Electric vehicle growth

in the U.S.

A LOOK INTO THE EV BATTERY SUPPLY CHAIN

March 2022

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INTRODUCTION

In August 2021, President Biden set forth an ambitious target to make half of all new vehicles sold in 2030 zero-emissions vehicles, including battery electric, plug-in hybrid electric, or fuel cell electric vehicles. Further, there's a global movement to target of 75% electric vehicle (EV) sales share by 2040.

To evaluate the supply chain challenges that must be addressed to achieve government goals for new sales of passenger electric vehicles[1] in the United States and globally, The American Petroleum Institute engaged with The Martec Group to conduct market research. Specifically, the research explores the minerals and processing necessary to achieve President Biden's administration's 2030 target and the global 2040 target. The information allows for discussion about a middle way forward that also can reduce carbon emissions in internal combustion engines. This pathway may include reducing the carbon intensity of liquid fuels (biofuel, gasoline, and diesel) and improving the efficiency of new vehicles as well as identifying new applications for natural gas and renewable natural gas vehicles.

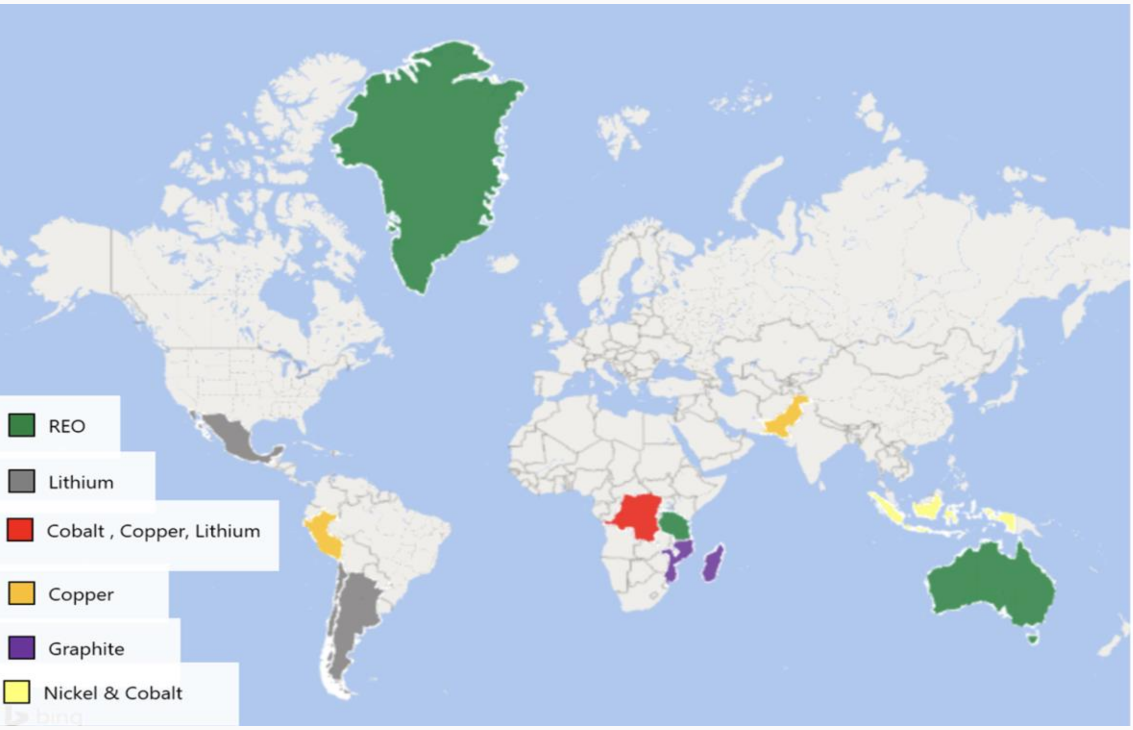
The Martec study shows that there are complex challenges that must be overcome before the U.S. can achieve the targeted EV penetration. Currently, the U.S. is not in a position "outcompete China" in the EV sector because the country lacks the energy/material security to produce EV batteries domestically. Significant mining operations must begin in the U.S. to ensure the country can supply even a fraction of what is needed to achieve these targets.

[1] *Passenger vehicles include sedans and light-duty trucks <8,500 lbs.*

ENERGY SECURITY

The U.S. has abundant resources but mining restrictions and a regulatory framework that is disparate from other countries such as China, Australia, Chile, and Canada impede EV battery supply chain security.

Currently, China dominates the global market for processing (smelting) with about 60% share of lithium, 67% of cobalt, and more than 80% of both copper and rare earth elements. Further, Chinese companies have already begun actively investing in key mineral mining projects globally. This finding is noteworthy because the timeline for getting a mining project from exploration to commercial production can range from five to 20+ years with an average of seven to 13 years.



Chinese companies are investing in several key mining projects globally in each of the critical minerals.

- Lithium (5):
  - *Argentina, (2) Chile, DRC-Congo & Mexico*
- Nickel (4):
  - *(4) Indonesia (mining & processing)*
- Cobalt (5):
  - *(4) DRC-Congo and (1) Indonesia*
- Graphite (4):
  - *(2) Mozambique & (2) Madagascar*
- Copper (4):
  - *(2) DRC-Congo, Pakistan, Peru*
- Rare Earth/REO (4):
  - *(2) Australia, Tanzania & Greenland*

Outside of copper the U.S. has a limited number of active mines in each of the critical EV battery supply chain minerals of lithium, nickel, cobalt, bauxite/aluminum, graphite, and rare earth oxides/elements. For the U.S. to supply the raw materials needed to achieve EV targets, a massive increase in local production of all the materials studied is necessary.

Lithium	Nickel	Cobalt	Copper	Aluminum	Graphite	Rare earth oxides/elements
Li	Ni	Co	Cu	Al (bauxite is the world's main source of aluminum)	(mineral used as anode material in Li-ion batteries)	(sometimes referred to as REOs)

For the U.S. to produce enough minerals to reach the Biden administration's 50% by 2030 target will require:

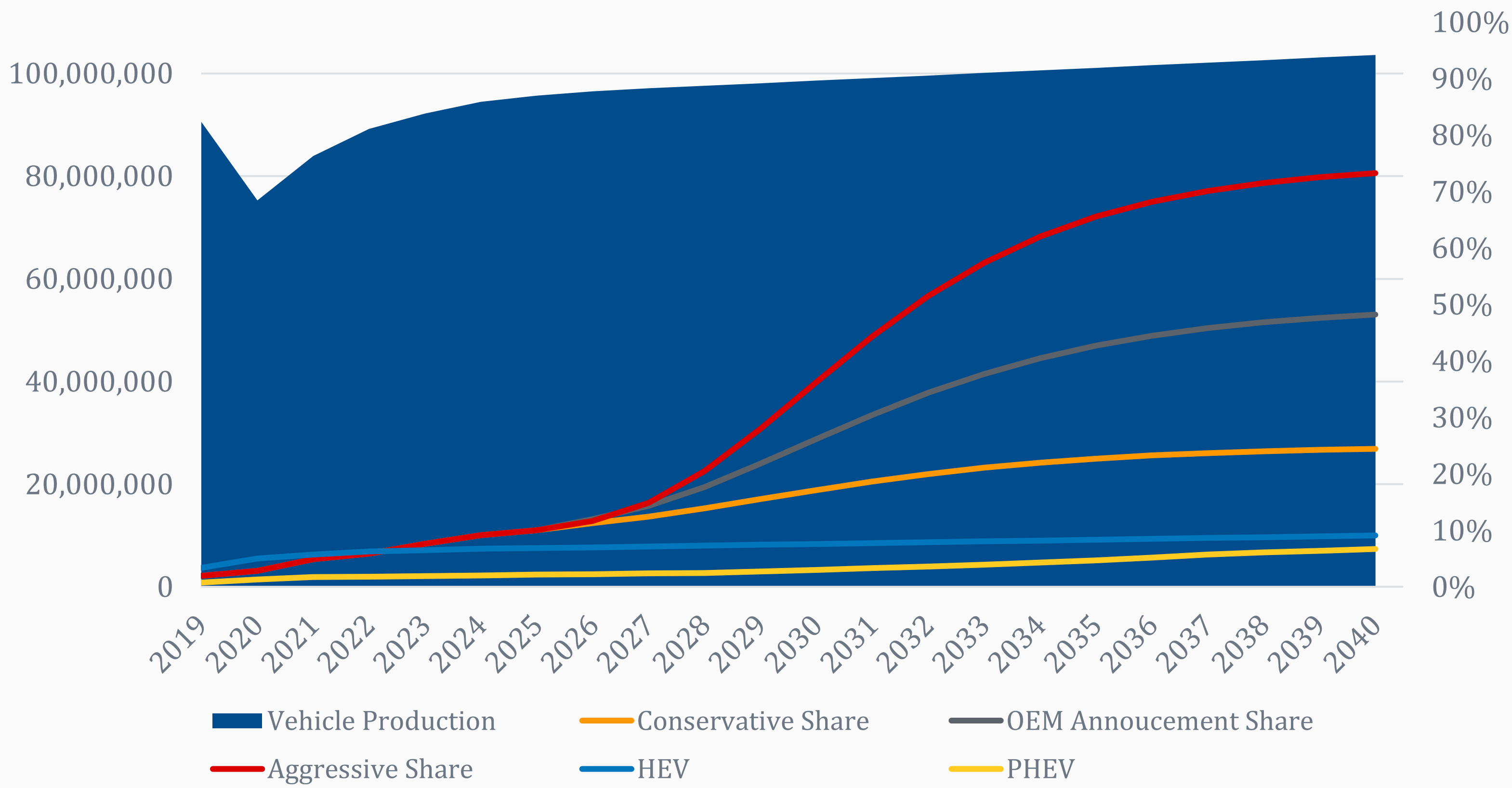
- **48x more lithium** (The U.S. has one active mine today.)*
- **16x more nickel** (The U.S. has one active mine today.)
- **29x more cobalt** (The U.S. has two active mines today, as a secondary material.)
- **Graphite is not produced at scale in the U.S.** (The U.S. has zero active mines today.)

To reach the global 75% by 2040 target, global production will require:

- **8x more lithium**
- **3x more graphite**
- **1.5x more rare earth elements**

**Note: Martec analysis was conducted in December 2021 and updated for release of this summary report in March 2022. Please see pg. 22 for U.S. mining development notes.*

GLOBAL LIGHT DUTY AUTO xEV PRODUCTION FORECAST*



Source: Martec analysis.
**Notes: Forecast is inclusive of both residential & commercial fleet for LD automotive vehicles (passenger cars, SUVs, and LD trucks); excludes medium & heavy duty vehicles.*
xEV = Industry term standing for electrified vehicles (BEV, HEV, and PHEV combined).

Scenario Logic

All scenarios follow expected vehicle OEM launch programs through 2025 as these programs are already in scheduled production plans.

Conservative

- Global demand peak of ~25% by 2040

OEM Announcements

- Follows announcements of all global OEM's expectations for EV penetration
- Global demand peak of ~50% by 2040

Aggressive

- Rapid acceptance of BEVs in all markets during the next 2-3 vehicle cycles
- Global demand peak of ~75% by 2040

HEV

- Full Hybrids will continue to be an alternative in electrification, but growth will be limited due to push towards BEVs

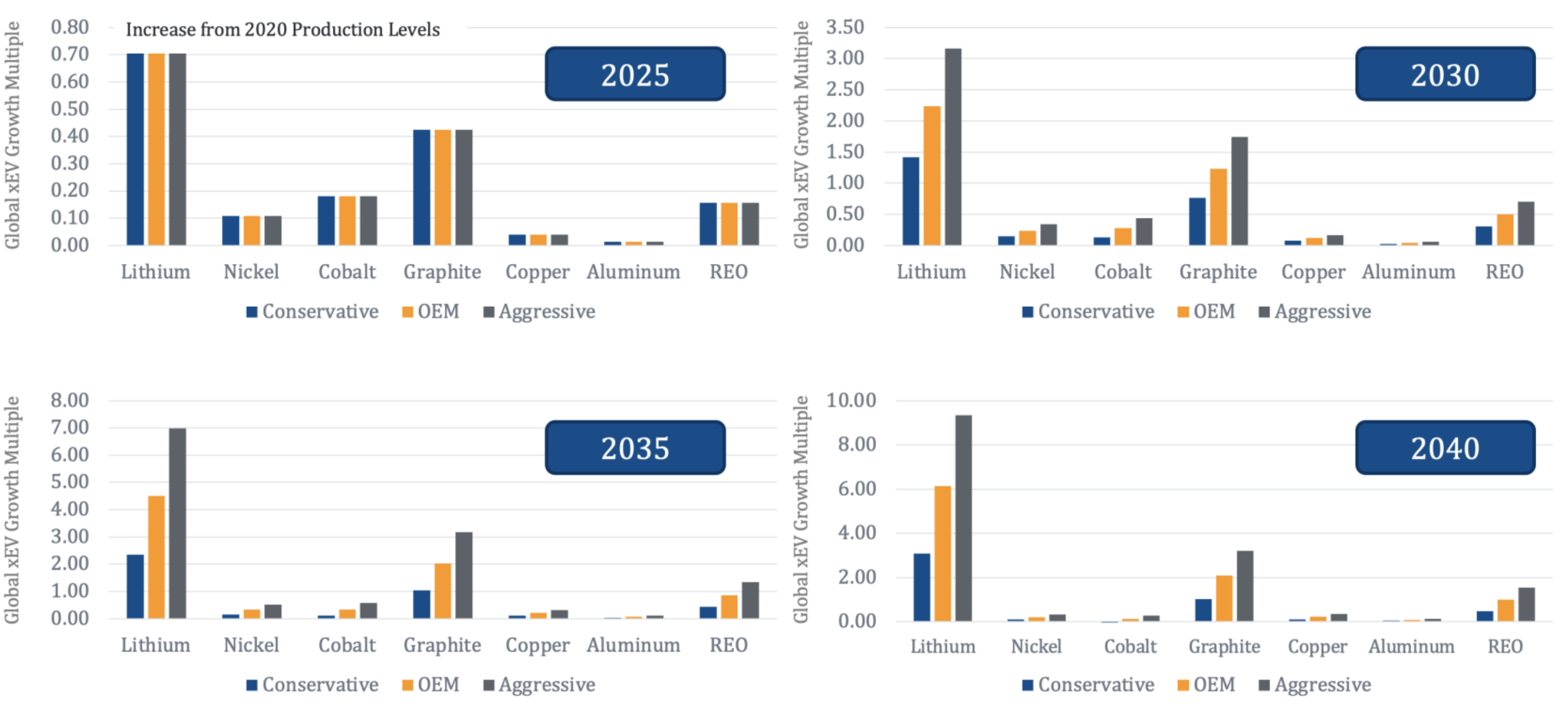
PHEV

- Consistent forecast for each scenario (same %)
- Optional OEM compliance solution

Next slides…2 options

Option A

1 page, 4 charts, and chem info



Notes: *2025 material demand does not change based on the different scenarios as production plans from vehicle OEMs are already in place. The different scenario plans have a bigger impact when looking at materials needed by 2030 and beyond.*
This analysis assumes no recycling takes place; also, it does not take into consideration growth in other mineral end applications outside of LD automotive (e.g., mobile electronics).

Yet, adding to the supply chain complexity is changing battery chemistry. More than 10 battery chemistries exist today across the globe with a high mix of mineral variations; for example:

- lithium nickel cobalt manganese oxide (NCM)
- lithium nickel cobalt aluminum oxide (NCA)
- lithium iron phosphate (LFP)

Some battery chemistries are still in a research and development (or pilot) stage (e.g., solid state lithium, sodium ion, and zinc ion).

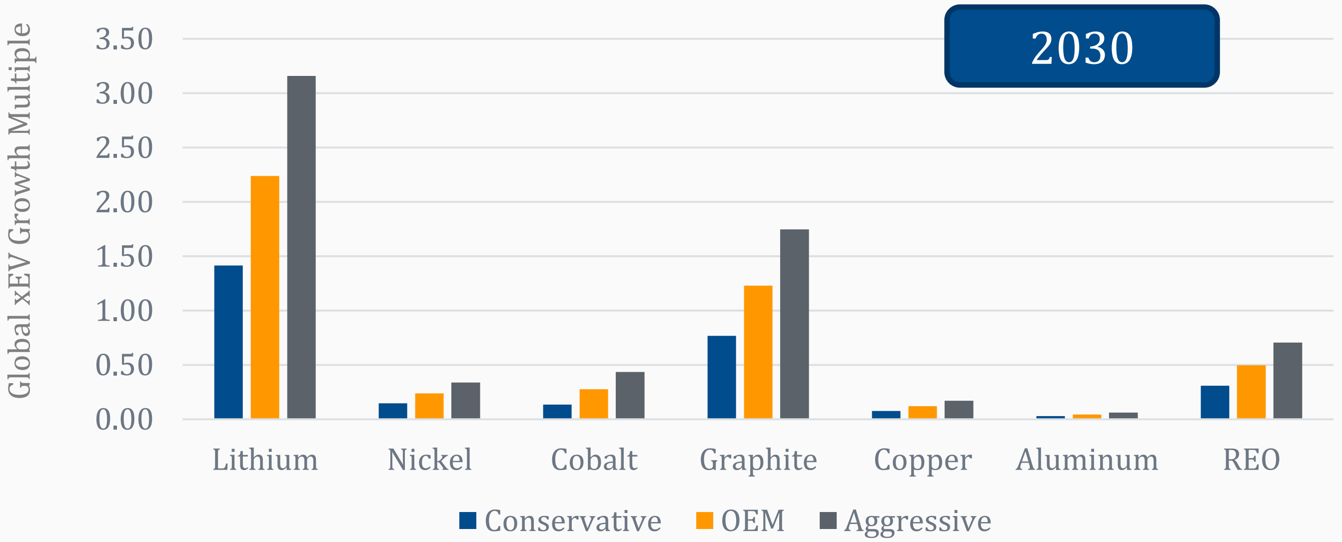
The challenge of knowing which chemistry will come out on top in the next five or more years adds to the uncertainty for investing in mining operations.

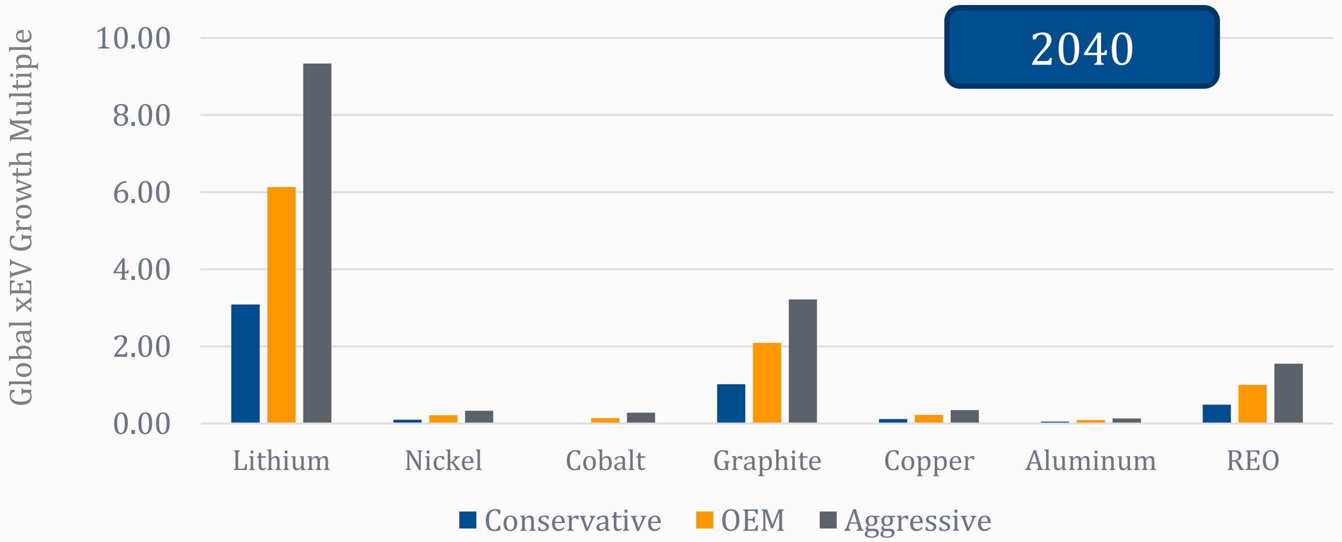
Next slides…2 options

Option B

2 pages, 2 charts, then chem info

SUMMARY OF GLOBAL MATERIAL DEMAND SCENARIOS FROM xEV GROWTH





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The challenge of knowing which chemistry will come out on top in the next five or more years adds to the uncertainty for investing in mining operations.

MINING CHALLENGES

The U.S. has abundant mineral resources to support high volume battery manufacturing but lacks the mining capacity and cost position to achieve this goal.

The U.S. has lower degree of ***available*** reserves and resources compared to other leading nations. Current U.S. mining regulations create 10- to 20(+)-year timelines for commercial production. Other countries including China, Australia, Chile, and Canada have more expedited processes.

	Exploration	Discovery	Construction	Production	Reclamation
Low to High Time Range	~2 – 10+ years	~2 – 5 years	~2 – 7 years	~10 – 40 years	~2 – 10+ years
Avg. Time by Stage	~5 years	~3 – 5 years	~2 – 3 years	~20 years	~3 – 5+ years
Comments	• China & Australia 1 – 3 years • U.S. 5 – 10+ years • Many times, started by smaller cos. & later acquired	• China, Australia, & Canada have more expedited processes • U.S. process varies by state & legal challenges	• 2 – 3 years is typical unless legal challenges or unplanned issues arise • REO mines can take longer due to extraction & market risk	• Some mines have gone beyond 50 years • Mining cos. prefer not to design mine to be <10 years due to poor ROI	• Varying req. by country • If radioactive materials will be longer • China, Russia, SE Asia, & South American countries tend to have lower standards
Key Steps by Stage	• Prospecting • Reconnaissance • Survey mapping • Sampling • Geochemical analysis • Resource estimation • Permitting	• Targeted drilling • Trenching • Sampling & analysis • Quality geological modeling • Resource estimation • Planning & investment • Final permitting	• Resource conversion to reserve • Mine design & schedule • Plant design • Pre-construction phase • Construction	• Ore extraction • Milling/Ore separation • Processing • Grade control • Waste rock, tailings, & wastewater mgmt. • Near mine exploration • Expansion life of mine	• Mine closure • Site clean up • Maintenance • Rehabilitation • Environmental monitoring

MINING CHALLENGES

Mining capital investment, from exploration to commercial production, can range from $500M to $1.5B.

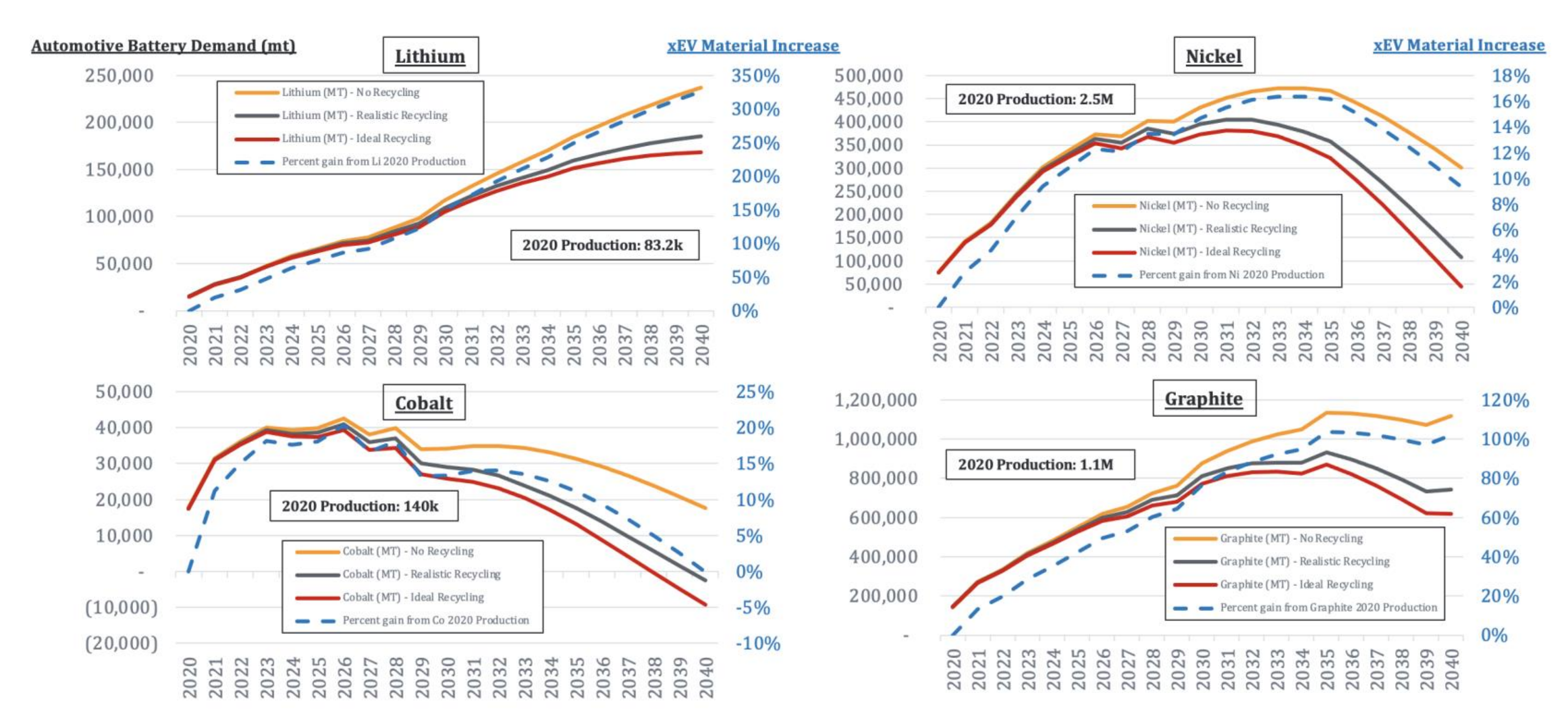
- Continued litigation will delay mining expansion in the U.S. thus prohibiting domestic production of key EV battery materials (Li, Ni, Co, and REOs).
    - U.S. civilian court injunctions are leading to significant delays at several mining locations; this also may be adversely impacting the willingness to invest.

	Exploration	Discovery	Construction	Production	Reclamation
Low to High Cost Range	\$10M – \$200M	\$50M – \$500M	\$50M – \$1,500M	\$10M – \$300M/yr.	\$20M – \$200M
Avg. Cost by Stage	~\$50M – \$100M+	~\$200M – \$300M	~\$300M – \$1,000M	~\$100M/yr.	~\$50M – \$100M
Comments	• Costly engineering surveying & studies are conducted to determine feasibility	• Need to determine what makes best sense for which zones to mine first, size of mine, & extraction rate • Once decisions are made, there is limited to no flexibility	• Type of mine has significant cost impact (open pit/surface, underground, in-situ/brine) • Li has high cost if brine • If size of mine is changed need to restart permit process (design to capacity)	• Size & type of production will have significant impact on annual costs • Can typically only expand production if target better grade zones	• U.S. & Europe known for being more expensive than other regions • Type & size of mine will have impact as well as location
Key Steps by Stage	• Prospecting • Reconnaissance • Survey mapping • Sampling • Geochemical analysis • Resource estimation • Permitting	• Targeted drilling • Trenching • Sampling & analysis • Quality geological modeling • Resource estimation • Planning & investment • Final permitting	• Resource conversion to reserve • Mine design & schedule • Plant design • Pre-construction phase • Construction	• Ore extraction • Milling/Ore separation • Processing • Grade control • Waste rock, tailings, & wastewater mgmt. • Near mine exploration • Expansion life of mine	• Mine closure • Site clean up • Maintenance • Rehabilitation • Environmental monitoring

Minerals needed now require more capital expenditure to ensure demand can be met. However, demand could peak just as a mine starts to produce commercially. An ideal timeline for a mine is ~20 years of production. Cobalt, nickel, graphite, and rare earth minerals researched in this study have demand peaks in 2030-2034.

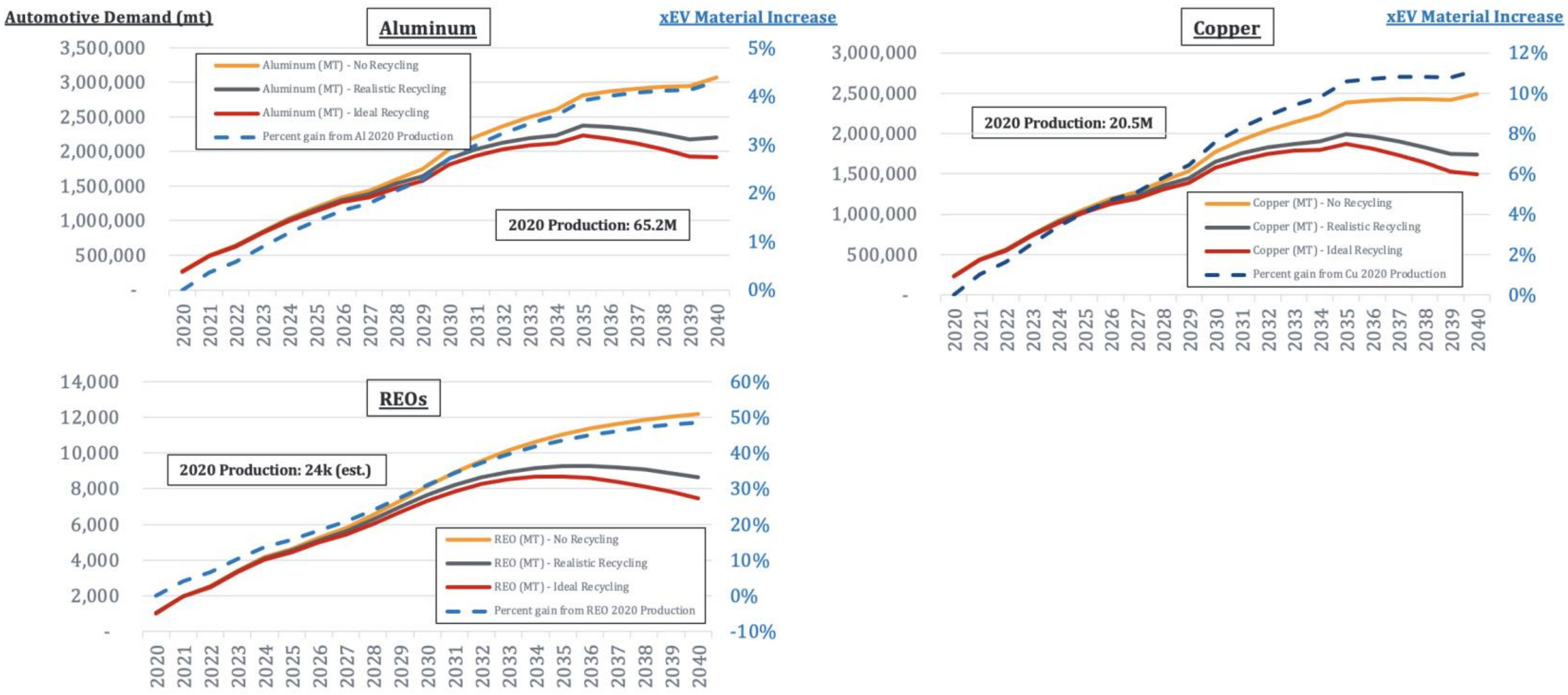
So, in addition to long timelines and considerable capital investment, demand peaks could limit further investment.

GLOBAL MATERIAL DEMAND CONSERVATIVE SCENARIO: ~25% EV by 2040



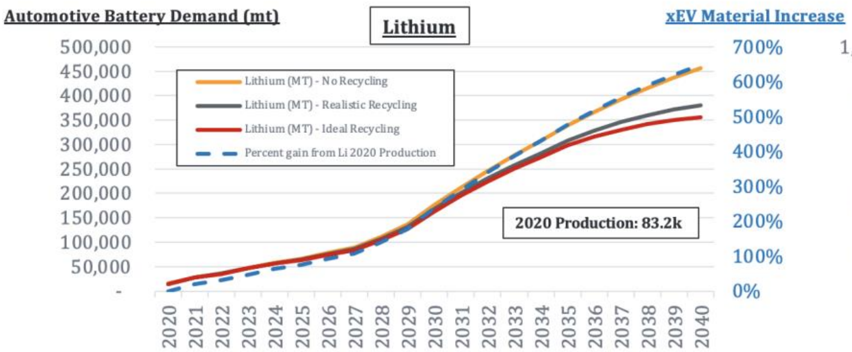
Source: Martec analysis.

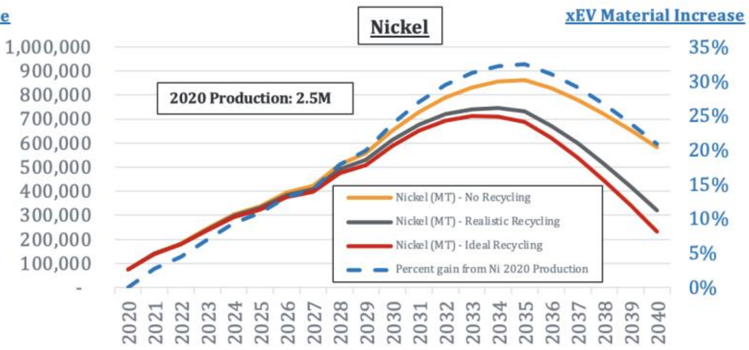
GLOBAL MATERIAL DEMAND CONSERVATIVE SCENARIO: ~25% EV by 2040

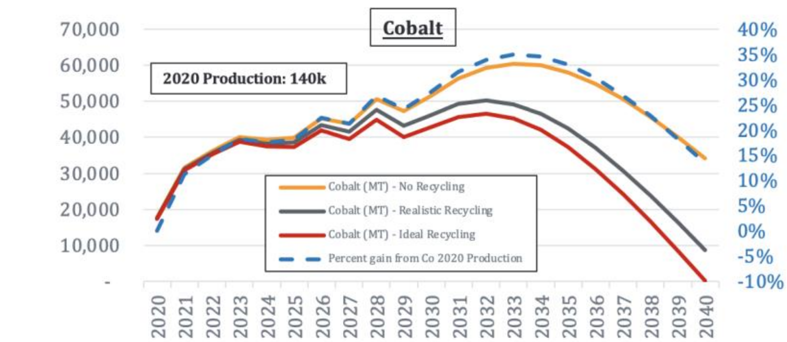


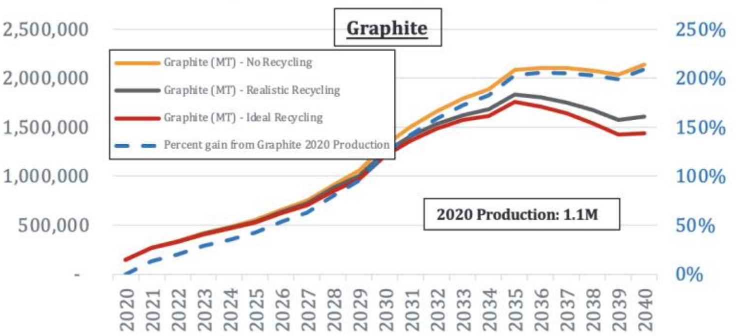
Source: Martec analysis.

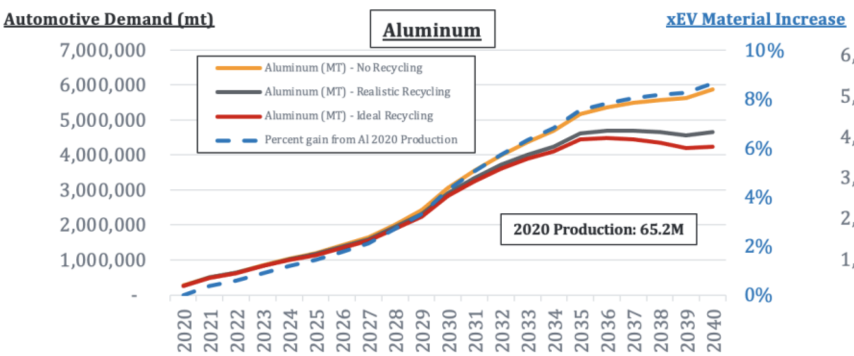
GLOBAL MATERIAL DEMAND OEM ANNOUNCEMENTS SCENARIO: ~50% EV BY 2040

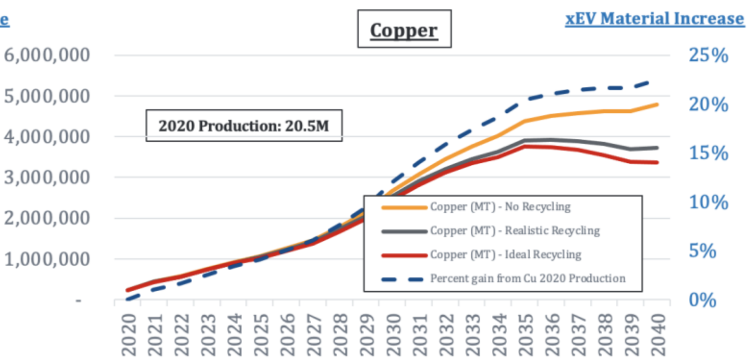


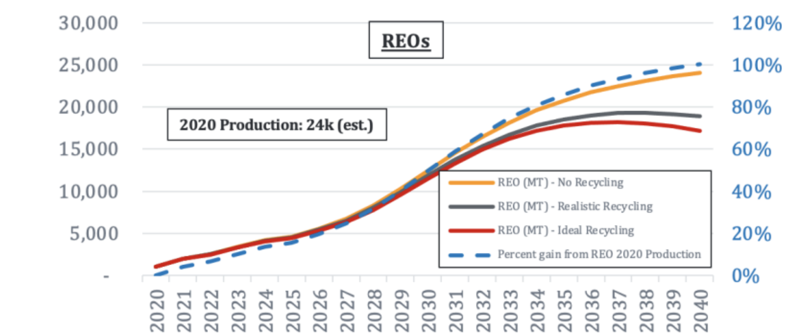






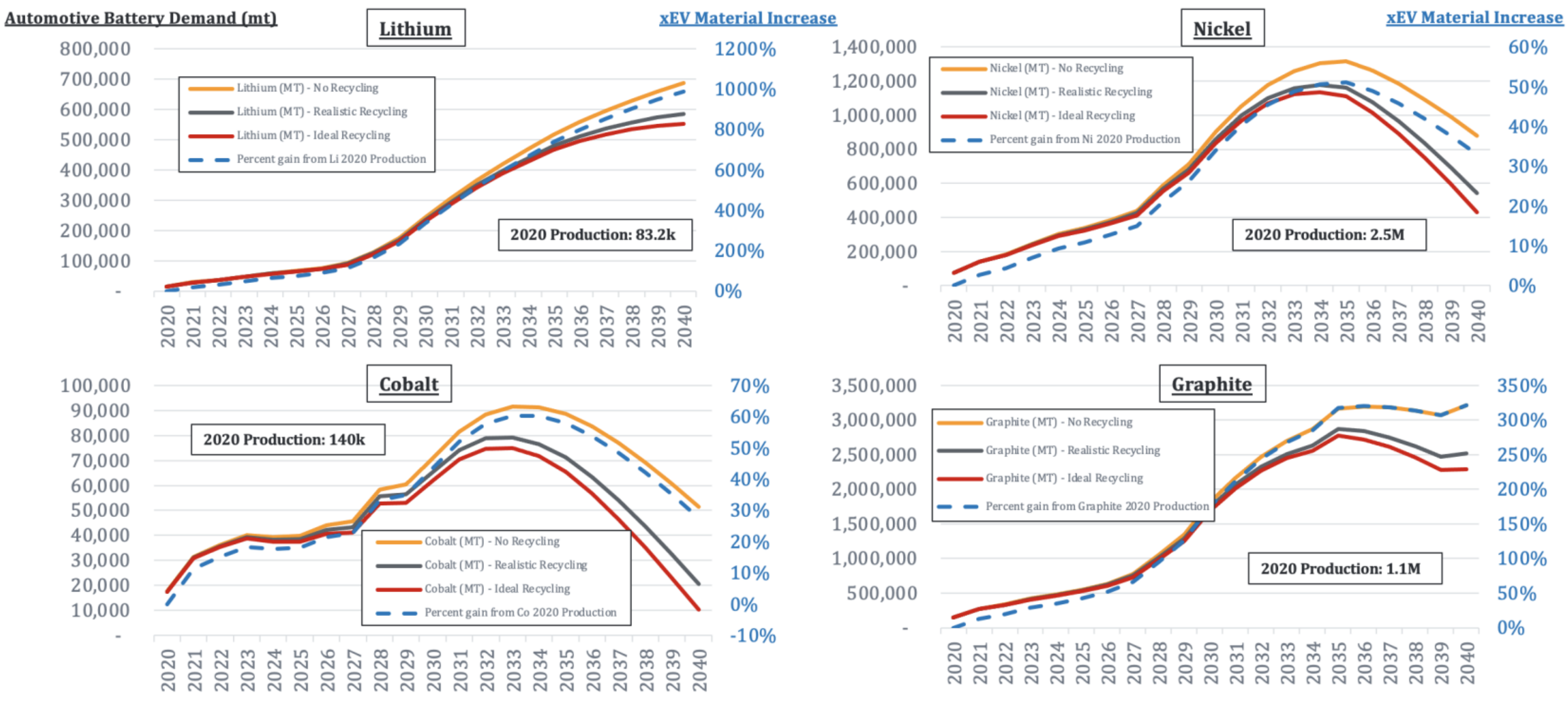


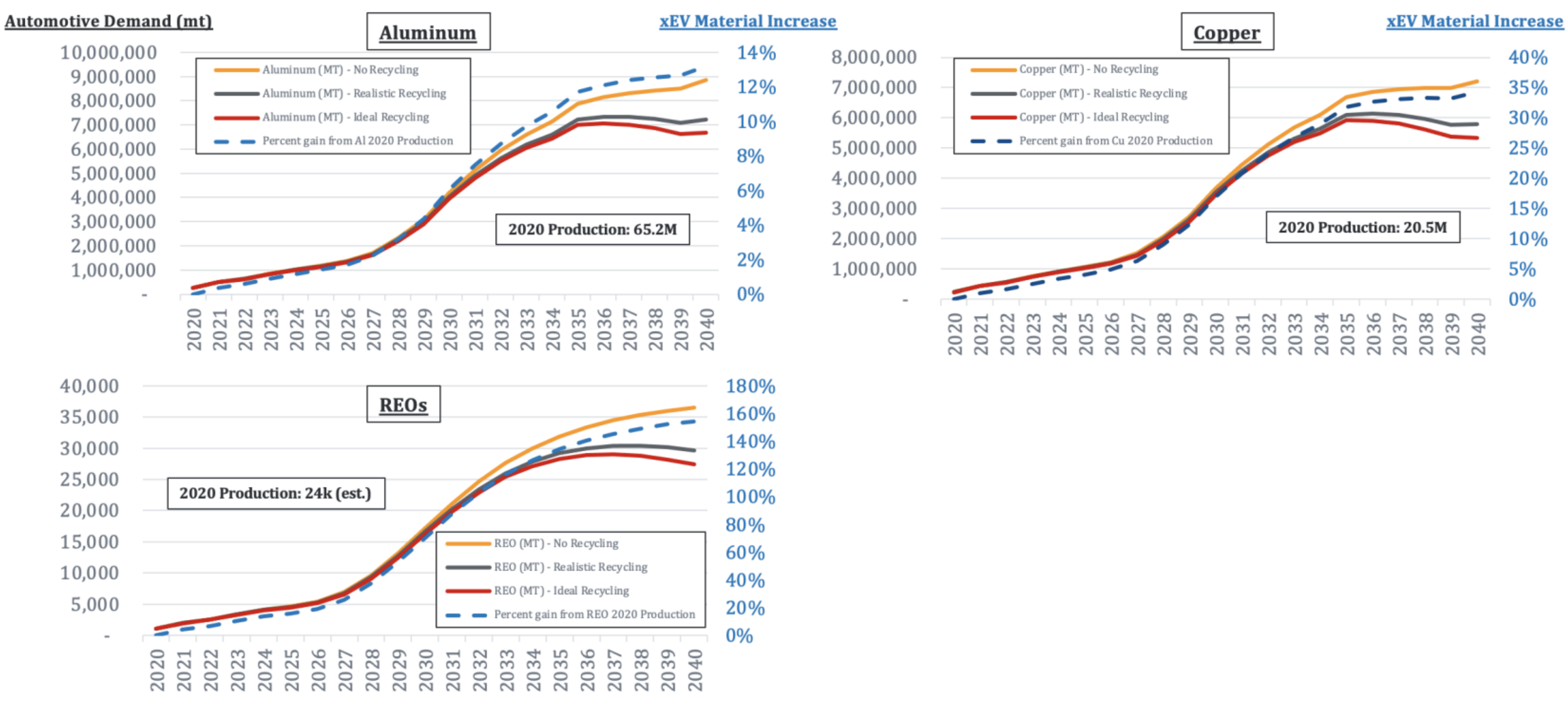




Source: Martec analysis.

GLOBAL MATERIAL DEMAND AGGRESSIVE SCENARIO: ~75% EV BY 2040





Source: Martec analysis.

MINING CHALLENGES

Battery chemistry is expected to change and use decreased amounts of cobalt. Global cobalt demand will peak in 2034 under the OEM and aggressive recycling scenarios researched in this study due to technology shifts and increased recycling.

- Recycling will play a critical role in future battery production, but it will take a considerable amount of time (10+ years) to build capacity.
- Recycling of batteries is something the automotive industry is focusing on to reduce the long-term impact of raw material shortages and cost increases.

Lithium, graphite, and rare earth elements will have increased demand regardless of improvements in battery technology as these are currently used in leading, and available, technologies.

Globally, ***nickel is potentially at risk of short supply*** as the specific type of nickel used for batteries is less than 30% of the total raw material production.

- Additionally, the high pressure acid leaching (HPAL) process that is being used increasingly to create battery-grade nickel is energy intensive, generates significant amounts of CO2 emissions, and produces waste tailings that can remain acidic for decades.

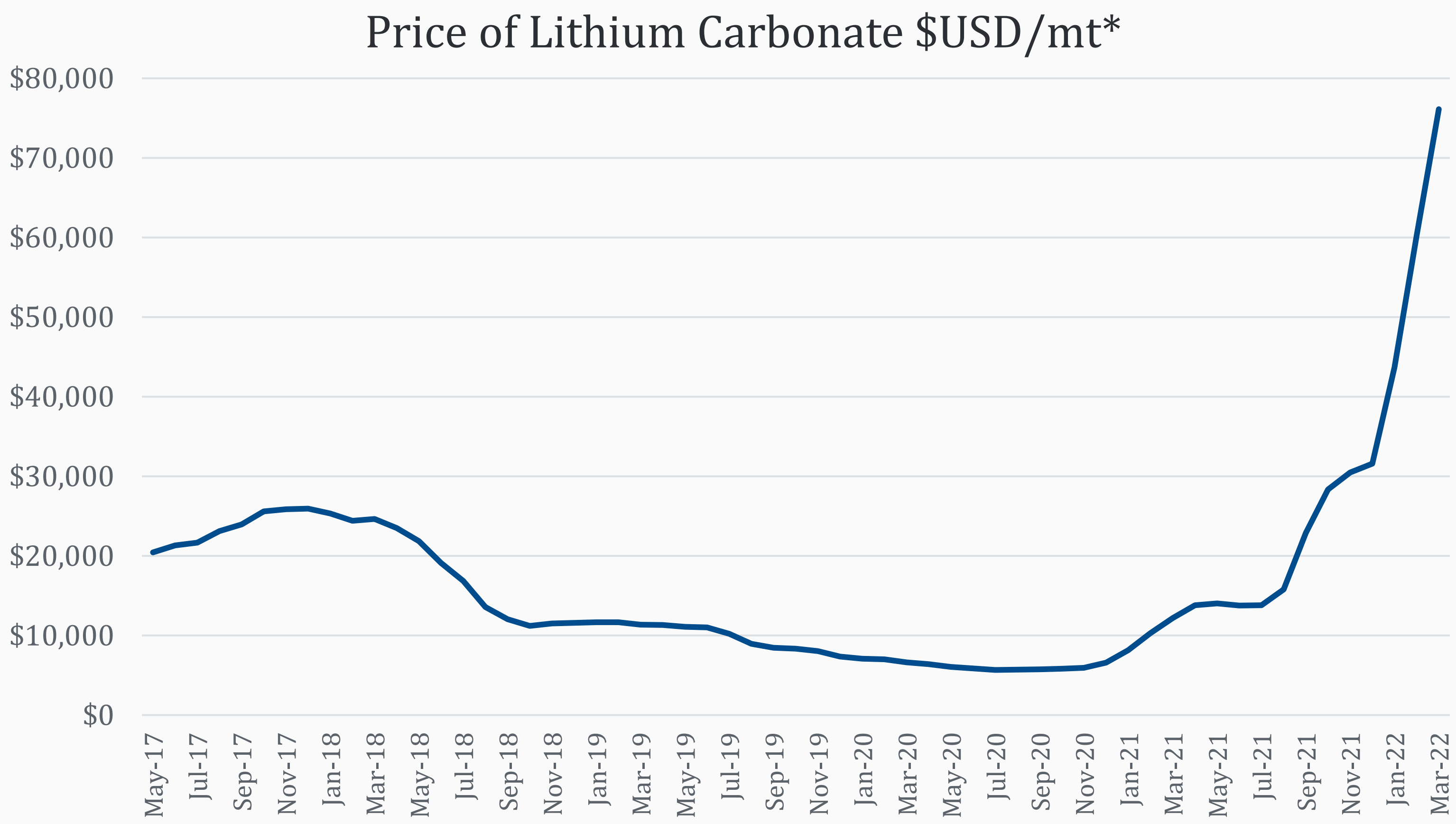
PRICE UNCERTAINTY

The increase in demand for the critical materials (lithium, nickel, cobalt, copper, neodymium, aluminum) necessary for battery and electric motor production could put upward pressure on the price of EVs. Over the past year, the price of each key mineral has experienced significant increases with lithium carbonate leading the way at greater than 12 times the price it was 12 months ago.

- Price increases from November 2020 to March 2022:
  - Li Carbonate 1,184%
  - Ni 136%
  - Co 127%
  - Cu 43%
  - Nd 177%
  - Al 85%
- A lack of competition among raw material suppliers gives them more pricing power for their goods.
- The upward pressure on the price of materials for EVs could ultimately be transferred to consumers.

Overall, the market is experiencing material pricing volatility. Increased demand is impacting prices for lithium carbonate, nickel, cobalt, copper, neodymium, and aluminum. All of these materials have increased in price over the past year—most above forecasted trends.

LITHIUM CARBONATE PRICING FROM MAY 2017 – MAR. 2022

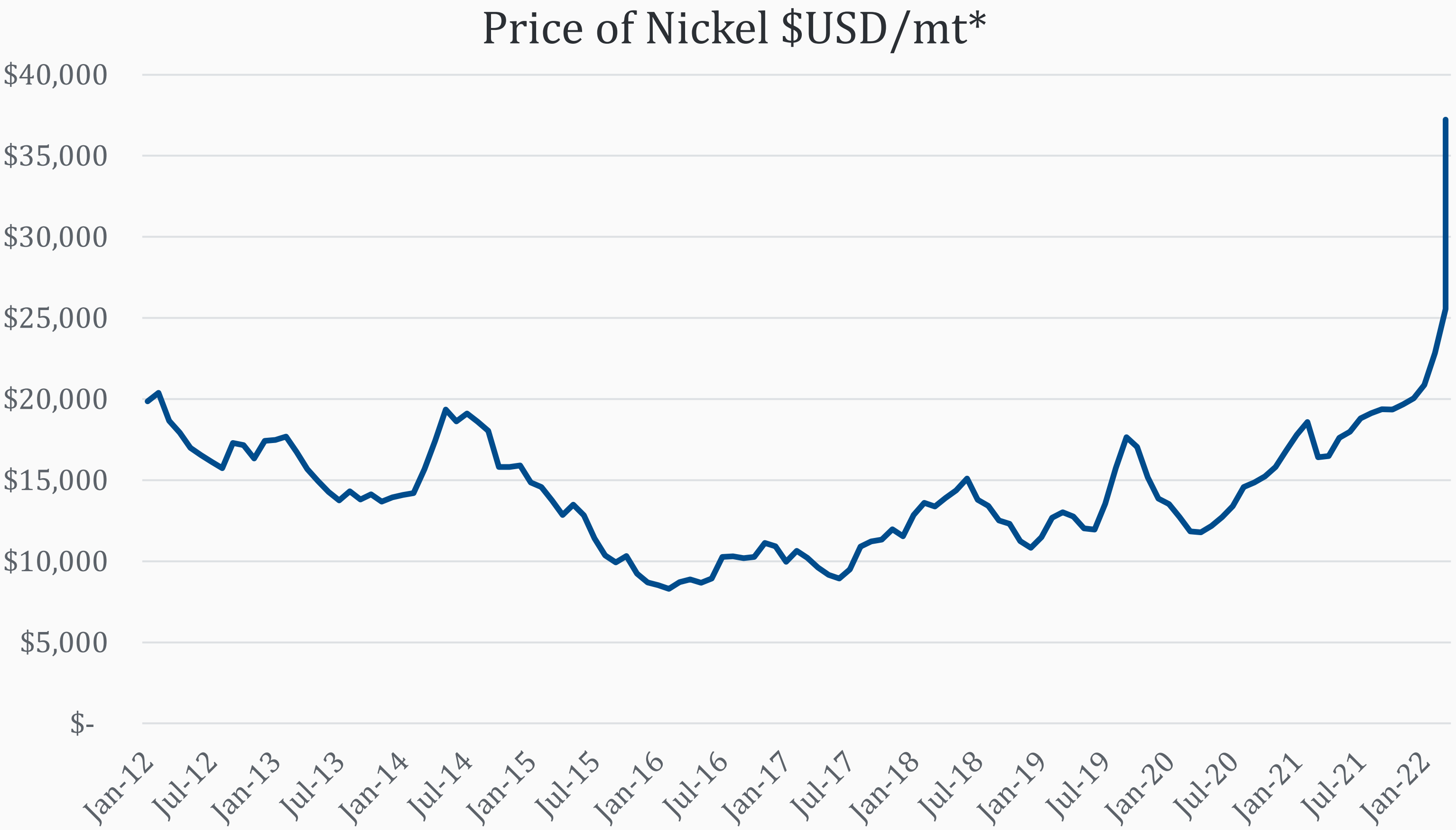


- Lithium carbonate has seen a 10x price increase since the November 2020 U.S. presidential election
- Currently, the world is experiencing a lithium shortage driven by one major area of demand: EV batteries
    - *"With lithium prices set to rise throughout the next decade, the EV sector in the West will have to face rising battery costs. If they pass costs on to the consumer, EV adoption will likely accelerate at a slower rate than previously expected"***
- Lithium carbonate pricing is anticipated to continue to rise through 2022 and beyond primarily due to ever increasing demand from Li-ion automotive battery growth

**Source: Trading Economies (monthly tracking).*
***Note: Quote from GlobalData report in Forbes article "Lithium Shortage May Stall Electric Car Revolution And Embed China's Lead."*

PRICE UNCERTAINTY

NICKEL PRICING FROM JAN. 2012 – MAR. 2022

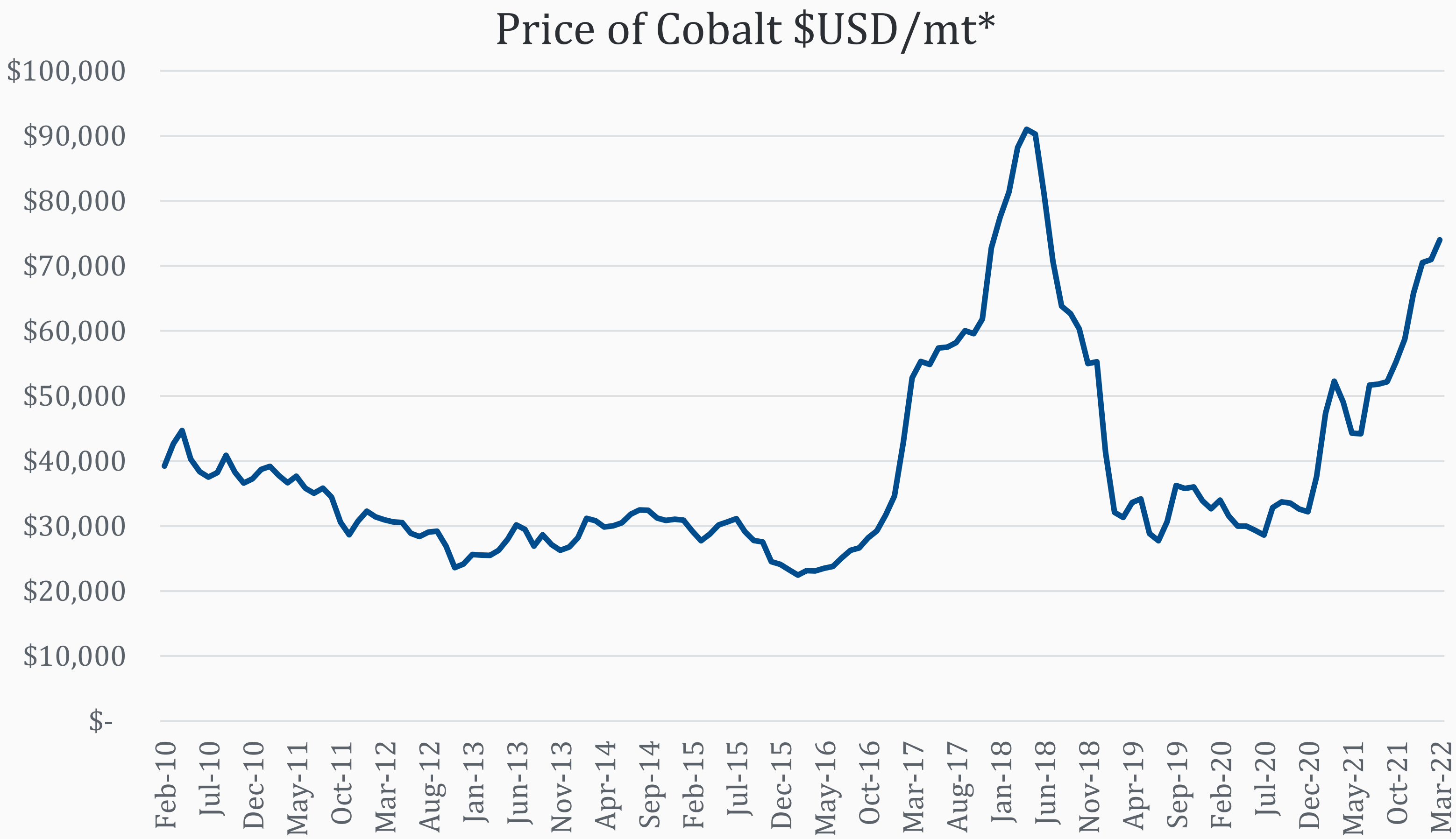


- Nickel prices* continue to rise
    - Due to weak supply, tightening supply chain, and demand for EV batteries
    - Experts have indicated producers are hoarding materials for 2022 due to speculation of supply shortages and delayed delivery times
    - Russia-Ukraine war is now impacting prices further as Russia is the third-largest producer of nickel, behind Indonesia and the Philippines, mining 250,000 metric tons of it in 2021, according to U.S. government data.

**Source: Trading Economies (monthly tracking).*
***Note: Pricing is not representative of refined battery-grade nickel sulphate. Nickel sulphate used for batteries is less than 30% of the total raw material production.*

PRICE UNCERTAINTY

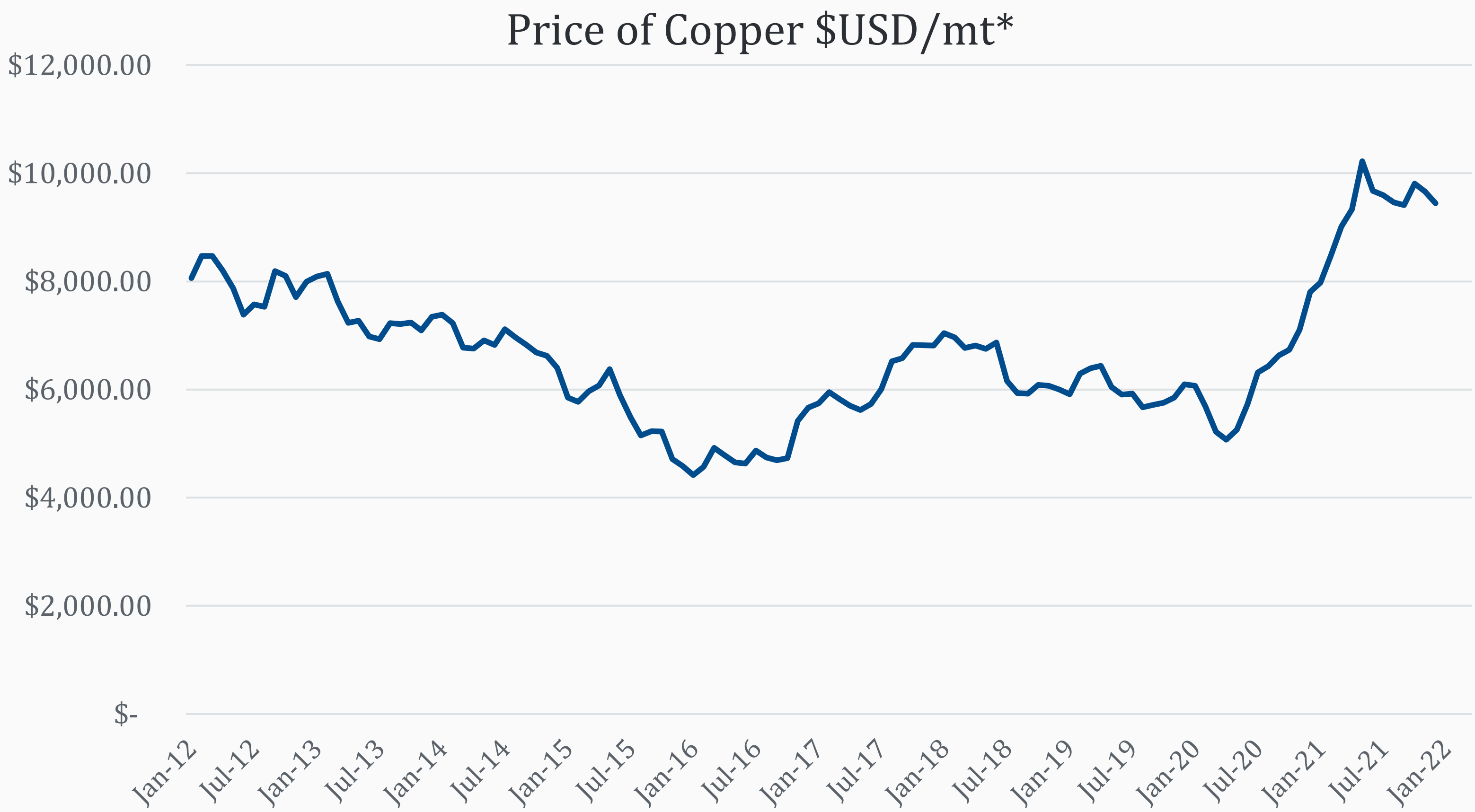
COBALT PRICING FROM FEB. 2010 – MAR. 2022



- Cobalt pricing has peaked twice in recent years due to EV demand
- Supply uncertainty and increased EV production raised 2017-2018 prices
- Another mine (Mutanda) coming back online in the Democratic Republic of the Congo will provide much of the new supply to meet growing demand
    - *Mutanda mine expected back online in early 2022*

**Source: Trading Economies (monthly tracking).*

COPPER PRICING FROM JAN. 2012 – MAR. 2022

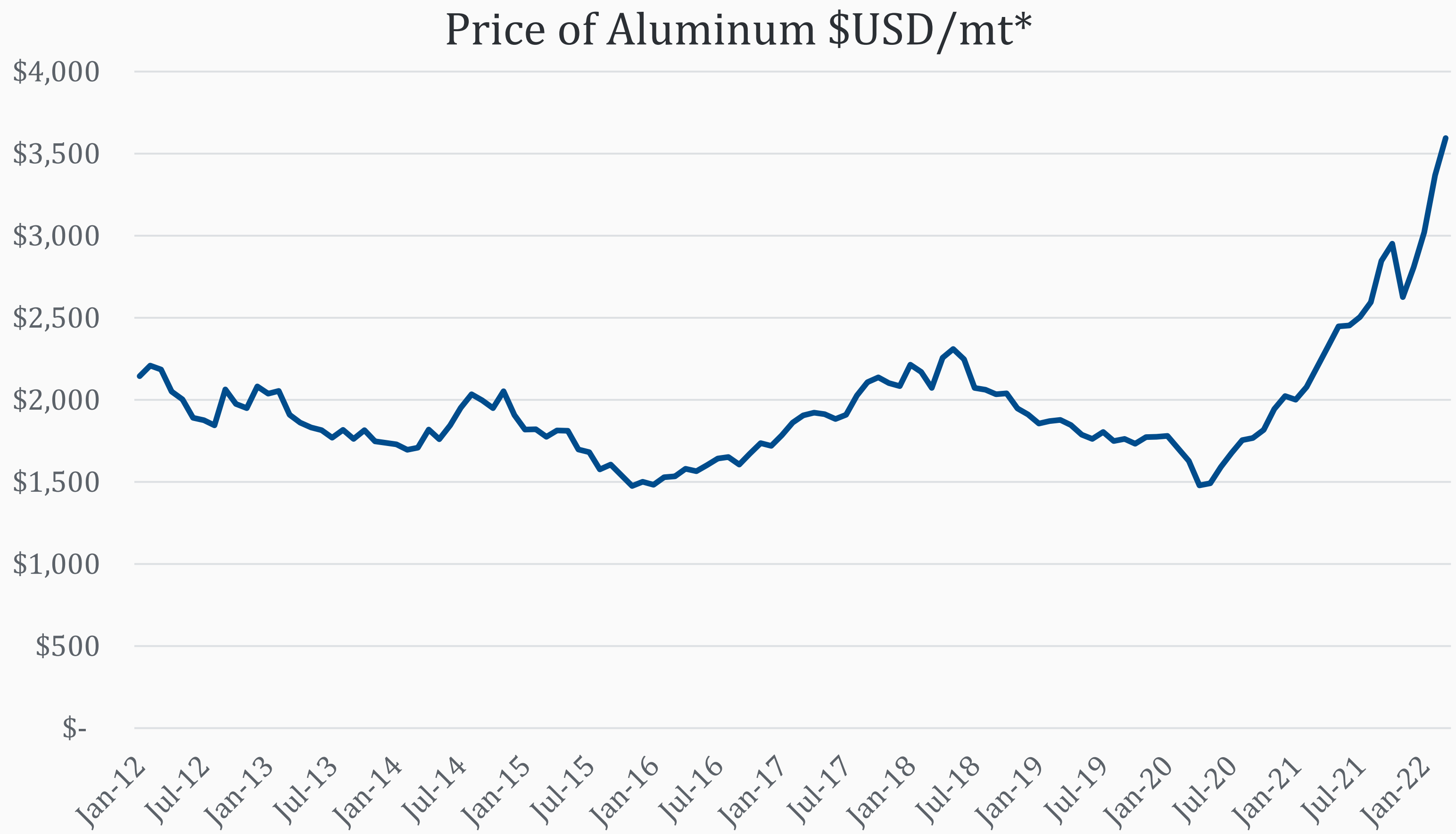


- Copper is at its highest value in 10 years
- Demand from China in late 2020 and early 2021 was the main driver for the most recent market price increases
    - Experts indicated supply chain challenges have played a role in pricing increases but have been offset by low interest rates and fiscal stimulus measures
- Experts find this price growth to be interesting since copper is one of the most mature and highly recycled commodities

**Source: Trading Economies (monthly tracking).*

PRICE UNCERTAINTY

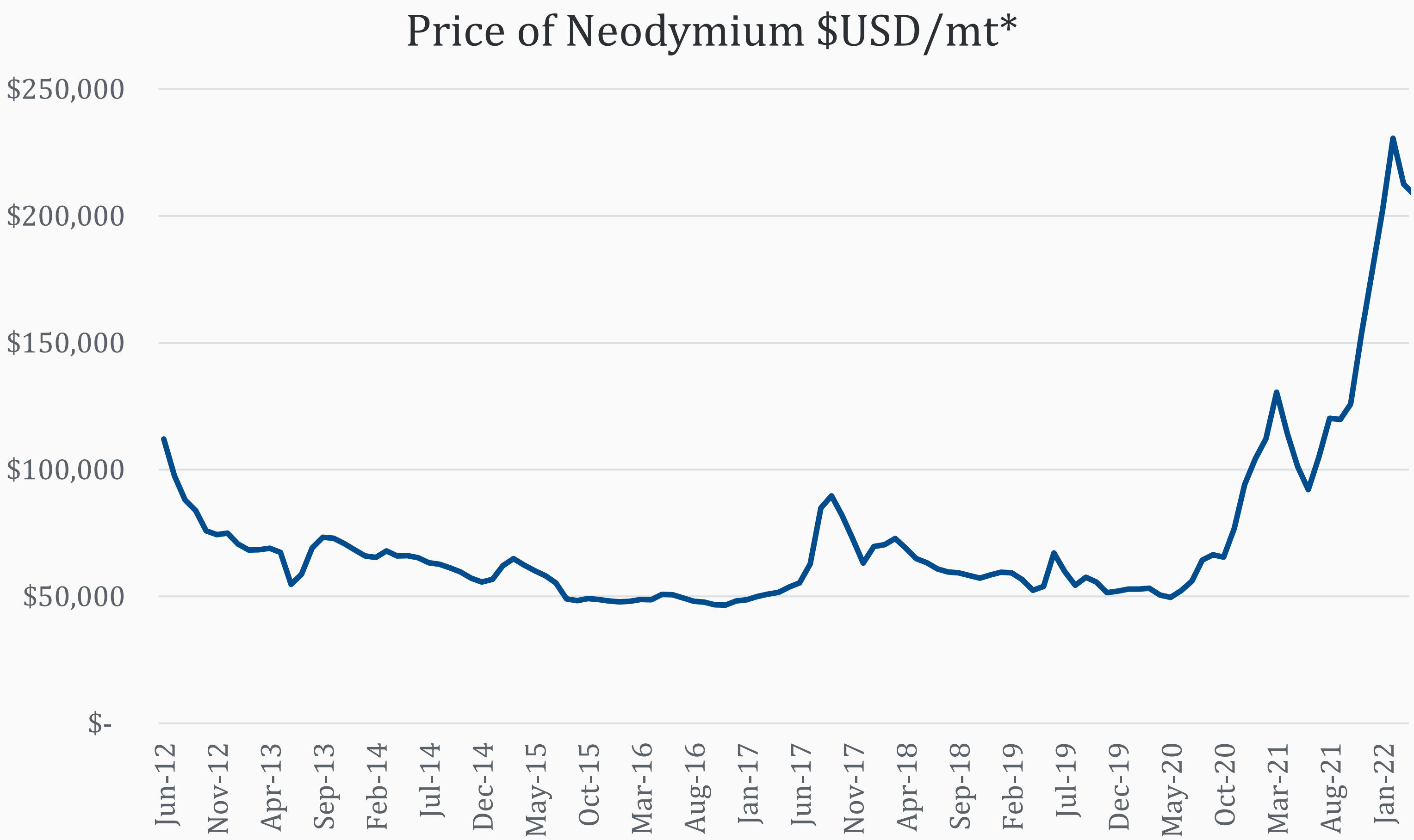
ALUMINUM PRICING FROM JAN. 2012 – MAR. 2022



- Aluminum pricing is at its highest value in 10 years
- Increased demand in homebuilding, aerospace, and EV markets
  - Price increases building on pandemic highs
- Political unrest in Guinea, a key market for the aluminum supply chain
  - Guinea is a key supplier of Bauxite to China
  - Guinea is the second largest producer of bauxite only behind Australia
- Experts find this price growth to be interesting since aluminum is one of the most highly recycled commodities

**Source: Trading Economies (monthly tracking).*

NEODYMIUM (RARE EARTH ELEMENT) PRICING FROM JUN. 2012 – MAR. 2022



- Key rare earth element neodymium (Nd) has seen an approximate 3x price increase since the November 2020 U.S. presidential election
- Rising demand from increased EV and wind energy production has been impacting Nd pricing
    - Sharp increases in pricing coming out of pandemic lows
- Decreased supply around the world has aided in the rising prices
    - China has been the only exporter to maintain a high level of production

**Source: Trading Economies (monthly tracking).*

ADDITIONAL COMMENTS

The "Buy American" Executive Order creates a murky situation often requiring unionized labor, which could create challenges in the future as several automotive companies have made announcements targeting investments in EV and battery manufacturing plants where unions are not as prevalent.

Additional U.S. employment and labor intensity impacts of EV growth is available upon request.

Level setting

- One Tesla Model Y/3 with a 75kWh battery is equivalent to ~6,000 cell phone batteries.
- The material demand for the ***entire*** mobile electronics industry today (1.5B cell phones, 164M tablets, 277M laptops) is equivalent to ~575,000 Tesla Model Y/3 vehicles. (In 2020, Tesla sold ~500,000 vehicles.)

March 31, 2022, Presidential action to secure large-capacity battery materials

President Biden is adding critical materials for the production of large-capacity batteries for the automotive, e-mobility, and stationary storage sectors to the list of items covered by the 1950 Defense Production Act.

This could help mining companies access $750M under the Defense Production Act's Title III fund. However, capital investment for a single mine, from exploration to commercial production, can range from $500M to $1.5B.

One mining project near the Salton Sea in southern California could benefit from this latest action. Controlled Thermal Resources' Hell's Kitchen Lithium and Power project is in early stages of the process. Yet, without a fully coordinated effort by Federal and State policymakers to ensure production occurs under strong environmental and labor standards, the projected 2024 production start date could be delayed.

If production of ~20,000 mt of lithium hydroxide from this site is added to the U.S.'s supply, this would equate to ~3,300 mt of Li that could be used to make large-capacity Li-ion batteries.

- Globally, this would represent an ~4% increase in Li production; this likely would not significantly impact pricing.
- Domestically, if production started in 2024-2025, it would strengthen the country's supply but a shortfall of ~60% would still exist to meet the Biden administration's 2030 target.

CONTACT US

More EVs are coming. It's an exciting technology to see being advanced. But where is the balance among energy security, mining, price, and timing within the EV battery sector? If OEM and aggressive targets are not economically viable, then a smooth transition cannot take place in the timeframes that have been announced.

Let's keep the discussion going

The information in this summary report allows for discussion about a middle way forward that also can reduce carbon emissions in internal combustion engines. This pathway may include reducing the carbon intensity of liquid fuels (biofuel, gasoline, and diesel) and improving the efficiency of new vehicles as well as identifying new applications for natural gas and renewable natural gas vehicles.

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