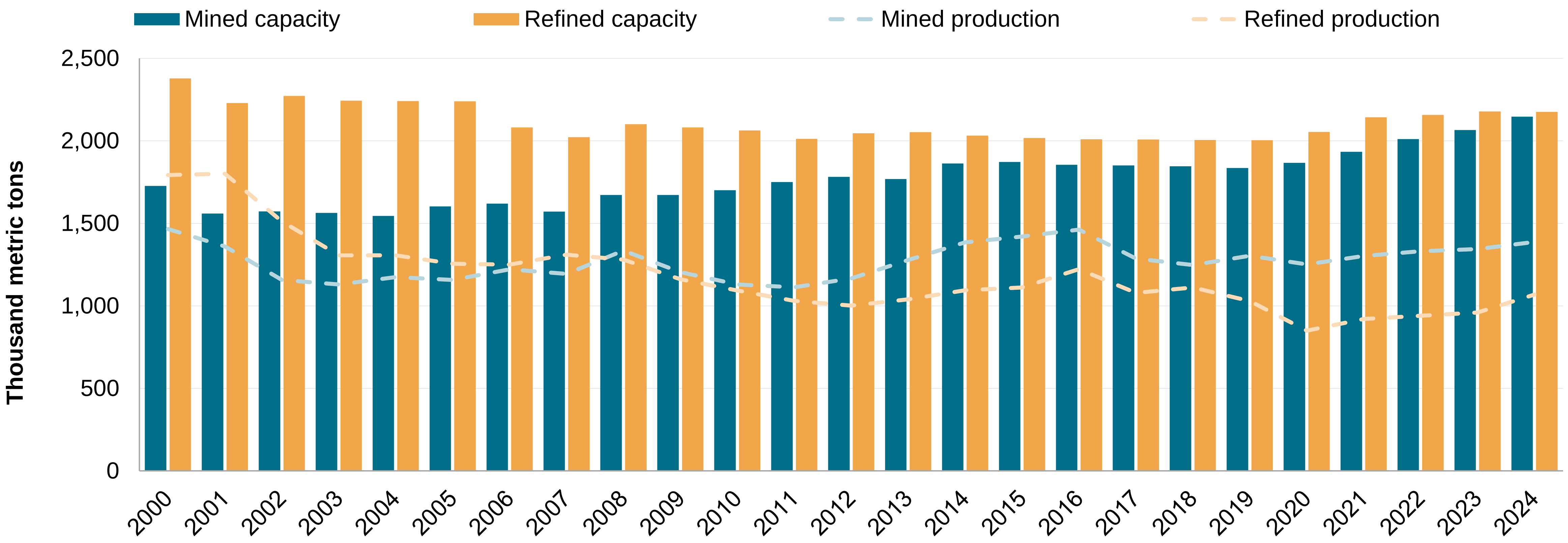
## Refined copper production by country grouping




Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

# US refining capacity and the number of smelters has fallen since 2000, while mined capacity has grown slowly; the decline in refined production means mined copper is exported rather than refined in the United States

## US copper capacity and production

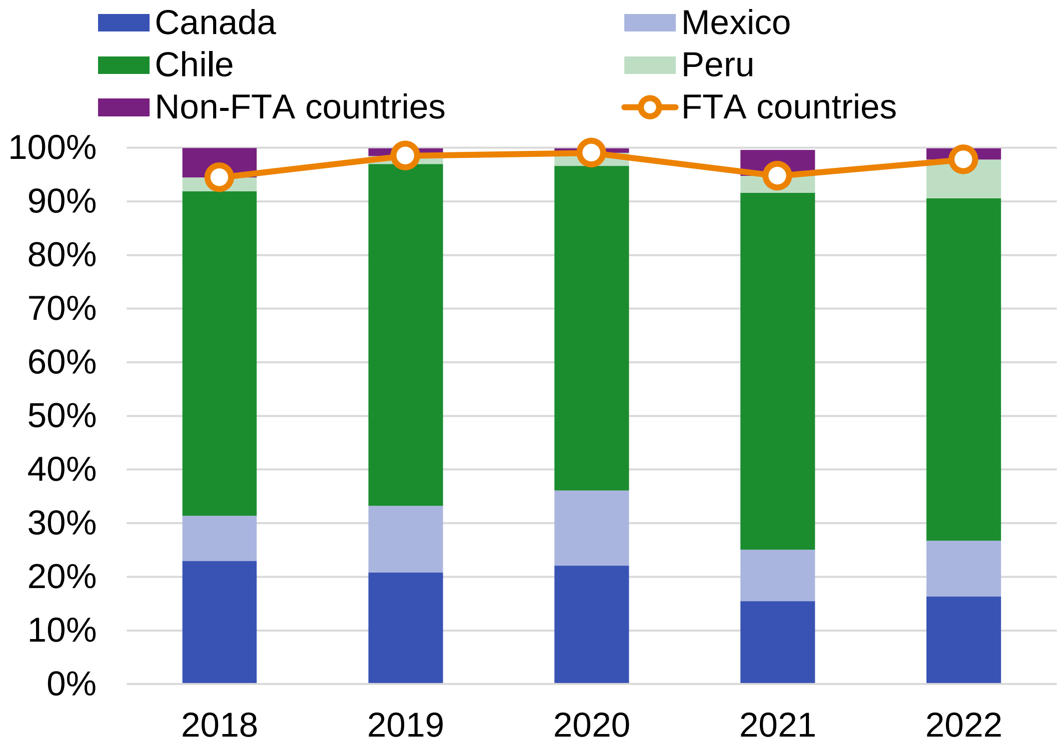



Data compiled Feb. 24, 2023.

Source: S&P Global Commodity Insights.

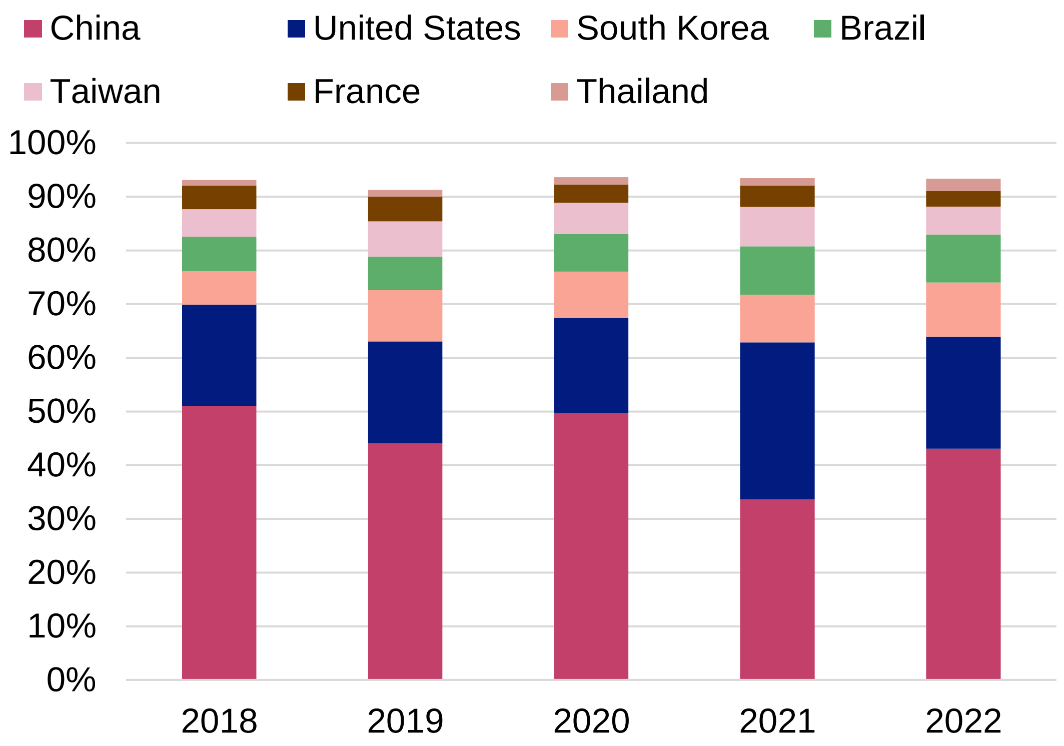
# The United States is reliant on Chilean imports to meet domestic copper demand, but the US represents a smaller share of Chilean exports

## Breakdown of US copper imports by source country




Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

## Breakdown of Chile copper exports by destination country




Data compiled Feb. 24, 2023.
Source: S&P Global Market Intelligence.

This asymmetric relationship means Chile has more bargaining power over the United States in their copper trade relationship, and that Chile may be more inclined to allocate new refined supply to China instead of the United States.

# Copper: Intensifying trade rivalries and increasing demand from other countries could threaten current trade patterns

- **There is no domestic sourcing requirement for copper.** Because copper is not listed as a critical mineral by the USGS, there is no domestic sourcing requirement for copper for energy transition applications. If there were, the United States would be reliant on imports to meet the requirement. Growing demand from energy-transition-related end markets is projected to outpace total US copper supply, meaning the US must rely on imports to meet overall copper demand.
- **The US is reliant on Chilean imports, but this relationship is not mutual.** The decline in US refined capacity has increased US reliance on imported refined copper. Chile represents roughly two-thirds of US refined copper imports. Meanwhile, the US makes up only about 20% of Chilean refined copper exports, while China's share is more than 40% of total exports. This imbalance means Chile holds substantial influence over the United States in copper trade.
- **Trade rivalries may threaten Chilean supply.** As copper demand increases globally, trade rivalries will intensify — especially if capacity additions cannot keep up with demand. China is the largest importer of Chilean copper. As demand increases globally and copper markets tighten, China has a better bargaining position than the US to secure Chilean supply, meaning the United States may struggle to secure enough supply to meet growing energy transition demand.
- **Permitting is just as important:** Adding both mining and refining capacity is the surest way for the United States to secure supply.

**Between the decline in refining capacity and a challenging permitting environment, the United States is reliant on imports to meet demand ambitions. An anticipated ramp-up in global demand means that trade rivalries will intensify, and supply from current trade partners is not guaranteed in the future.**

**Bottom line: Due to domestic permitting challenges and limited capacity additions, as well as rising trade rivalries, US access to copper could be at risk.**

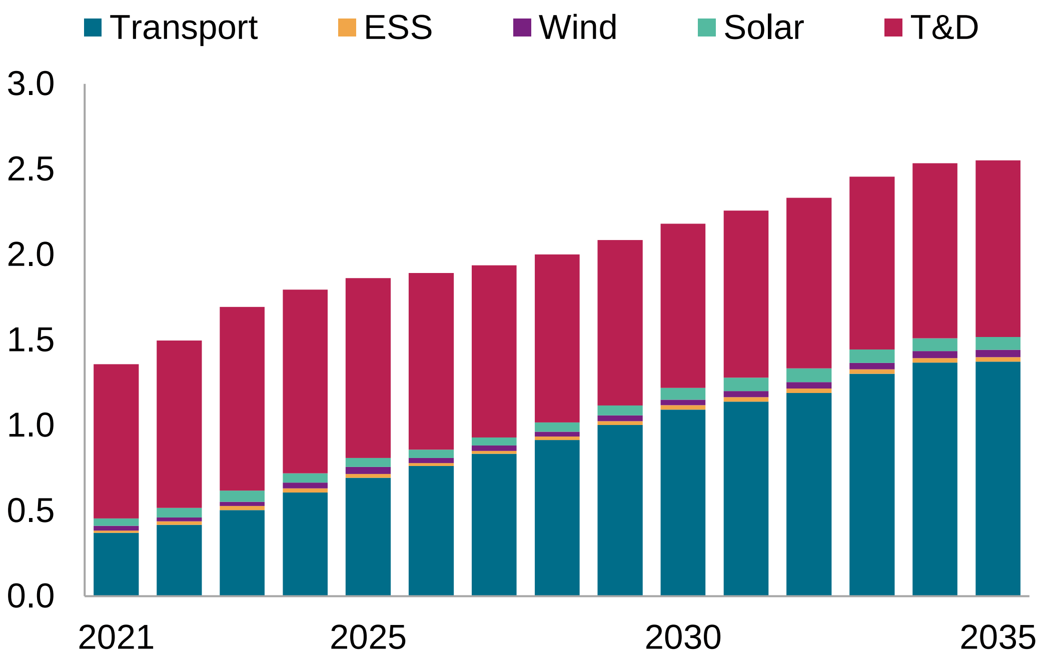
# Demand and sourcing summary: copper, lithium, cobalt and nickel

# Energy transition demand for Cu is expected to nearly double; demand for critical minerals is projected to grow by 23x

The accelerated shift to EVs and renewable generation capacity, spurred by the IRA, will likely be the main drivers of increased need for copper and critical minerals for energy transition demand

## US ET-related copper demand by sector

Million metric tons Cu



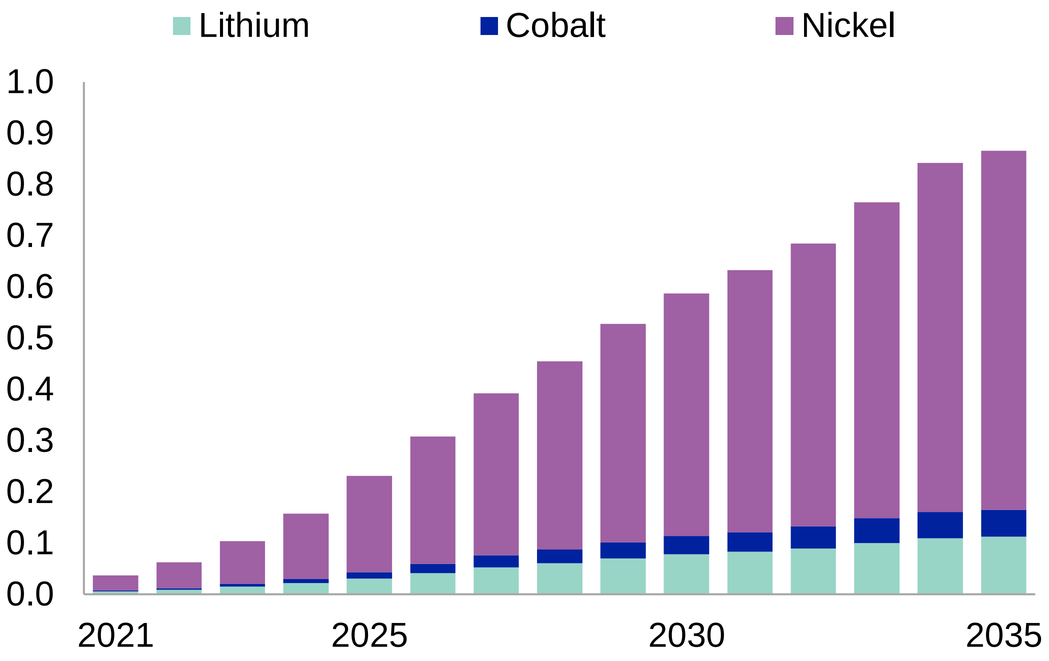

Data compiled February 2023.

Countries will be competing for the same copper supply as all countries shift toward more renewable energy capacity additions and electrification of their energy supply – this will further limit potential for supply availability.

Source: S&P Global Commodity Insights.

## US ET-related critical minerals consumption

Million metric tons metal




Data compiled February 2023.

Countries will be competing for the same supply as all countries shift toward more renewable energy capacity additions and electrification of their energy supply – this will further limit potential for supply availability.

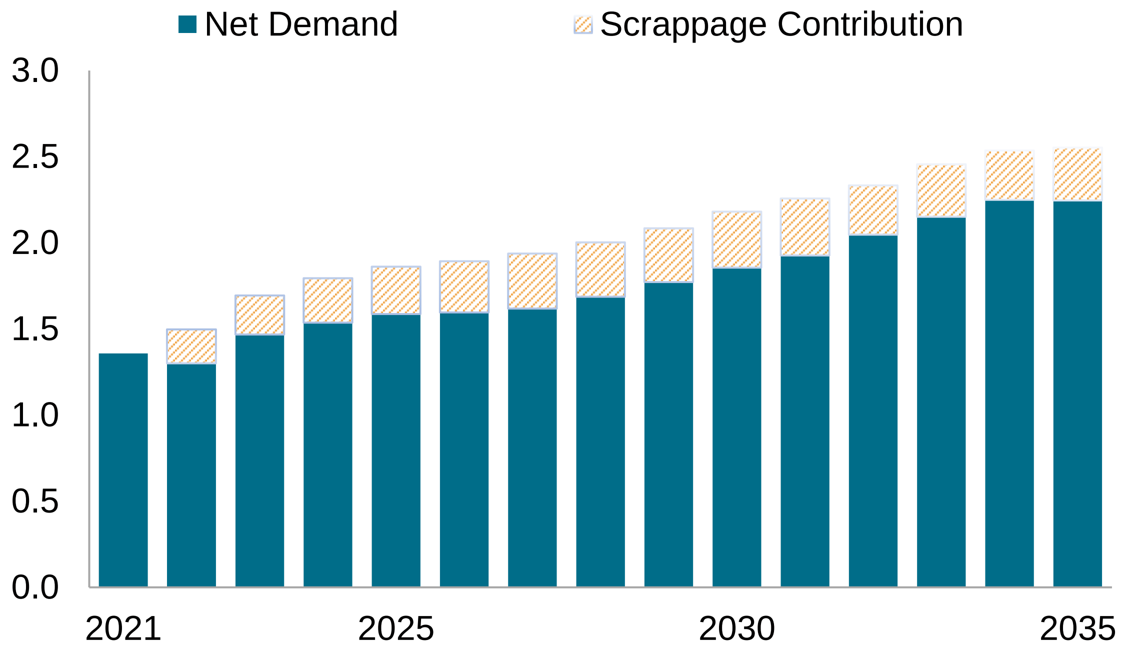
Source: S&P Global Commodity Insights.

# Overall, net demand for copper and critical minerals will continue to grow

While battery recycling and increased recycling of vehicles (for copper) partially reduce demand for metals, net demand is projected to grow by 3.7% and 25.3% annually for copper and critical minerals, respectively

## US ET-related copper demand (net of recycled Cu from vehicles)

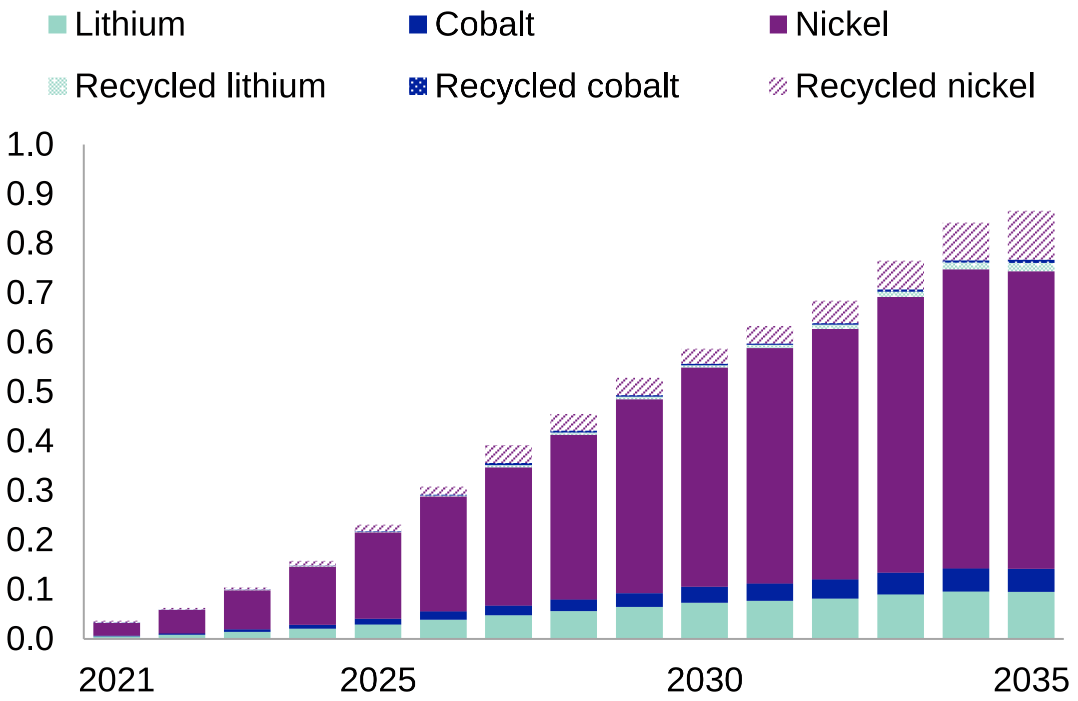
Million metric tons Cu




Data compiled February 2023.
Source: S&P Global Commodity Insights.

## US ET-related net critical minerals demand by metal

Million metric tons metal




Data compiled February 2023.
Source: S&P Global Commodity Insights.

# Overall, the IRA has a direct impact on demand for copper and critical minerals

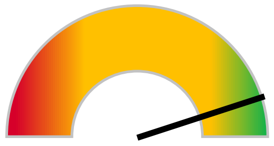
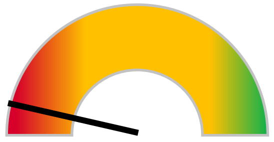
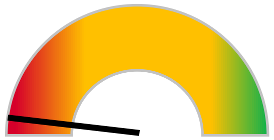
## Copper

- The direct IRA impact on copper demand for wind and solar energy is clear as tax credits directly impact the cost competitiveness of these technologies and accelerate renewable capacity additions, and so inherent demand for copper.
- IRA also clearly impacts energy storage systems capacity and hydrogen capacity, but the projected effect is more limited on actual copper demand.
- The direct IRA impact on EV batteries is harder to truly measure because part of the changing outlook is driven by OEMs' decisions to progressively shift production to EVs for regulatory and other reasons, not just the IRA.
- Copper demand in the United States is expected to double by 2035 as the energy transition accelerates (the IRA accelerates solar and wind capacity additions in the shorter term).

## Lithium, nickel and cobalt

- The IRA provides tax credits for EV sales, which will contribute to increased sales in the foreseeable future.
- The overall shift toward EVs and electrification of transport has a direct impact on increasing US lithium, nickel and cobalt consumption.
- Arguably, the most important impact of the IRA is its domestic sourcing requirements for battery manufacturing — these domestic sourcing requirements will pose a major supply challenge for the critical minerals as the full value chain needs to be developed outside China and other non-FTA/US jurisdictions.

# Sourcing for some critical minerals will be harder than for others

| Metal | Likeliness to meet domestic sourcing requirement through 2035 | Rationale |
|---|---|---|
| **Lithium** |  **Unlikely** **Likely** | Planned capacity additions in the United States are enough to meet domestic demand, but these could be stalled by permitting and social license concerns |
| **Cobalt** |  **Unlikely** **Likely** | Would require reorientation of trade patterns across several countries |
| **Nickel** |  **Unlikely** **Likely** | Not enough supply in FTA countries to meet US energy transition-related demand ambitions |

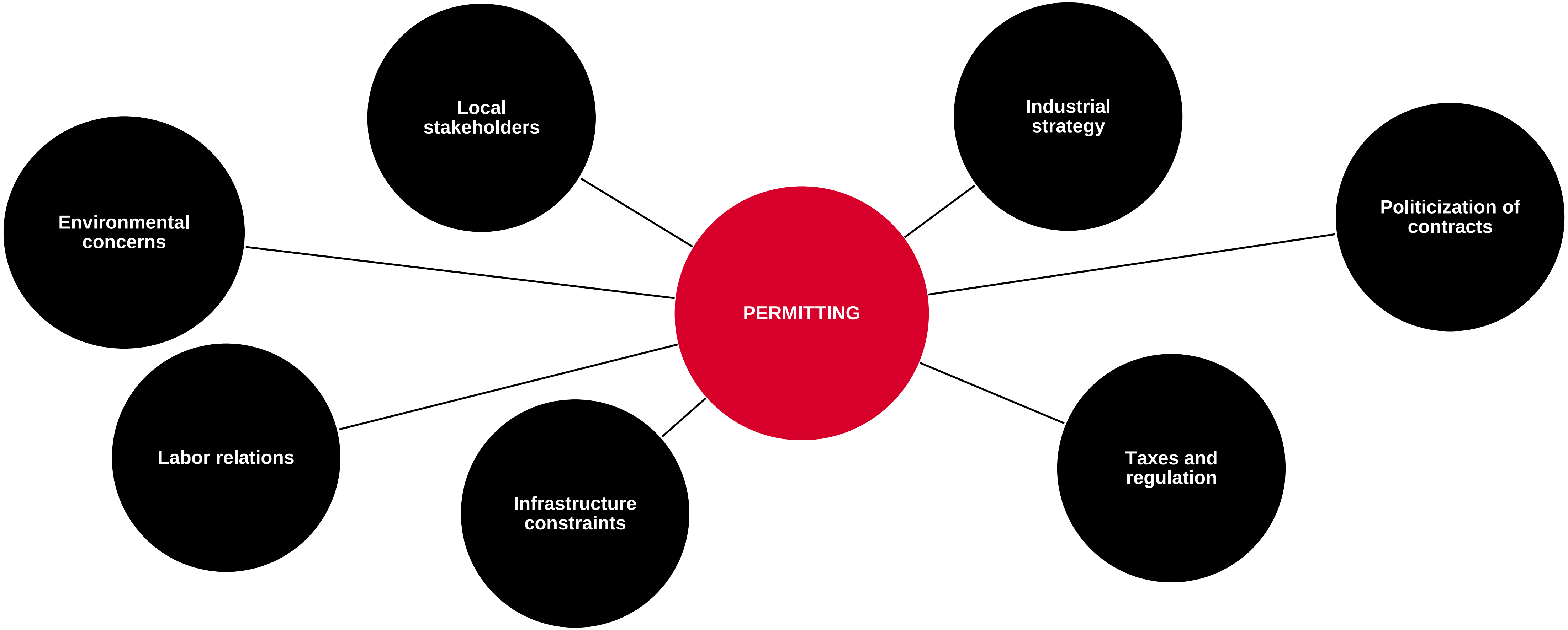
Given that copper is not currently designated a critical mineral, it does not have a domestic sourcing requirement. As such, it is not represented here.

# Operational challenges in North America

# Operational challenges: permitting as a central concern

The IRA privileges the US's North American neighbors, Canada and Mexico, via the United States-Mexico-Canada Agreement (USMCA). Under the IRA, at least 50% of battery components of electric vehicles seeking tax credits in the United States must be finally assembled in North America, and this rises to 100% by 2029. This has intensified interest in "reshoring" supply chains, including mining and processing minerals. In the North American environment, reshoring must meet a number of operational challenges. Central to these is the complexity of lengthy, multi-authority permitting processes and post-permit litigation risks. This challenge subsumed the others identified across 16 major mining and/or refining countries in *The Future of Copper*.

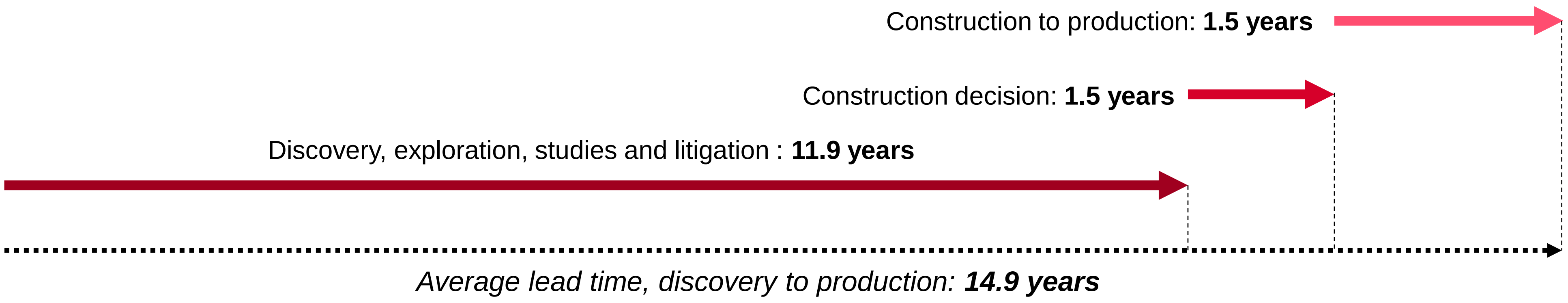
Note that we consider here only aboveground challenges; there are others as well, such as falling ore grades.



# Permitting: complexity and delays

Particularly in developed markets with high levels of transparency and both political and civil society scrutiny of policy, timely and transparent permitting is a fundamental operational challenge to supplying metals for the energy transition. The complicated interaction of federal, state and local laws; the wide range of authorities and regulatory bodies involved; the role of courts; and the range of issues from consultation with local communities to highway safety and water and hazardous waste management — all these add to the scale and complexity of permitting. The process can often take two decades or more and billions of dollars before the first production.

Associated litigation risks are similarly complex. The possibility of legal intervention during and after all stages of the permitting process is acute in countries with a highly developed, multilevel, multi-jurisdiction judiciary, with several opportunities for delays and injunctions, which can continue for six years after a permit is granted. This is especially so in the first two phases from initial discovery through to the construction decision, accounting for the longest duration. These factors can also apply in sourcing countries and are compounded by political uncertainty and intervention. According to S&P Global data on 127 mines across the world that began production between 2002 and 2023, a major new discovery today likely would not be a productive mine until 2040 or after. Furthermore, this is on average: large and complex projects in politically sensitive areas can take longer.




Source: S&P Global.
Based on 127 mines across the world, including for copper, gold, nickel, silver and zinc.

# Permitting: new urgency post-IRA

Post-IRA, we project a 23% increase in demand for EV battery capacity in the United States in 2035, implying additional demand for cobalt, nickel and lithium of 13%-15%. There will likely be a similar increase in US demand for copper across all its energy-transition-related applications. (See *Demand Requirements* section).

But lead times for new mining projects have extended dramatically over recent decades. A 1956 US Bureau of Mines report stated that copper mines may take as long as "three to four years" to construct and deliver product — a process that would have included permitting along with everything else. Today, the permitting process alone can take 7-10 years. The result can extend total project time from discovery to production for 20 years or more — half or more of a professional's entire career. Growing activism around environmental issues and local populations add to the risk of delay in both mature and emerging economies.

Expediting permitting processes could attract capital, accelerate execution and reduce uncertainty as the IRA boosts demand for energy transition applications. The June 2023 debt ceiling legislation (the Fiscal Responsibility Act of 2023) includes what are described "modest," but not "major," permitting reforms to the National Environmental Policy Act. It sets time limits for environmental assessments (one year) and environmental impact statements (two years) — although that time can be extended. There also limits on the number of pages — a maximum of 300 pages for environmental impact statements. Project sponsors can challenge agency delays in court and can prepare environmental impact statements rather than depending on the strained resources of agencies.[1]

**13%**

Post-IRA, additional projected US demand for **cobalt** for EV batteries and vehicles in 2035

**14%**

Post-IRA, additional projected US demand for **nickel** for EV batteries and vehicles in 2035

**15%**

Post-IRA, additional projected US demand for **lithium** for EV batteries and vehicles in 2035

**12%**

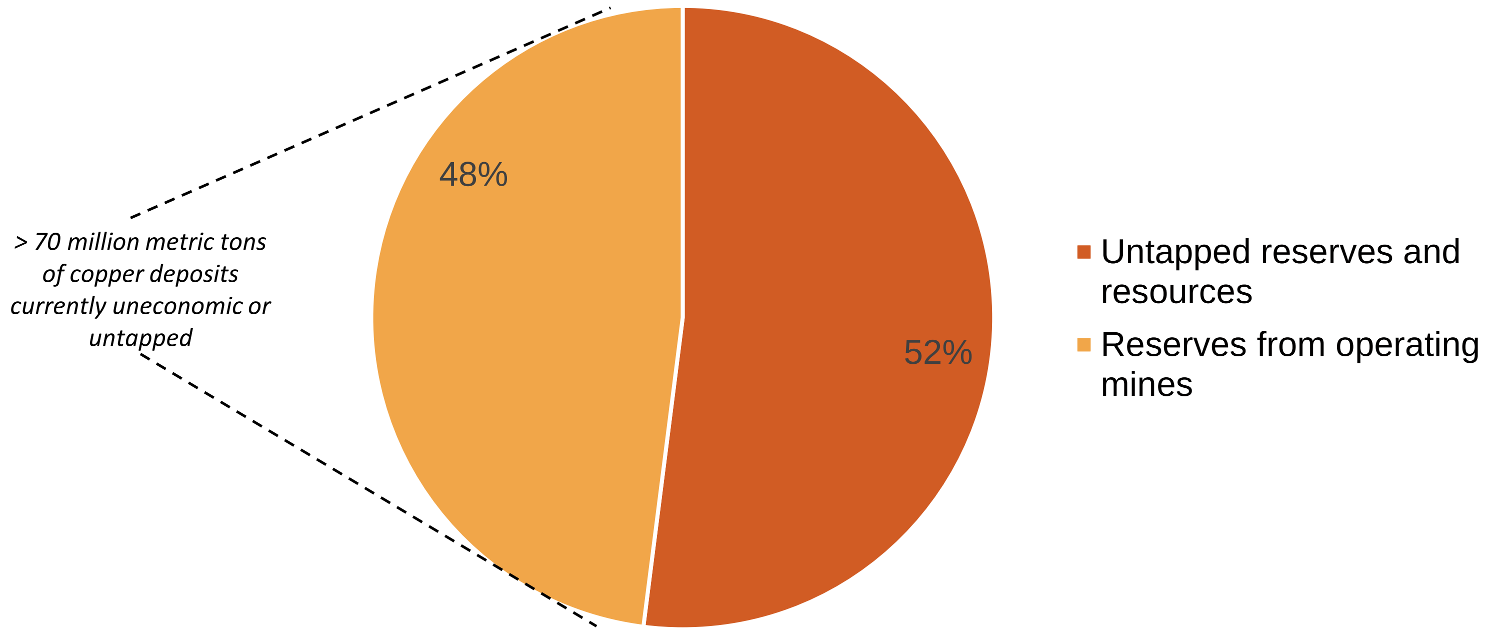
Post-IRA, additional projected US demand for **copper** across all energy-transition-related applications in 2035

[1]Vinson & Elkins, *President Biden Signs Modest Permitting Reforms into Law with the Debt Ceiling Bill*, June 7, 2023, accessed 12 June 2023: https://www.velaw.com/insights/president-biden-signs-modest-permitting-reforms-into-law-with-the-debt-ceiling-bill/.

# Permitting: the US's copper opportunity

- Copper, especially, offers a substantial opportunity in the United States. The country has over 70 million metric tons of untapped copper reserves and resources that could be developed on top of production from existing operating mines.
- This 70 million metric tons of uneconomic or untapped copper represents three times the average global primary copper production in 2023 (~23 million metric tons). For the US itself, it would satisfy more than 20 years of copper demand, even at the level projected for 2035, once energy-transition-related demand has peaked.
- Reserves and resources from the five largest projects not yet operating account for over 54% of the 70 million metric tons of copper deposits, with a number of these awaiting permitting.
- Apart from permitting, other challenges such as social license to operate and infrastructure constraints can inhibit or prevent this supply from coming into production. This means some of the untapped projects are at least 3-4 years from first production of concentrate (for large-scale developments) and further still from reaching run-rate production levels.
- These deposits could also contribute to producing additional critical minerals such as molybdenum, nickel, cobalt or precious metals.

## US primary copper mine reserves and resources by status



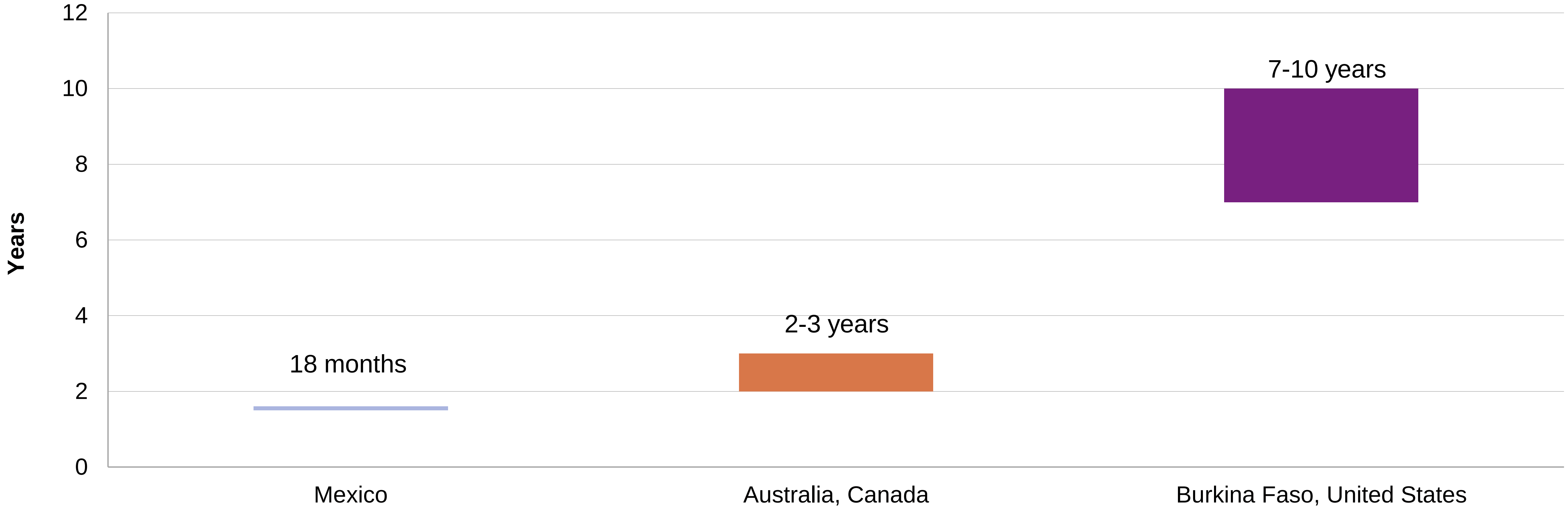

Data compiled April 2023.

Untapped reserves and resources were calculated based on probabilistic assumptions for deposits by development status. Measured recoverable reserves were unrisked. Measured resources risked at 40% probability; inferred resources at 20% probability to approximate conversion to recoverable reserves. Top 5 largest projects not in operation include projects in permitting stage, pre-feasibility, feasibility and pre-production phase.

Source: S&P Global Commodity Insights.

# Permitting takes 7-10 years on average in the United States — longer than many other countries

**Mining permitting process timeline for select countries**




Data compiled June 9, 2023.

Testimony of Mitch Krebs to the House Energy and Mineral Resources subcommittee on July 20, 2017.

Source: National Mining Association.

# Unrisked mines and reserves & resources in the United States by mineral and stage

## Mines in the United States by mineral and stage

| Status | Cobalt | Copper | Lithium | Nickel |
|---|---|---|---|---|
| Operating | 0 | 25 | 2 | 1 |
| Pre-production and feasibility | 1 | 8 | 9 | 0 |
| Possible | 8 | 112 | 72 | 5 |

## US reserves and resources by mineral and stage, thousands of metric tons

| Status | Cobalt | Copper | Lithium | Nickel |
|---|---|---|---|---|
| Operating | 0 | 104,956 | 0 | 73 |
| Pre-production and feasibility | 25 | 91,514 | 26,652 | 218 |
| Possible | 28 | 41,206 | 13,363 | 0 |

Preproduction and feasibility = preproduction, construction planned or construction stage, commissioning, feasibility complete or started

Possible = reserves development, advanced exploration, exploration, prefeasibility/scoping, late-stage, target outline

Data compiled from S&P Capital IQ PRO: June 9, 2023.

Source: S&P Global Market Intelligence, S&P Global Commodity Insights.

# Unrisked mines and reserves & resources in Canada by mineral and stage

## Mines in Canada by mineral and stage

| Status | Cobalt | Copper | Lithium | Nickel |
|---|---|---|---|---|
| Operating | 0 | 6 | 3 | 1 |
| Pre-production and feasibility | 1 | 5 | 5 | 6 |
| Possible | 30 | 306 | 74 | 125 |

## Canada reserves and resources by mineral and stage, thousands of metric tons

| Status | Cobalt | Copper | Lithium | Nickel |
|---|---|---|---|---|
| Operating | 0 | 12,795 | 944 | 1,856 |
| Pre-production and feasibility | 74 | 7,257 | 2,574 | 11,965 |
| Possible | 1 | 34,838 | 15,782 | 15,647 |

Preproduction and feasibility = preproduction, construction planned or construction stage, commissioning, feasibility complete or started
Possible = reserves development, advanced exploration, exploration, prefeasibility/scoping, late-stage, target outline

Data compiled from S&P Capital IQ PRO: June 9, 2023.
Source: S&P Global Market Intelligence, S&P Global Commodity Insights.

# Unrisked mines and reserves & resources in Mexico by mineral and stage

## Mines in Mexico by mineral and stage

| Status | Cobalt | Copper | Lithium | Nickel |
|---|---|---|---|---|
| Operating | 0 | 11 | 0 | 0 |
| Pre-production and feasibility | 0 | 5 | 1 | 0 |
| Possible | 0 | 27 | 5 | 0 |

## Mexico reserves and resources by mineral and stage, thousands of metric tons

| Status | Cobalt | Copper | Lithium | Nickel |
|---|---|---|---|---|
| Operating | 0 | 22,336 | 0 | 0 |
| Pre-production and feasibility | 0 | 20,584 | 3,562 | 0 |
| Possible | 0 | 11,860 | 98 | 0 |

Preproduction and feasibility = preproduction, construction planned or construction stage, commissioning, feasibility complete or started

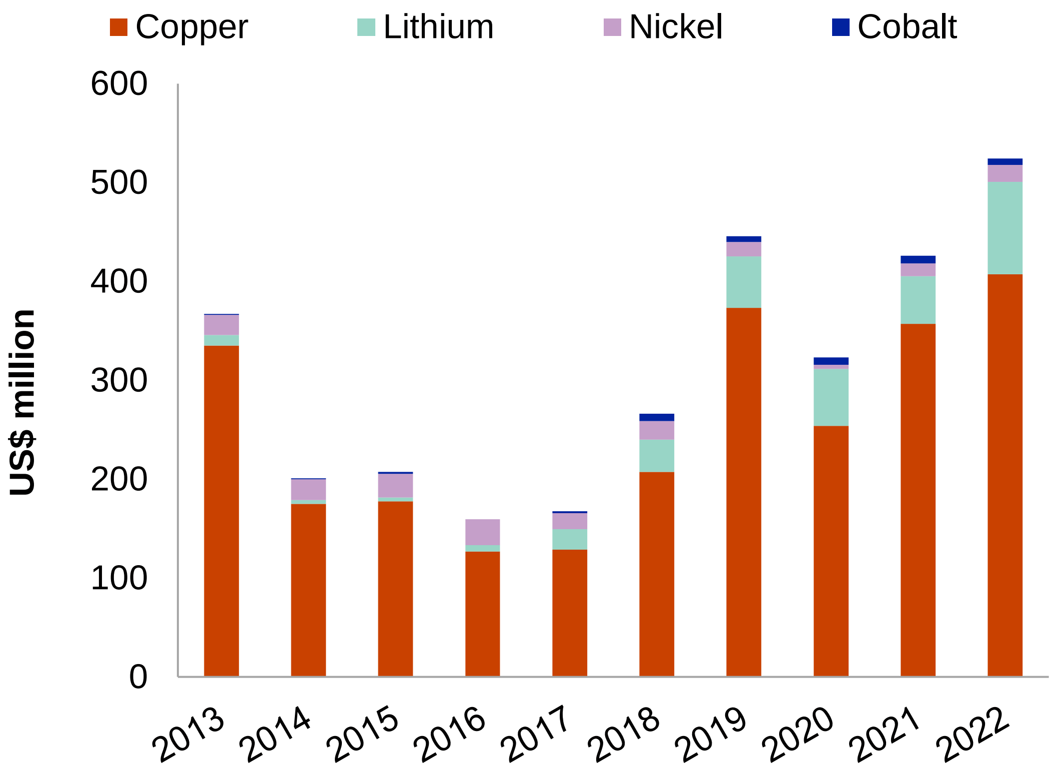
Possible = reserves development, advanced exploration, exploration, prefeasibility/scoping, late-stage, target outline

Data compiled from S&P Capital IQ PRO: June 9, 2023.

Source: S&P Global Market Intelligence, S&P Global Commodity Insights.

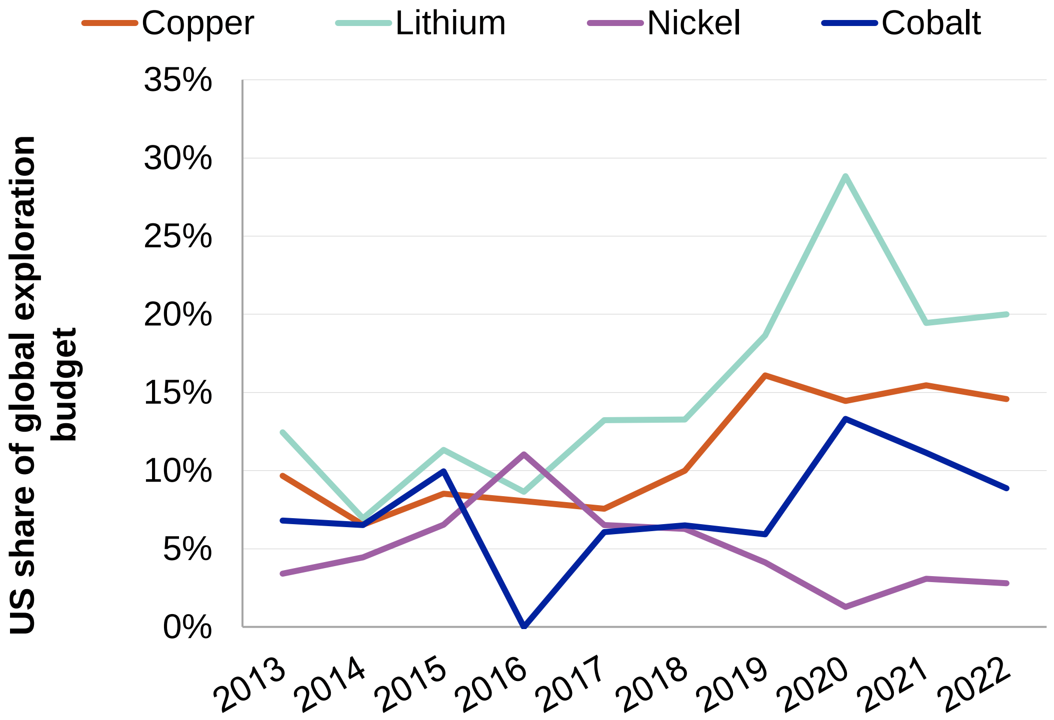
# Copper dominates US mining exploration budgets, but lithium exploration is rising

## US mining exploration budget by mineral




Data compiled June 9, 2023.
Source: S&P Global Market Intelligence.

## US share of global mining exploration budgets by mineral




Data compiled June 9, 2023.
Source: S&P Global Market Intelligence.

## Securing supply: the US's "permitting pandemic" (1)

- There is widespread recognition across the US political spectrum that permitting has become a huge stumbling block for the development of US energy projects — from offshore wind to natural gas pipelines.
    - It will likely be a major constraint on developing minerals for energy transition, too.
- Challenges vary depending on the jurisdiction.
    - On private or state lands, permitting is generally more predictable, with a relatively clear path for approval.
    - On federal lands, permitting is characterized by delays, unpredictability and increasing costs.
        - This is a major constraint because federal government lands comprise almost half of the total terrain of the 11 mineral-rich western states.
- Moreover, the up-front costs for hard rock mining are much greater than for other kinds of energy projects.

# Securing supply: the US's "permitting pandemic" (2)

Mine development consists of the following three phases:

1) A detailed plan of operations must be submitted to the federal agency, which, if satisfied, will issue a completeness determination (i.e., a complete plan of operations or a complete permit application has been submitted). This can take **two to three years.**
2) Then, required processes under the National Environmental Policy Act that produce an environmental impact statement can begin. This can take **five to seven years.**
   a) This phase involves several federal agencies including the Bureau of Land Management, the Forest Service, the US Army Corps of Engineers and the Fish and Wildlife Service.
   b) These agencies may ask for revisions of the environmental impact statement.
   c) The process faces several institutional hindrances, including overworked and inadequate staffing in agencies and the federal register notification process.
3) Once federal agencies have made their determination to issue a permit, legal challenges may arise. These typically take **three to eight years** to resolve. There may be:
   a) Judicial challenges to agency determination.
   b) Challenges regarding the applicability of conflicting case law.
   c) Variability in approach among courts — in terms of courts of appeal, "your panel is your destiny."

As a result, the permitting process is not only challenging and time-consuming, but also unpredictable.

# Appendix A

# Methodology

# Automotive demand (1) – copper

For the automotive sector, S&P Global conducted a bottom-up analysis of copper content in the components of different powertrains. The following powertrains were analyzed:

- Internal combustion engine vehicles (ICEVs)
- Battery electric vehicles (BEV)
- Hybrid electric vehicles (HEV)
- Plug-in hybrid electric vehicles (PHEV)
- Fuel-cell electric vehicles (FCEV)

Copper is present both in the harness of a vehicle and in the electric motors (e-motors). Copper intensity estimates were developed for each component.

- For harnesses: estimates were made for three price levels: entry, midrange and premium cars to reflect the increased number of electronic features and varying degrees of copper wiring in high-end cars.
- For e-motors: the copper intensity of each type of motor was estimated.

The figure provides a summary of copper intensity assumptions by component.

## Copper intensity assumptions by component: Automotive

| Harness | |
|---|---|
| **Price class 1 (entry)** | 14 kg/vehicle |
| **Price class 2 (mid)** | 19 kg/vehicle |
| **Price class 3 (premium)** | 24 kg/vehicle |

| e-motor (EVs and hybrids only) | |
|---|---|
| **IPM and AFPM** | 0.02-0.04 kg/kW |
| **IM, CEWRSM, CPSM** | 0.16-0.17 kg/kWh |
| **SPM** | 0.9 kg/kW |

Results are based on data available at the time of analysis, February 2022.
IPM = interior permanent magnet; AFPM = axial flux permanent magnet; IM = induction motor; CEWRSM = current-excited wound rotor synchronous motor; CPSM = claw-pole synchronous motor; SPM = surface-mounted permanent magnet.
Sources: S&P Global analysis, A2Mac1 Teardown data – harnesses and motors.

# Automotive demand (2) – copper

In addition, potential copper intensity reduction was modeled based on technological evolution and efficiency improvements.

In particular, composite adoption in collectors could lead to the replacement of a share of copper in batteries.

In harnesses, wire gauge will remain a barrier of substitution to aluminum. Aluminum cables require a larger cross-section for the same specifications, which poses an issue for vehicles.

Composite adoption in new vehicles will have a larger impact as it results in a significant reduction of copper requirements in battery collectors.

In this study, a 14% penetration of composite in collectors by the end of the period was assumed.

**Non-battery-pack copper content by vehicle**

| (kg/vehicle) | 2022 | 2030 | 2035 |
|---|---|---|---|
| **BEV** | 35.69 | 33.17 | 31.61 |
| **FCEV** | 25.20 | 25.24 | 27.04 |
| **FHEV** | 42.28 | 41.09 | 45.58 |
| **PHEV** | 42.28 | 41.09 | 45.58 |
| **MHEV** | 23.12 | 24.61 | 24.13 |
| **HEV** | 32.70 | 32.85 | 34.86 |
| **ICEV and other** | 15.85 | 15.56 | 15.52 |

**Source: S&P Global Commodity Insights.**



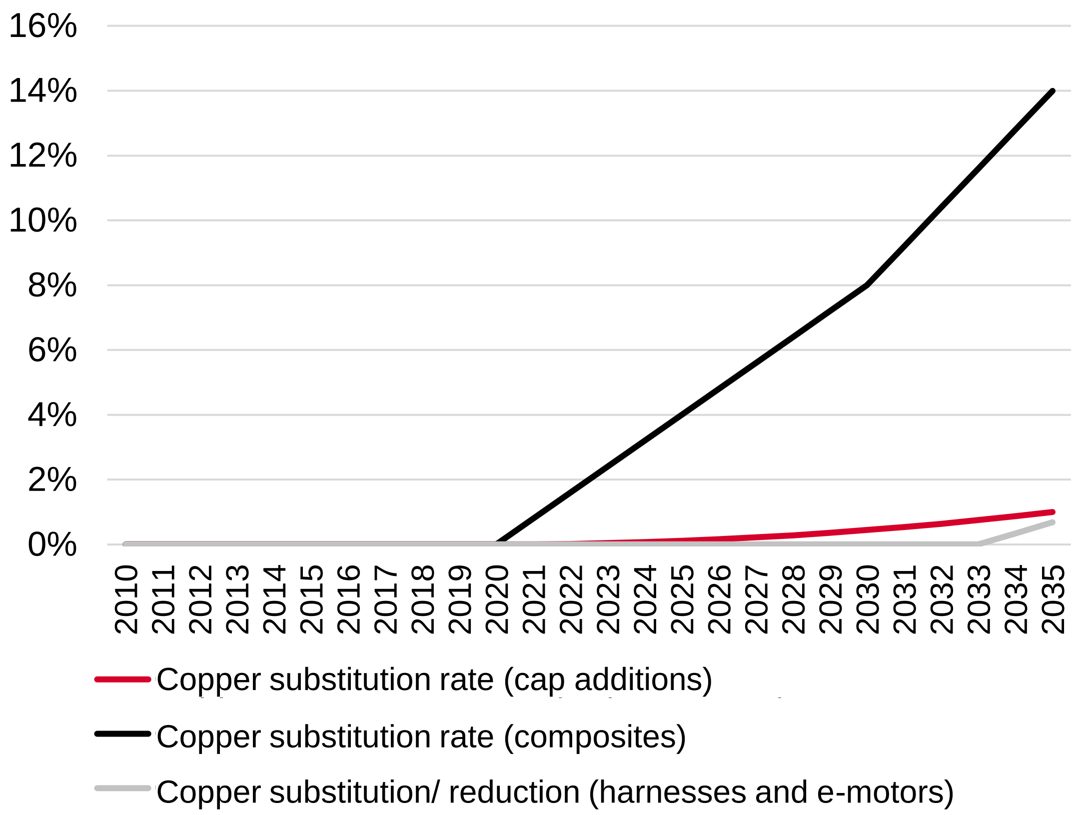
**Copper content in battery by chemistry**

| (kg/kWh) | 2022 | 2030 | 2035 |
|---|---|---|---|
| **LCO** | 0.83 | 0.77 | 0.77 |
| **LFP** | 1.02 | 0.95 | 0.95 |
| **LMO** | 0.83 | 0.77 | 0.77 |
| **LMNO** | 0.84 | 0.79 | 0.79 |
| **NCA80** | 0.83 | 0.77 | 0.77 |
| **NCA90** | 0.58 | 0.55 | 0.55 |
| **NMC333** | 0.83 | 0.77 | 0.77 |
| **NMC532** | 0.83 | 0.77 | 0.77 |
| **NMC622** | 0.63 | 0.59 | 0.59 |
| **NMC811** | 0.62 | 0.58 | 0.58 |
| **NMCA** | 1.67 | 1.56 | 1.56 |

**Source: S&P Global Commodity Insights.**



## Copper substitution assumptions




Data compiled June 2022.
Source: S&P Global Commodity Insights.

# Solar PV intensity demand assumptions (1) – copper

For solar PV, a bottom-up analysis of copper intensity per megawatt of installed capacity was conducted. Solar PV systems were broken down in the following subcomponents containing copper:

- PV cell tabbing and interconnection ribbon
- PV module cables and connectors (4-square-milimeter [mm2] cables)
- PV plant array cable (16 mm2 cables)
- PV plant field cable (50 mm2 cables)
- Inverters
- Step-up transformers

For each of these subcomponents, a range of existing academic literature, technical specifications from suppliers, and industry sources, as well as conversations with inverter suppliers and engineering, procurement, and construction (EPC) developers were relied upon to validate the findings.

The figure provides a summary of copper intensity by component for current (2020) solar PV installations.

## Copper intensity assumptions by component: Solar PV

| | |
|---|---|
| **PV cell tabbing and interconnection ribbon** | 550 kg/MW |
| **PV module cables and connectors (4 $mm^2$)** | 117 kg/MW |
| **PV plant array cable (16 $mm^2$)** | 261 kg/MW |
| **PV plant field cable (50 $mm^2$)** | 419 kg/MW |
| **Inverters** | 70 kg/MW (utility scale)<br>450 kg/MW (non-utility scale) |
| **Step-up transformers** | 820 kg/MW (average 2020)<br>1,320 kg/MW (utility scale) |
| **Total (excl. transmission)** | 2,290 kg/MW |

Results are based on data available at the time of analysis, February 2022.
Analysis, primary and secondary research including private conversations with inverter suppliers and engineering, procurement, and construction developers.
Source: S&P Global.

# Solar PV intensity demand assumptions (2) – copper

Based on the analyses and observed historical trends, continuous efficiency improvements (including substitution, when appropriate) were assumed for each of the modules.

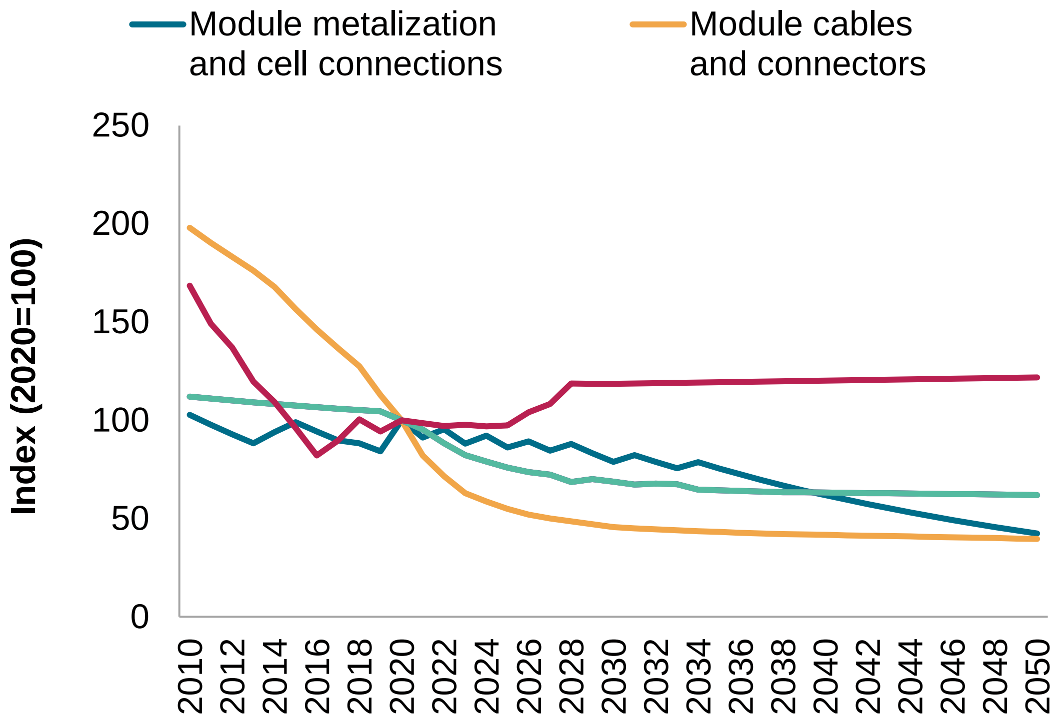
The decreasing amount for copper demand is mainly driven by technological improvements, such as increasing power (efficiency) per module, larger-size modules and new designs of split junction boxes to the sides of the panel.

In utility-scale solar PV installations, optimized systems using multiple panels in a string will require fewer wiring cables in the field. Increasing efficiency in panels with a rising share of N-type products and bifacial technology will offset increased copper usage in wires.

The figure provides the evolution of copper intensity for each component from the year estimates.

Finally, copper intensity of inverters varies significantly between utility-scale and residential or commercial installations when estimated on an installed capacity basis. Utility-scale solar PV inverters are about 70 kg/MW as opposed to residential/commercial solar PV inverters at 450 kg/MW.

## Solar PV copper intensity efficiency improvement by component




Data compiled June 2022.

Source: S&P Global Commodity Insights.

# Wind intensity demand assumptions (1) – copper

For wind-generation technologies, onshore and offshore wind have very different copper intensities, owing to the technologies used in the turbines, as well as the need for long transmission lines to shore for offshore wind.

For onshore wind, life-cycle assessments published by Vestas were relied upon. The table provides a summary of copper intensity for the selected life-cycle assessments of various onshore wind plants between 2015 and 2020.

Onshore wind relies mostly on doubly fed induction generators with a gearbox (GB-DFIG), with permanent magnet synchronous generators (PMSG) comprising only about 20% of capacity additions.

Offshore wind, on the other hand, relies primarily on direct-drive (DD) PMSG turbines, which have a much higher copper intensity.

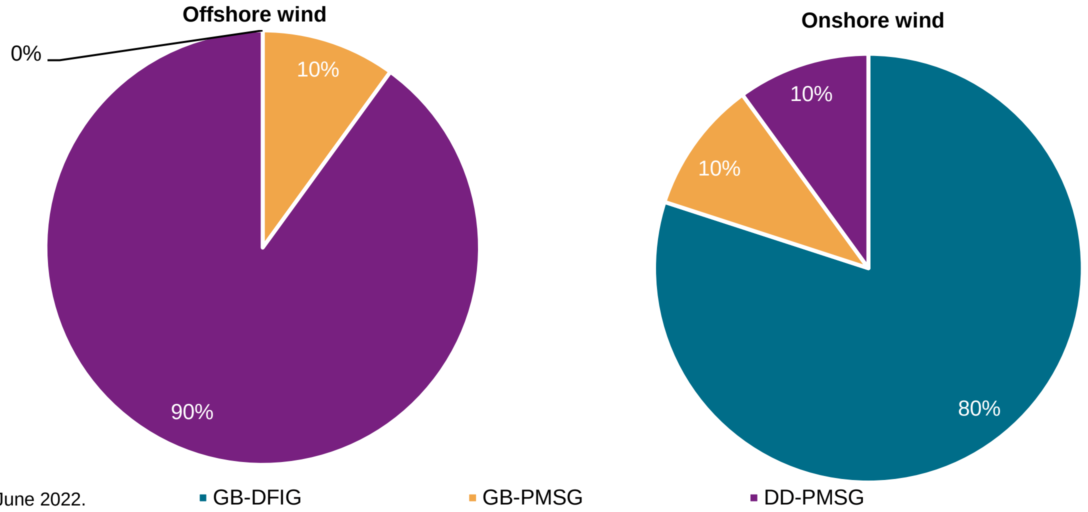
The graphs provide an overview of capacity additions assumptions by turbine types.

## Copper use across various turbines (Vestas reports)

| | | | | Copper requirements (per wind farm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Turbine size** | **Report date** | **Recycling rate** | **Wind farm size** | **Turbines** | **Foun-dations** | **Site cables** | **Switch-gears** | **Trans-former** | **Number of turbines** | **Total** | **Turbines only** | **Total without site cables** | **Site cables** |
| **MW** | | **%** | **MW** | **Metric tons** | **Metric tons** | **Metric tons** | **Metric tons** | **Metric tons** | | **kg/MW** | **kg/MW** | **kg/MW** | **kg/turbine** |
| 2 | Dec-15 | 92% | 50 | 28 | 1 | 41 | 2 | 11 | 25 | 1660 | 560 | 840 | 1640 |
| 2 | Dec-18 | 92% | 50 | 49 | 1 | 41 | 2 | 11 | 25 | 2080 | 980 | 1260 | 1640 |
| 2 | Dec-15 | 92% | 50 | 30 | 1 | 41 | 2 | 11 | 25 | 1700 | 600 | 880 | 1640 |
| 3.3 | Jun-14 | 92% | 100 | 61 | 1 | 44 | 2 | 8 | 30 | 1160 | 610 | 720 | 1452 |
| 3.45 | Jul-17 | 92% | 100 | 92 | 1 | 43 | 2 | 8 | 29 | 1460 | 920 | 1030 | 1484 |
| 4.2 | Nov-19 | 92% | 100 | 83 | 1 | 40 | 2 | 8 | 24 | 1340 | 830 | 940 | 1680 |
| 4.2 | Nov-19 | 92% | 100 | 83 | 1 | 40 | 2 | 8 | 24 | 1340 | 830 | 940 | 1680 |
| 4.2 | Nov-19 | 92% | 100 | 89 | 1 | 40 | 2 | 8 | 24 | 1400 | 890 | 1000 | 1680 |
| 4.2 | Mar-22 | 92% | 100 | 89 | 1 | 40 | 2 | 8 | 24 | 1400 | 890 | 1000 | 1680 |

Source: S&P Global Commodity Insights, Vestas Life Cycle Assessment of electricity production from an onshore wind plant (models: V112-3.3 MW, V105-3.3 MW, V117-3.45 MW, V117-4.2 MW, V136-4.2 MW, V150-4.2 MW).

### Wind turbine type distribution assumptions




Data compiled June 2022.

Note: GB-DFIG = doubly fed induction generators with a gearbox; GB-PMSG = permanent magnet synchronous generators with a gearbox; DD-PMSG = direct-drive permanent magnet synchronous generators.

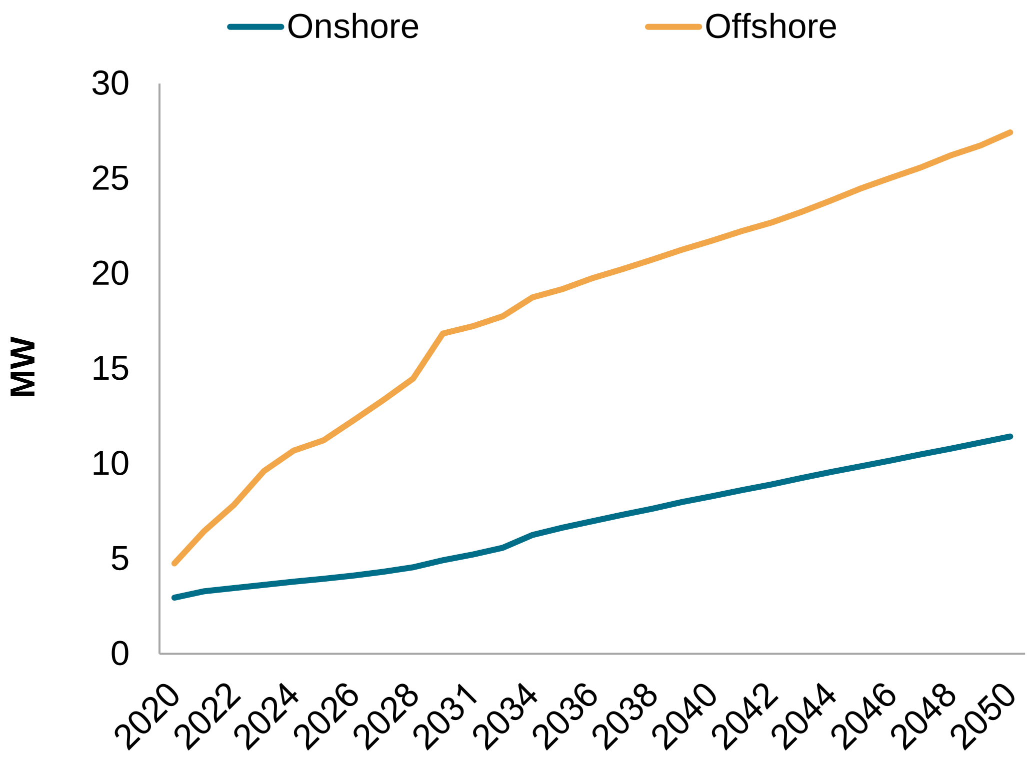
Source: S&P Global Commodity Insights.

# Wind intensity demand assumptions (2) – copper

Turbine size has been steadily increasing with technological evolution. That trend is expected to continue with onshore turbine size going above 10 MW in the mid-2040s and offshore turbines reaching close to 30 MW. This turbine size increase will decrease copper intensity per megawatt of installed capacity.

As the best locations are progressively taken, offshore wind farms will be installed increasingly farther from shore. The weighted average distance to shore is projected to increase from about 22 km in 2020 to 64 km in 2050 for bottom-fixed installations and from 50 km to 120 km for floating installations over the same period. Mechanically, this will increase the copper required for subsea transmission lines. The copper intensity of lines is estimated at approximately 44 kg/(km x MW).

**Evolution of turbine capacity**




Data compiled June 2022.

Source: S&P Global Commodity Insights.

# Battery storage demand – copper

Copper intensity in battery storage technologies varies primarily based on the energy density of each technology. The key battery storage technologies currently in the market are:

- Lithium-iron-phosphate batteries (LFP)
- Nickel-manganese-cobalt (NMC) 622 and 811
- Nickel-cobalt-aluminum oxides (NCA)
- Nickel-manganese-cobalt-aluminum (NMCA)
- Lithium-nickel-manganese oxide (LNMO)

Owing to a lower energy density, LFP batteries have the highest copper intensity per kilowatt-hour of capacity. The assumptions are derived from the Greet2 model developed by Argonne National Laboratories.

The table provides the underlying copper intensity assumptions for battery storage by technology.

## Copper intensity assumptions by technology: Battery storage

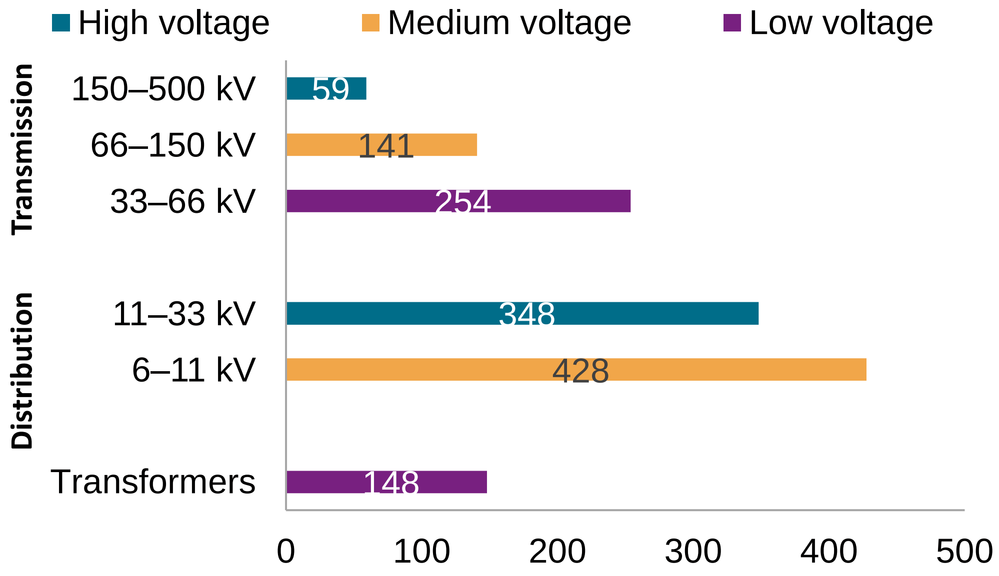
| | |
|---|---|
| **LFP** | 1.05 kg/kWh |
| **LNMO** | 1.00 kg/KWh |
| **NMC 622** | 0.65 kg/KWh |
| **NMC 811** | 0.64 kg/KWh |
| **NCA** | 0.60 kg/KWh |

Results are based on data available at the time of analysis, February 2022.
LFP = lithium iron phosphate batteries; NMC = nickel manganese cobalt 622 and 811; NCA = lithium nickel cobalt aluminum oxides; LNMO = lithium-nickel-manganese oxide.
Sources: Argonne National Labs, Greet2 model.

# Transmission and distribution demand (1) – copper

## Copper demand in transmission and distribution systems

kg copper (Cu) per km and MW (T&D) and kg copper (Cu) per MVA (transformers)

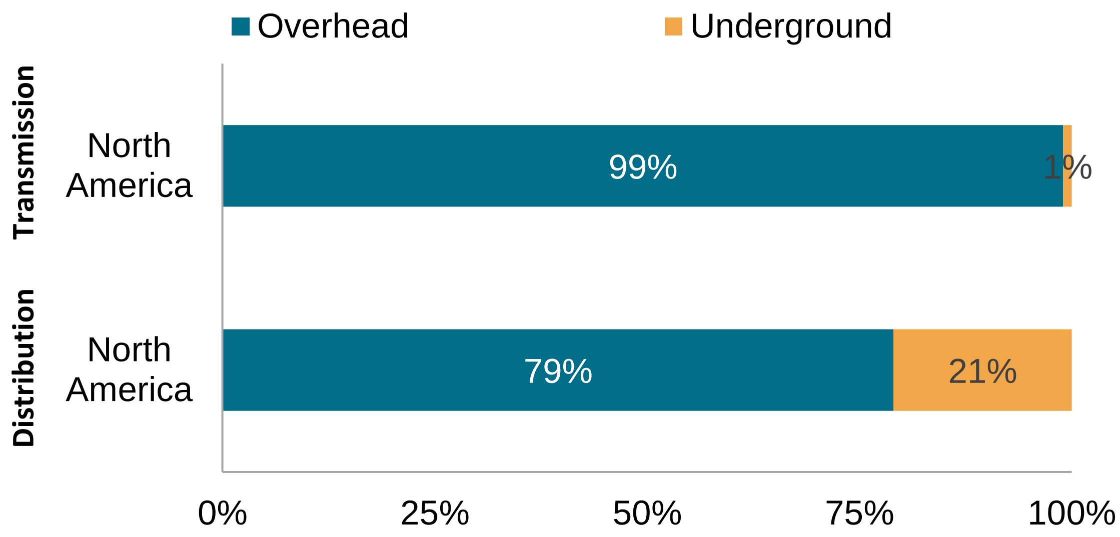



Data compiled June 2022.

Note: Copper is primarily used in transformers and underground power lines, which are mostly concentrated in the distribution segment.

Source: S&P Global Commodity Insights.

## Estimated grid mix in key regions




Data compiled June 2022.

Source: S&P Global Commodity Insights, State Grid Corporation of China, National Grid, American Electric Power, US Department of Homeland Security.

Although copper has technical advantages over aluminum, copper has been displaced for overhead systems due to its weight- and cost-related disadvantages. For underground and subsea systems, where weight is not a concern, copper is a preferred material for its high corrosion resistance and strength.

# Transmission and distribution demand (2) – copper

## Copper demand assumptions – T&D

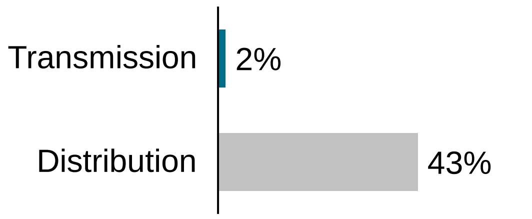
| | |
|---|---|
| Average power factor | 0.9 |
| Recycling rate[1] | 60% |
| **Transmission** | |
| Price increase for underground[2] | 2x |
| Average conductor cross-sectional area | 1,000 $mm^2$ |
| **Distribution** | |
| Price increase for underground[2] | 3x |
| Average conductor cross-sectional area | 220 $mm^2$ |

[1] Based on International Energy Agency (IEA), applied only to lines replacement.
[2] Based on case studies for built underground and subsea transmission systems.
Source: primary and secondary research from major conductor manufactures.

## Investment in T&D

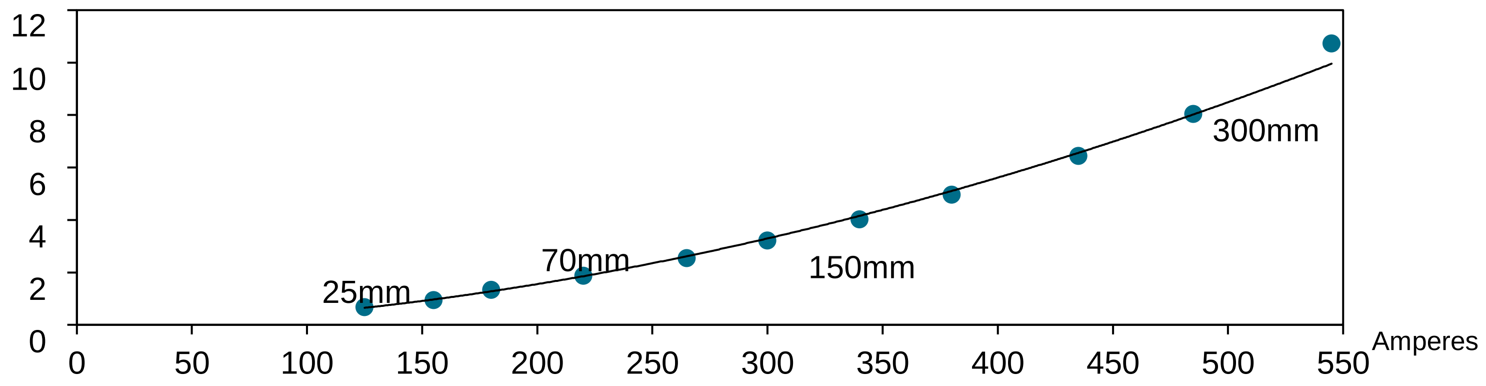
The S&P Global investment numbers include required investments for the grid interconnection of generation technologies (increased interconnection costs from distributed renewable electricity), grid strengthening and replacement of aging lines, and overall T&D network expansion to support the electrification of the economy.

Share for underground systems
Percentage




## Conductor’s size and current rating correlation

Kg/km vs. amperes




Data compiled June 2022.
Source: S&P Global Commodity Insights.

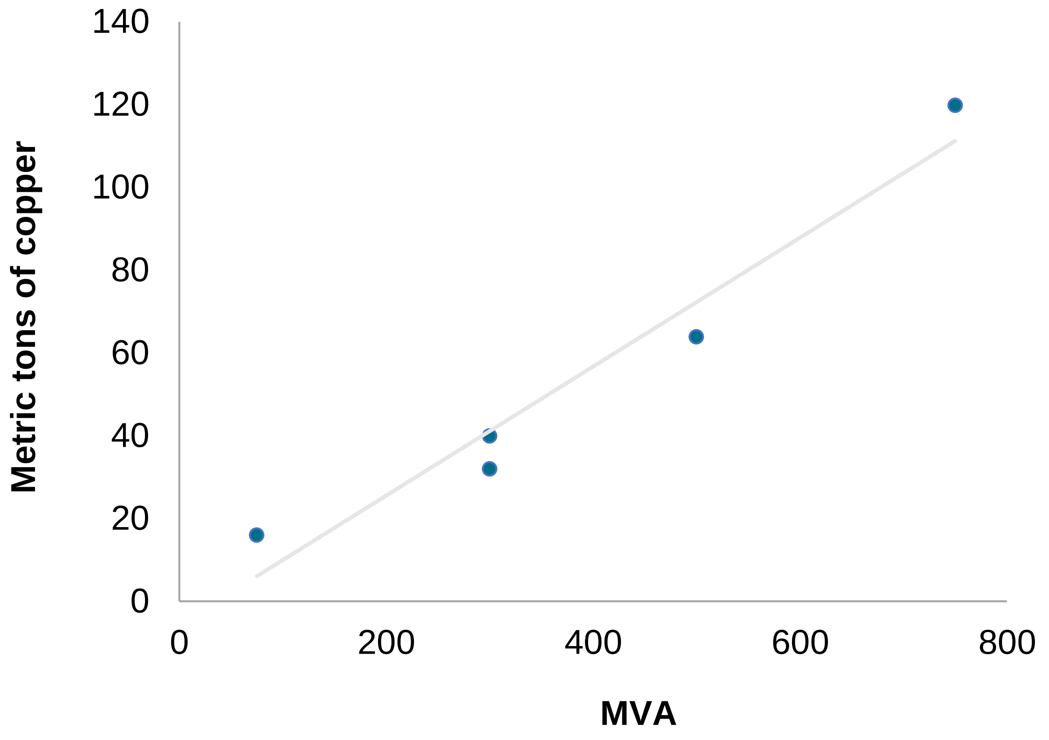
# Transmission and distribution demand (3) – copper

## Copper demand assumptions in transformers

| | |
|---|---|
| Cost associated to copper[1] | **13%-18%** |
| Copper price (2011) | **8.87 US$/kg** |
| Power transformer type | **Three-phase** |
| Price range (2011)[2] | **US$2 million-US$7 million** |
| Growth rate per km added | **3 MVA/km** |

[1] From copper.org Transformers case study.
[2] From US Energy Large Power Transformers and the US Electric Grid study.
Source: primary and secondary research from major conductor manufactures.

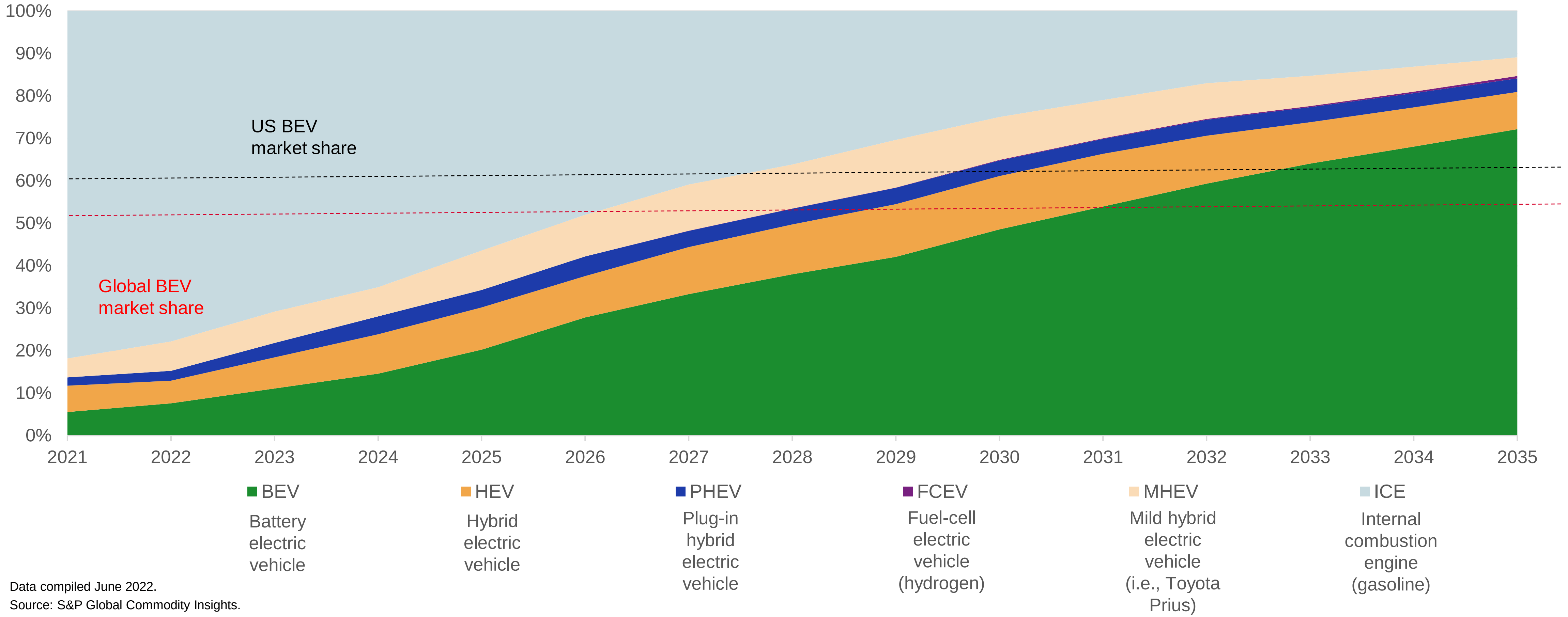
## Three-phase transmission transformers weight and MVA rating correlation




Data compiled June 2022.
Source: Primary and secondary research from major transformer manufacturers.

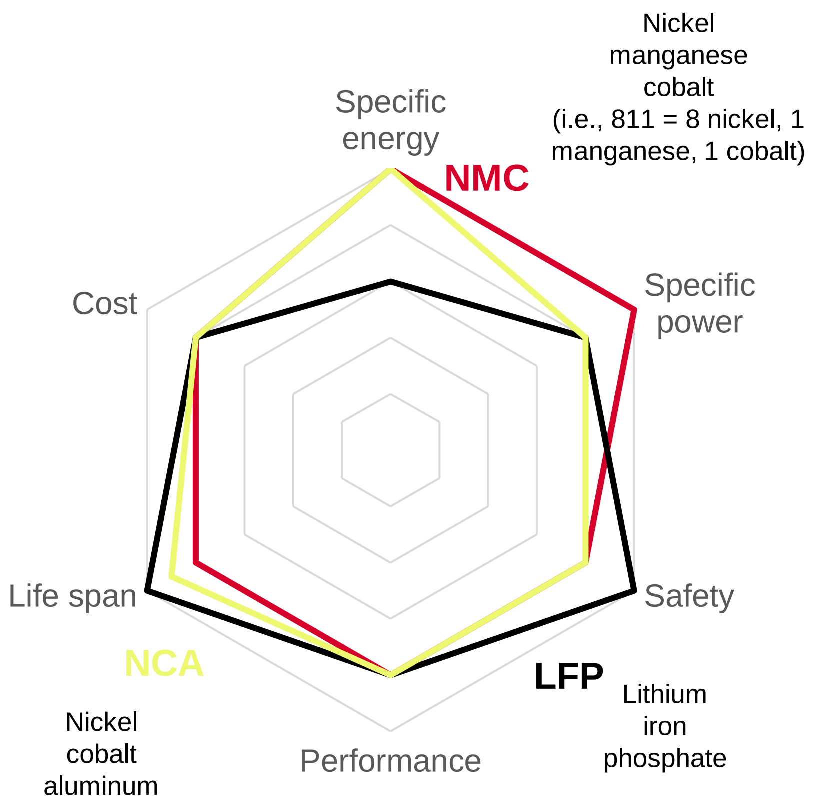
# Electric vehicle and battery forecast – key assumptions

**US share of new vehicle sales by fuel type (light vehicle)**
*%*




Data compiled June 2022.
Source: S&P Global Commodity Insights.

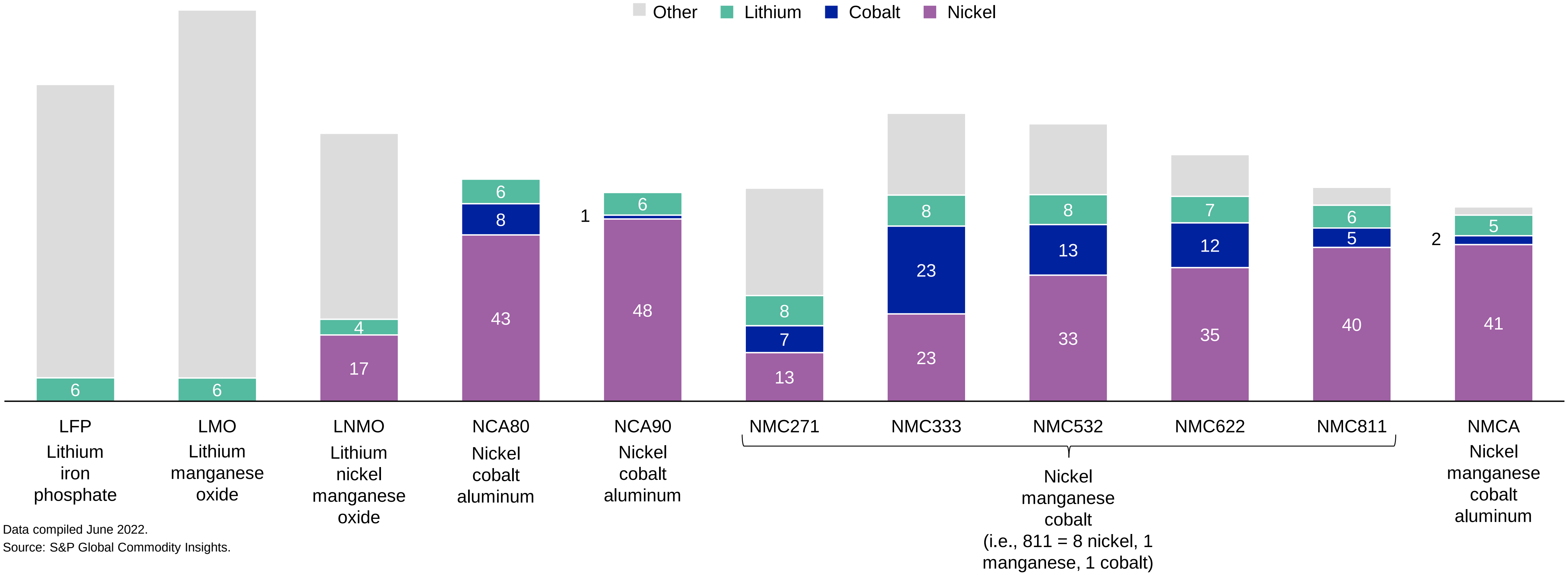
# Cathode chemistry comparison




| Cathode | Anode | Cathode | Pros | Cons |
|---|---|---|---|---|
| Lithium iron phosphate — LFP | Graphite carbon | Phosphate | Long life cycle, 2,000 80%-100% discharges without any damage, better thermal safety | Low specific energy, and they don't perform well at lower temperatures |
| Lithium nickel manganese cobalt oxide — NMC | Graphite | Nickel, manganese, cobalt | High specific power and specific energy | Toxic material, and thermal runaway at moderately high temperatures |
| Lithium nickel cobalt aluminum oxide — NCA | Graphite | Nickel, aluminum, cobalt | High specific energy, better fast charging capabilities | Expensive, less safe than others |

# Cathode chemistry assumptions

**Cathode chemistry by major battery type**
*(kg for a 60kwh battery)*




Data compiled June 2022.
Source: S&P Global Commodity Insights.