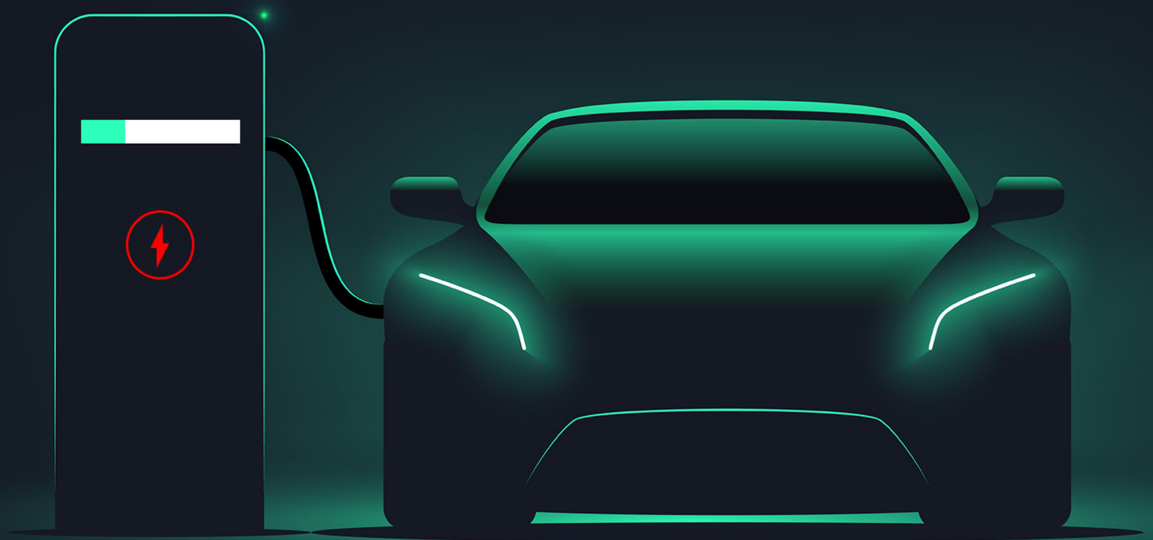
2023

FAILURE TO CHARGE

A Critical Look at Canada's EV Policy



Can Metal Mining Match the Speed of the Planned Electric Vehicle Transition?

Kenneth P. Green

CAN METAL MINING MATCH THE SPEED OF THE PLANNED ELECTRIC VEHICLE TRANSITION?

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Executive Summary

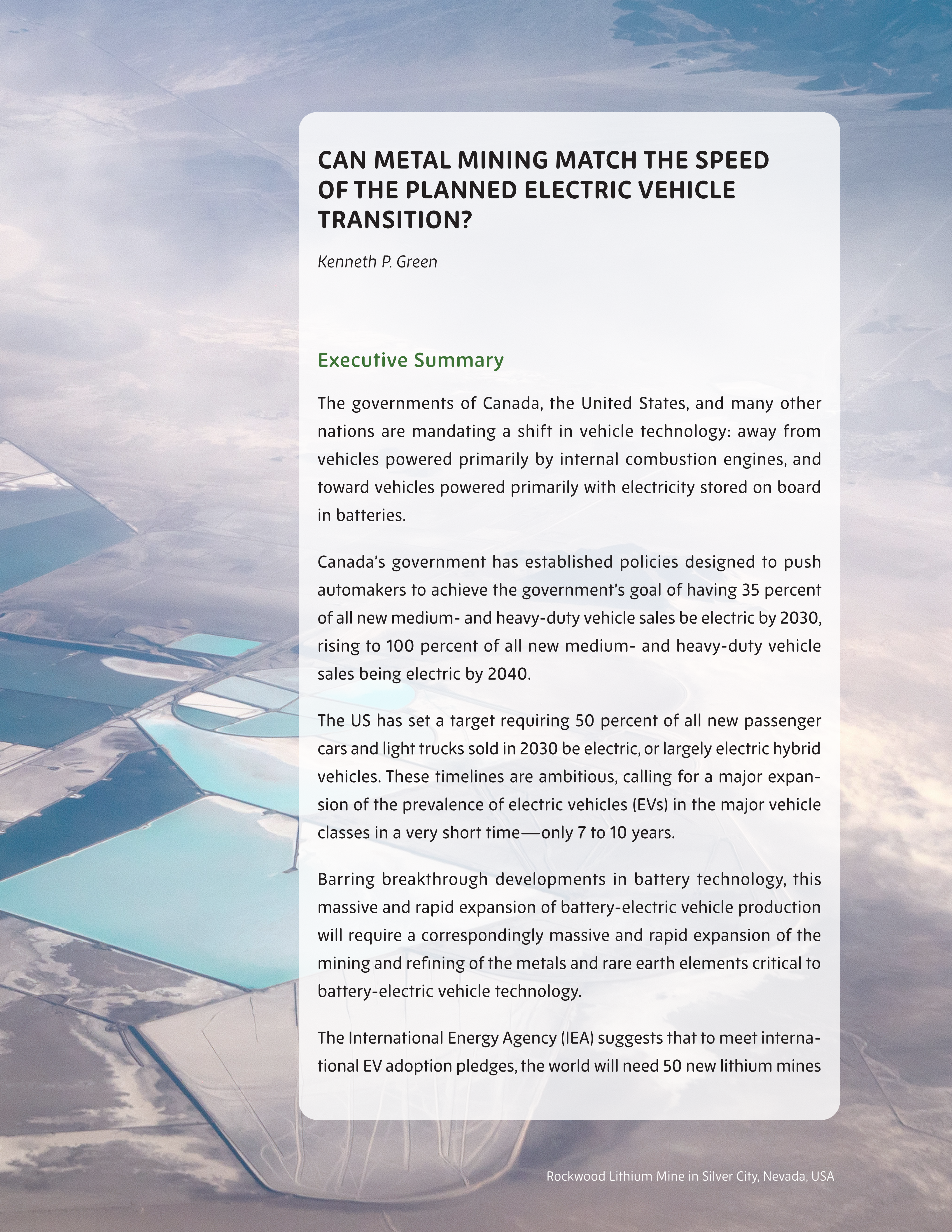
The governments of Canada, the United States, and many other nations are mandating a shift in vehicle technology: away from vehicles powered primarily by internal combustion engines, and toward vehicles powered primarily with electricity stored on board in batteries.

Canada's government has established policies designed to push automakers to achieve the government's goal of having 35 percent of all new medium- and heavy-duty vehicle sales be electric by 2030, rising to 100 percent of all new medium- and heavy-duty vehicle sales being electric by 2040.

The US has set a target requiring 50 percent of all new passenger cars and light trucks sold in 2030 be electric, or largely electric hybrid vehicles. These timelines are ambitious, calling for a major expansion of the prevalence of electric vehicles (EVs) in the major vehicle classes in a very short time—only 7 to 10 years.

Barring breakthrough developments in battery technology, this massive and rapid expansion of battery-electric vehicle production will require a correspondingly massive and rapid expansion of the mining and refining of the metals and rare earth elements critical to battery-electric vehicle technology.

The International Energy Agency (IEA) suggests that to meet international EV adoption pledges, the world will need 50 new lithium mines



Rockwood Lithium Mine in Silver City, Nevada, USA by 2030, along with 60 new nickel mines, and 17 new cobalt mines. The materials needed for cathode production will require 50 more new mines, and anode materials another 40. The battery cells will require 90 new mines, and EVs themselves another 81. In total, this adds up to 388 new mines. For context, as of 2021, there were only 270 metal mines operating across the US, and only 70 in Canada. If Canada and the US wish to have internal supply chains for these vital EV metals, they have a lot of mines to establish in a very short period.

"Mining and refining facilities are both slow to develop and are highly uncertain endeavors plagued by regulatory uncertainty and by environmental and regulatory barriers."

Historically, however, mining and refining facilities are both slow to develop and are highly uncertain endeavors plagued by regulatory uncertainty and by environmental and regulatory barriers. Lithium production timelines, for example, are approximately 6 to 9 years, while production timelines (from application to production) for nickel are approximately 13 to 18 years, according to the IEA.

The establishment of aggressive and short-term EV adoption goals sets up a potential conflict with metal and mineral production, which is historically characterized by long lead-times and long production timelines. The risk that mineral and mining production will fall short of projected demand is significant, and could greatly affect the success of various governments' plans for EV transition.

POLICY BACKGROUND

Concerned about the prospects of severe man-made climate change, governments around the world have instituted programs to phase out the use of fossil fuel-powered, internal combustion-driven transportation systems—beginning primarily with cars and light trucks—and replace them with Battery-Electric Vehicles (BEV); or vehicles mostly powered by electricity but which also feature internal combustion backup power, called Plug-in Hybrid Electric Vehicles (PHEVs).

In December 2022, the Canadian government introduced regulations that would lead to the phasing out of sales of new fossil-fuel powered, internal combustion vehicles, to be replaced by sales of vehicles designated as "Zero Emission Vehicles," or ZEV in legislation.[1] Canada's Action Plan will "set annually increasing requirements towards achieving 100 percent new light-duty zero-emission vehicle sales by 2035, including mandatory interim targets of at least 20 percent of all new light-duty vehicles offered for sale by 2026 and at least 60 percent by 2030" (Canada, 2022).

Further, to reduce emissions from medium- and heavy-duty vehicles:

> The Government of Canada will aim to reach 35 per cent of total new medium- and heavy-duty vehicle sales being zero-emission vehicles by 2030. In addition, the Government will develop a medium- and heavy-duty zero-emission vehicle regulation to require 100 per cent of new medium- and heavy-duty vehicle sales to be zero-emission vehicles by 2040 for a subset of vehicle types based on feasibility, with interim 2030 regulated sales requirements that would vary for different vehicle categories based on feasibility, and explore interim targets for the mid-2020s. (Government of Canada, 2022)

According to the cost-benefit analysis published in the *Canada Gazette* describing Canada's new ZEV transition plan:

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1 This categorization scheme includes BEVs only, not PHEVs.

> From 2026 to 2050, the proposed Amendments are estimated to have incremental ZEV vehicle and home charger costs of $24.5 billion, while saving $33.9 billion in net energy costs. These impacts accrue to those who switch to ZEVs in response to the proposed Amendments. The cumulative GHG emission reductions are estimated to be 430 megatons (Mt), valued at $19.2 billion in avoided global damages. The proposed Amendments are thus estimated to have net benefits of $28.6 billion and would help Canada meet its GHG emissions reduction targets of 40 per cent below 2005 levels by 2030 and net-zero emissions by 2050. (Canada Gazette, 2022)

As Canada and the United States share an integrated automobile market, it is also worth noting that the US has plans for a transition to electric vehicles, though the strategies of the two countries differ considerably. US and Canadian plans for vehicle electrification are different in forms and functions, timelines, and targets. The first distinction is that the US includes plug-in hybrid electric vehicles into its "ZEV" category, along with fuel cell electric vehicles, which are currently niche vehicles sold primarily in California, rather than mainstream production vehicles (Voelcker, 2022).

In the United States, the Biden Administration published Executive Order 14037 in 2021 which contained the stated goal "that 50 per cent of all new passenger cars and light trucks sold in 2030 be zero-emission vehicles, including battery electric, plug-in hybrid electric, or fuel cell electric vehicles" (United States Federal Register, 2021). The inclusion of plug-in hybrid vehicles (generally not considered to be zero-emission vehicles) is a significant distinction between the US and Canadian electric vehicle plans.

President Biden also issued another executive order in 2021 that would require the federal government to stop acquiring gasoline-powered cars in its own vehicle fleets. Executive Order 14057 requires "100 percent zero-emission vehicle acquisitions by 2035, including 100 percent zero-emission light-duty vehicle acquisitions by 2027" (United States Federal Register, 2021b).

Internationally, vehicle electrification goals are different still. The International Energy Agency (IEA) in its *Global EV Outlook 2021* characterizes the collective EV target of "all existing policies, policy ambitions and targets that have been legislated for or announced by governments around the world. It includes current EV-related policies and regulations, as well as the expected effects of announced deployments and plans from industry stakeholders. STEPS [the "Stated Policy Scenario" of the IEA] aims to hold up a mirror to the plans of policy makers and illustrate their consequences" (IEA 2021a: 73).

In this scenario, the IEA finds that "the collective target of the EV30@30 signatories [a coalition of city governments and EV industry groups] to achieve 30 percent sales share in 2030 for light-duty vehicles, buses and trucks is surpassed at the global level (reaching almost 35%), which reflects increasing ambitions for widespread EV deployment" (IEA 2021a: 73).

It is self-evident that increasing production of electric vehicles will require a corresponding increase in the constituent materials from which they are manufactured. In the case of electric vehicles powered by large batteries, one must assume that increasing the production of electric vehicles will require a massive increase in the production of metals used in battery and EV manufacturing, such as lithium, nickel, cobalt, copper, manganese, graphite, and other elements sometimes designated as rare earth elements (REEs), or energy critical elements.

Canada has begun to ramp up its production refining capacity for lithium and other rare earth elements required for the electric vehicle transition. For example, the Canadian government recently showcased lithium production in Canada. In James Bay, Quebec, the government has approved the James Bay Lithium Mine Project, a proposal to mine 5,800 tonnes of lithium-bearing ore per day in the Eastman Cree community (D'Andrea, 2023). In Saskatchewan, the government has approved a plan to produce and refine lithium at a plant in the southern part of the province. According to the government, "Stage one of the project will produce [from Saskatchewan oilfield brines] 1 to 1.75 kilograms (kg) of lithium hydroxide per day. Stage two will include the construction of one of Canada's first lithium extraction and refining facilities, which will produce approximately one tonne of lithium hydroxide per day, resulting in 365 tonnes per year. This will serve as a demonstration plant prior to full commercialization" (Saskatchewan, 2020).

Rare earth elements production is also underway in the NWT with the processing and refining of two rare earth elements critical to the production of powerful magnets used in electric vehicle motors to take place in Saskatchewan (Frew and Ponticelli, 2023). The Nechalacho mine "hosts a world-class resource" of rare earth ores, relatively rich in neodymium and praseodymium, metals used in the production of high-strength magnets used in electric motors and battery alloys (Vital Metals, 2020). Most recently (as of time of writing), the Canadian government announced that it will pay CAN$13 billion in subsidies to Volkswagen to establish a battery manufacturing facility in Ontario (Scherer, 2023). This pledge was matched with a CAN$15 billion subsidy to Stellantis for a second battery manufacturing facility in Ontario (Shakil, 2023).

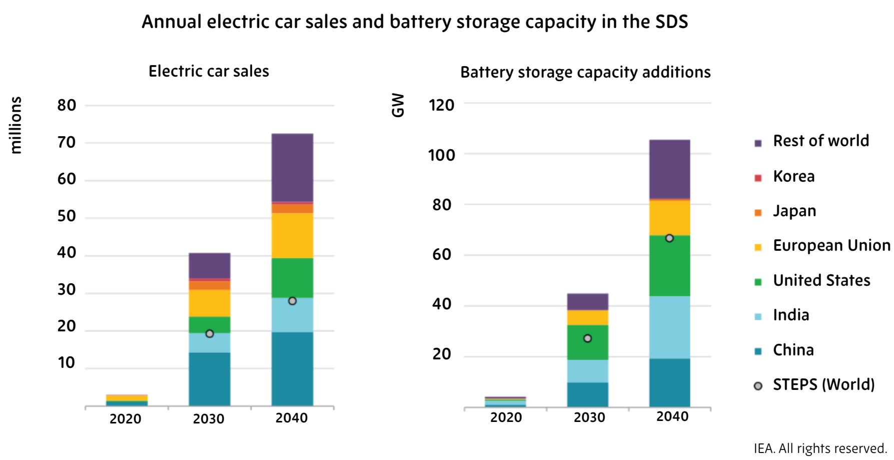
The International Energy Agency would like to see Canada move still more quickly in its development of rare earth mining and refining capacity. At a Canadian government-organized panel discussion in February 2023, Fatih Birol, the head of the IEA, "warned that the energy shortages currently gripping Europe could be repeated as the world transitions to cleaner fuels, if Western countries do not increase the availability of rare earth minerals and develop friendlier sources of them." Further, according to an article in the *Globe and Mail* covering the event, Mr. Birol said he would like to see countries like Canada more involved on the international stage because "there is rule of law, there is transparency, and there is also accountability of the government… The sooner that happens, the better, he said" (Walsh and Graney, 2023).

WHAT DO GLOBAL VEHICLE ELECTRIFICATION GOALS LOOK LIKE, NUMERICALLY?

Figure 1, from *The Role of Critical Minerals in Clean Energy Transition*, shows expected EV market penetration to 2030 under IEA's Sustainable Development Scenario, or SDS. The SDS reflects what the IEA believes would be required to satisfy international agreements under the Paris Climate Accords (IEA, 2021b).[2]

As is readily apparent from the graph, both electric vehicle sales and battery storage capacity growth are expected to be several orders of magnitude greater than production in 2020. Electric car sales (in the left panel), are expected to rise from approximately 3 million in 2020,

Figure 1: The Adoption of EVs and Battery Storage is Set to Accelerate Rapidly over the Coming Decades



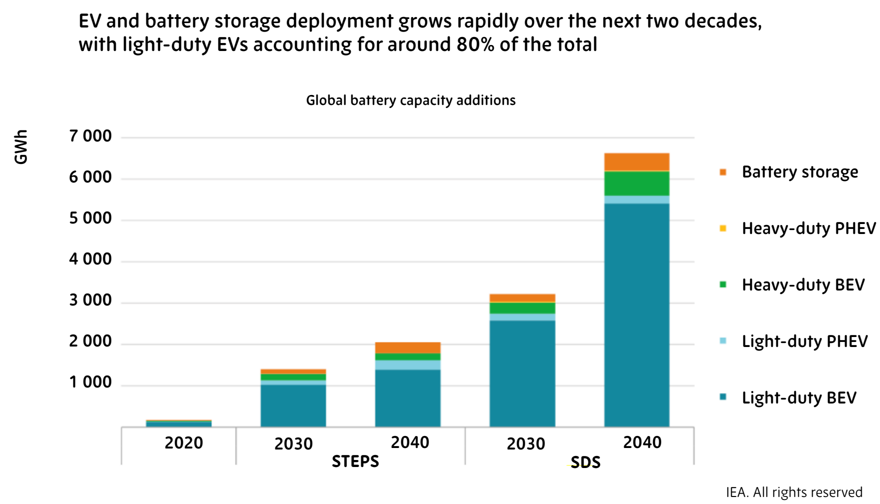
Note: Electric cars include battery electric and plug-in hybrid electric passenger light-duty vehicles, but exclude 2/3-wheelers.
Source: IEA (2020c).

Source: IEA, 2021b: 84.

2 The International Energy Agency publishes a great deal of data regarding electric vehicle production, composition, manufacturing, and production of raw materials. As the IEA is considered an authoritative, quasi-independent source of information on these issues, we will rely heavily on their latest publications in this study.

At the same time, the author makes no claims regarding the plausibility of IEA's mathematical modeling used to generate some of these estimates. However, as it is assumed that IEA's data will significantly infuse government policy development, these modeled estimates are worthy of attention. As with most mathematical modeling exercises, which frequently rely (of necessity) on an array of subjective assumptions, the author advises caution in assuming these models are reliable reflections of reality.

Figure 2: EV and Battery Storage Deployment Growth through 2040



Source: IEA, 2021b: 87.
Note: STEPS = Stated Policy Scenarios of world governments pursuant to Paris climate accord.
SDS = Sustainable Development Scenarios of the International Energy Agency.

to 40 million in only 10 years: a more than 10-fold increase, and to then nearly double in the decade between 2030 and 2040.

Readers should note that this IEA model includes "plug-in hybrid" electric vehicles which, as previously mentioned, are not treated uniformly in various national and international plans regarding vehicle electrification targets and timelines discussed above.

Correspondingly, IEA estimates that battery production will also increase significantly in coming years as is displayed in figure 2.

As with figure 1, one will note that the "ramp" of increased battery power production is very steep. As the IEA states, "In the SDS [Sustainable Development Scenarios], global installation of utility-scale battery storage is set for a 25-fold increase between 2020 and 2040, with annual deployment reaching 105 GW by 2040. The largest markets for battery deployment in 2040 are India, the United States and China" (IEA, 2021b: 86).

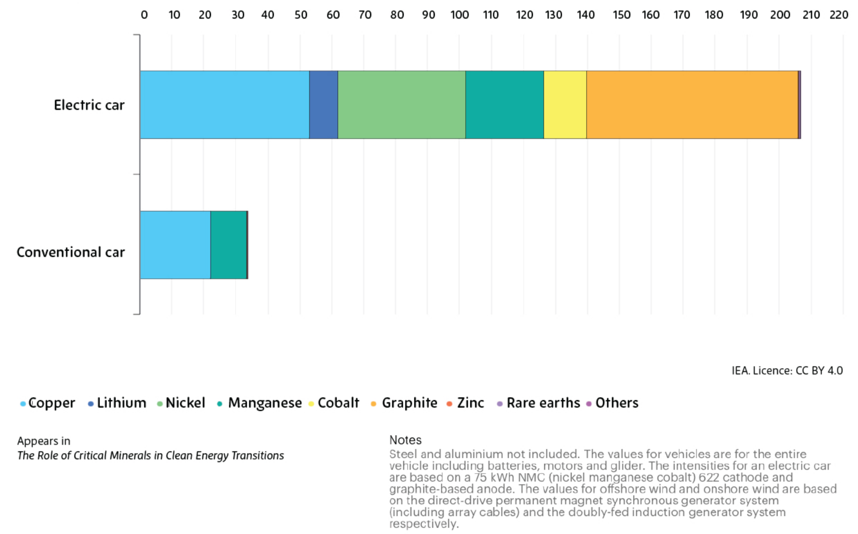
The increased production of batteries will inevitably lead to increased demand for the metals used in their fabrication. Hence, the IEA also projects significant growth in demand for EV battery metals and minerals.

HOW WILL GLOBAL VEHICLE ELECTRIFICATION INFLUENCE MINERAL AND METAL PRODUCTION REQUIREMENTS?

According to the International Energy Agency, electric vehicles use about six times more rare metals than do internal combustion vehicles. Figure 3 breaks this out graphically by the various metals required for EV production. The data in figure 3 show the key metals used in the vehicle electrification equation. Copper, lithium, nickel, cobalt, and graphite stand out sharply as components of electric vehicles that will be needed in quantities far higher than is the case for conventional internal combustion vehicles.

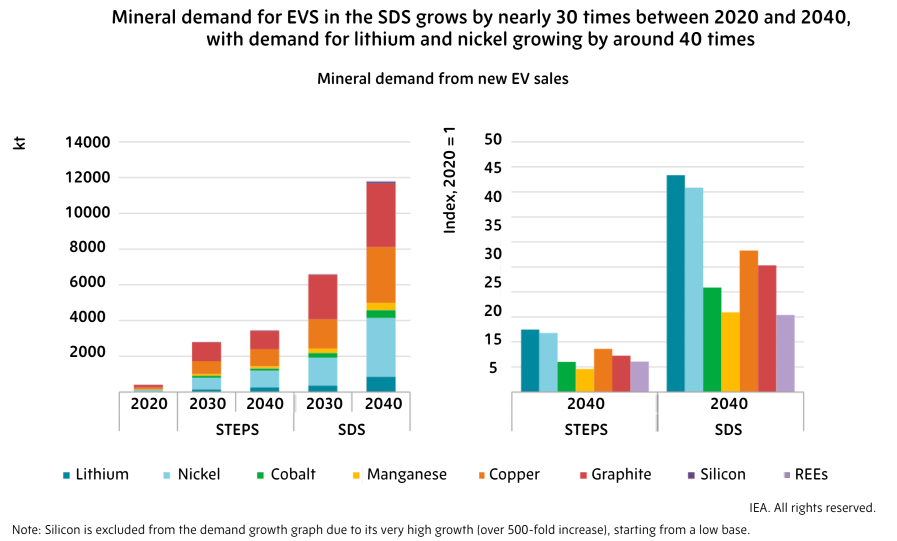
Figure 4 puts this information into context with respect to IEA's projected growth in mineral demand for EVs through 2040. Readers will note that the chart of expected demand essentially shows exponential growth. Looking at the right-hand panel of the chart, one notes that two metals—lithium and nickel (critical battery elements) are expected to

Figure 3: Minerals Used in Electric Cars Compared to Conventional Cars (kg/vehicle).



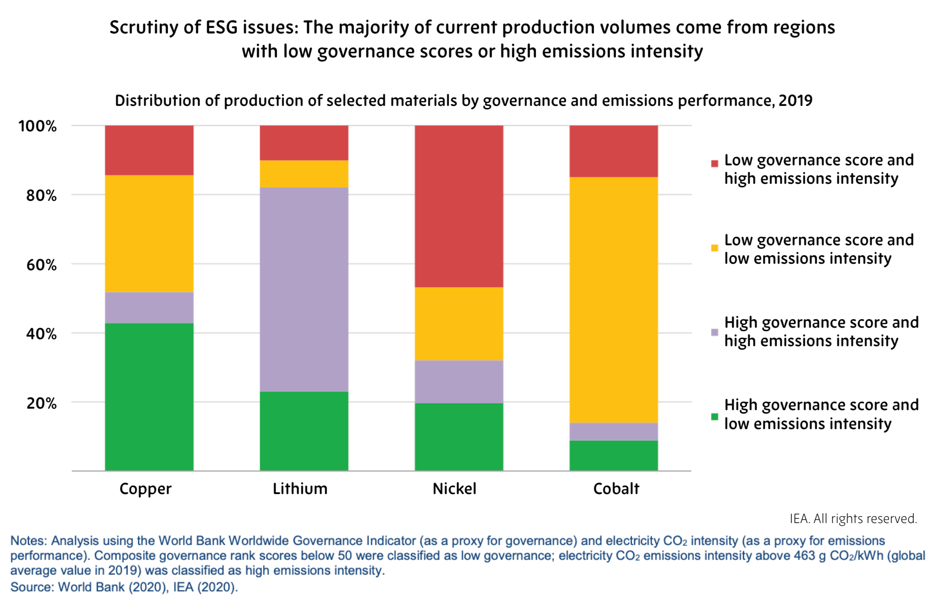
Source: IEA 2021d.

Figure 4: Projected Growth in Mineral Demand for EVs, 2020 through 2040.



Source: IEA, 2021b: 98.
Note: STEPS = Stated Policy Scenarios of world governments pursuant to Paris climate accord.
SDS = Sustainable Development Scenarios of the International Energy Agency.

Figure 5: Distribution of the Production of Selected Minerals by Governance and Emissions Performance, 2019



Source: IEA, 2021b: 126.

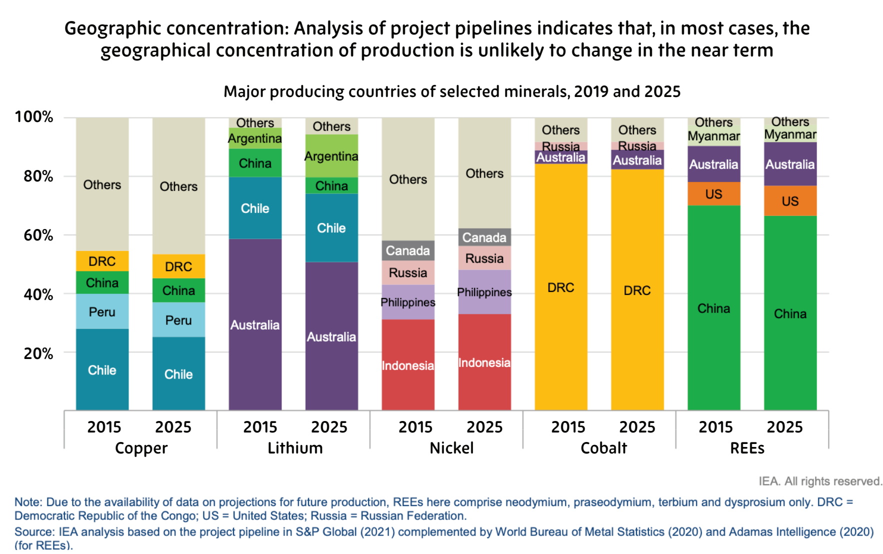
see the greatest growth in demand, followed by copper (a key component of electronic systems), and graphite, also a critical component in the production of batteries. Added demand for steel-making metals (manganese and cobalt), while large, is lower than that related to EV battery production.

Figure 5 shows where the International Energy Agency expects the metals and minerals needed for the electric vehicle transition to come from, and characterizes the quality of governance in the mining regions that currently produce needed EV metals.

Figure 6 suggests, further, that the IEA does not expect the production locales of these critical metals to change very much in the near future.

How will all of this play out with regard to the mining of EV battery metals and minerals? In its *Global Electric Vehicle Outlook 2022*, the IEA again offers estimates. As Figure 7 shows, both of IEA's future scenarios require a massive increase in the number of mines needed to provide materials for every aspect of the EV transition. Fifty new lithium mines are needed by 2030, in the "Announced Pledges scenario" (a variation

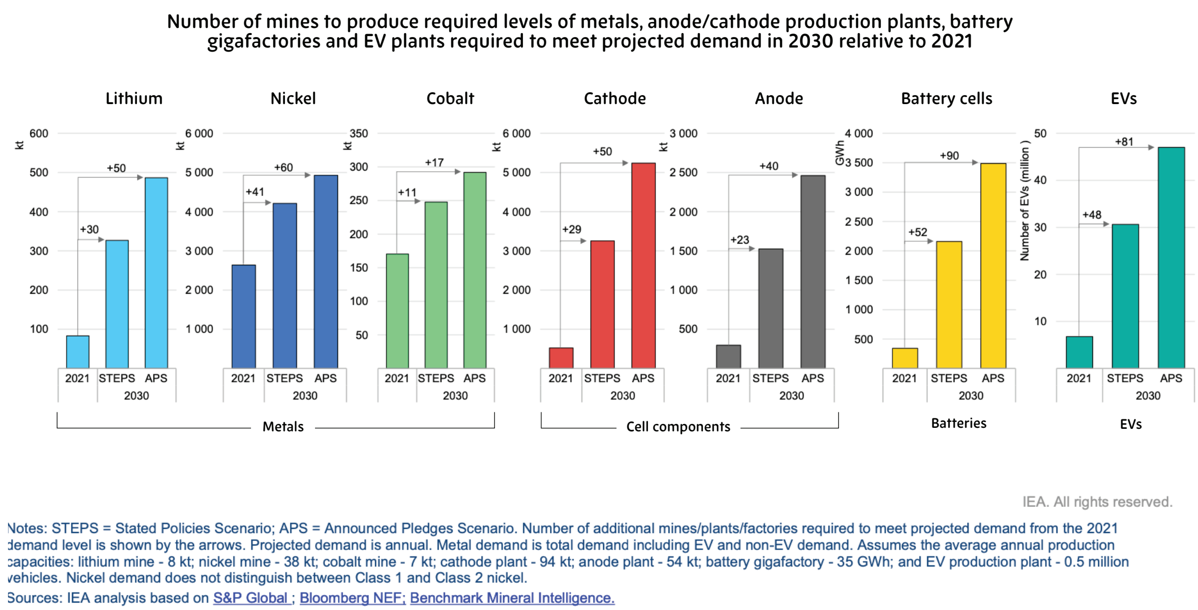
Figure 6: Expected Change in Distribution of Countries Producing EV Minerals, 2019 to 2025



Source: IEA, 2021b: 121.

on the STEPS scenario based on established government pledges) along with 60 more nickel mines, and 17 more cobalt mines. The materials needed for cathode production will require 50 more mines, and anode materials another 40. The battery cells will require 90 more mines, and EVs themselves another 81 (IEA, 2022: 175). In total, this is 388 new mines. For context, as of 2021, there were only 270 metal mines operating across the US, and only 70 in Canada.

Figure 7: Number of Mines Required to Produce Needed Minerals for the Growth of Electric Vehicles

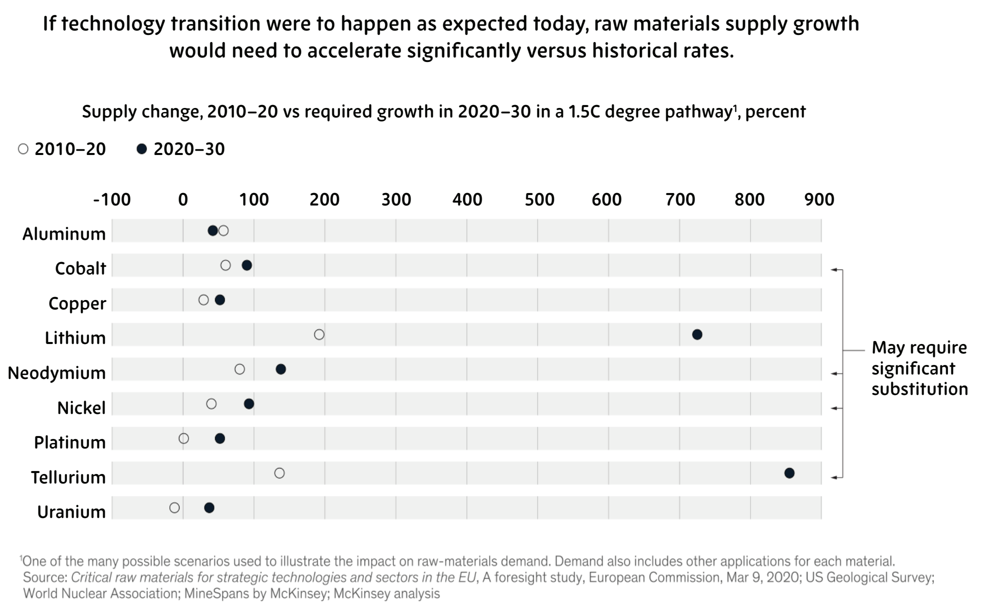


Source: IEA, 2022: 175.
Note:: STEPS = Stated Policy Scenarios of world governments pursuant to Paris climate accord.
SDS = Sustainable Development Scenarios of the International Energy Agency.
APS = Announced Pledges Scenario (Assumed comparable to SDS above).

In a 2022 article titled "The Raw-Materials Challenge: How the Metals and Mining Sector Will Be At the Core of Enabling the Energy Transition," the McKinsey company shows how it envisions the supply of raw materials for metals would have to expand from current levels to meet the EV sales growth targets under a scenario of limiting climate change to 1.5°C (which is essentially the Paris Accord upper limit for containing climate change).

As figure 8 shows, while all metals production is projected to increase, lithium production is expected to increase over 700 percent, with demand running so high that substitute elements could be required to meet demand.

Figure 8: Raw Material Supply Growth Needed to Satisfy Predicted Electric Vehicle Sales Growth



Source: McKinsey, 2022.

IS MINING FOR EV METALS AND MINERALS LIKELY TO KEEP UP WITH PROJECTIONS LIKE THOSE OF THE IEA AND MCKINSEY?

A critical assumption embedded in the idea of an EV transition is that the world will be able to produce the materials—particularly the metals—needed to build electric vehicles, in government's chosen quantities, on government's chosen timelines. Those materials include numerous metals, including copper, lithium, nickel, manganese, cobalt, graphite, and a smattering of other metals and minerals generally lumped into the category of rare earth elements. Skeptical voices are, well, skeptical.

In an interview with Yahoo! Finance, Keith Phillips, CEO of Piedmont Lithium (PLL), told reporter Akiko Fujita that "There's going to be a real crunch to get the material. We don't have enough in the world to turn that much [lithium] production in the world by 2035." Phillips continued to explain that, "…a slow permitting process has stalled approvals for new production sites. Meanwhile, China has continued to dominate the industry, refining more than half of all lithium supply while Australia and Chile remain the largest producers in the world. Projects get permitted [in Australia] in under a year… Here, it's two, four, six, seven, eight years, which is a problem, especially in a business that's booming so fast" (Fujita, 2022).

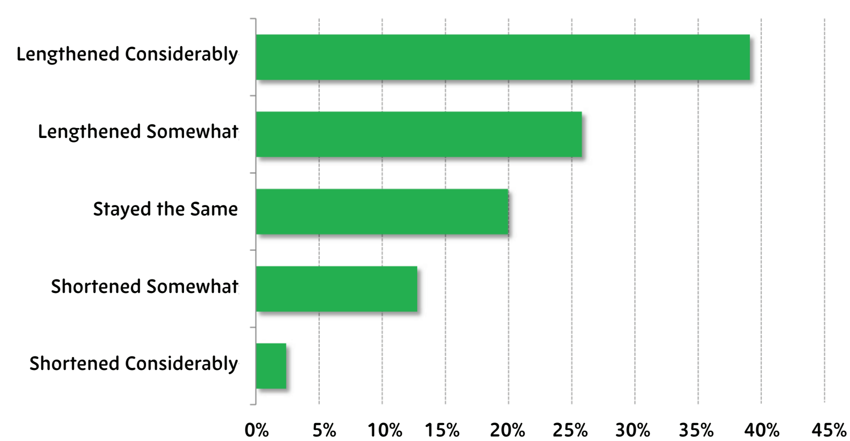
Others believe the fears of a Lithium crunch are overblown. In an article by David Kramer in *Physics Today*, Benchmark (a mineral-market analysis firm) product director Andrew Miller observes that while forecast shortages take into account what's happening now, and known to be in development, "lithium is not scarce, so the question is how quickly resources can be developed or accelerated to meet these requirements." In the same article, Roderick Eggert, an economics professor at the Colorado School of Mines, is quoted as observing, "There is a significant amount of unused mining capacity, principally in Australia, that should allow growth in demand over the next few years to be met without a dramatic increase in price." Eggert further observes that "There are a lot of undeveloped resources from both Australia and South America, and they will compete against one another" (Kramer, 2021).

For all that mining is a massive global endeavour, hard data on the timelines of mining planning, permitting, construction, and production are scarce in publicly accessible literature. The Fraser Institute has attempted to measure timeline uncertainty, and its growth, in publications since 2015. In the first effort, the author (with colleague Taylor Jackson), looked at the timelines of permit acquisition in Canada. What we found, even then, is grounds for skepticism about the rapid expansion of mining activities in Canada, or in countries with comparable regulatory regimes (Green and Jackson, 2015).

As figure 9 shows, even in 2014 (when the data was gathered) mining permit times in Canada were perceived by mining company executives (globally) to have been lengthening for 10 years.

Mining permitting and development timelines do not look much better in the United States. In an article in *Mining Magazine* from 2020, Kevin Shaw and Dan Whitmore give an example of one US-based mining endeavour that took rather longer than expected: "The property for the Kensington gold mine was purchased in 1987. The initial permits

Figure 9: Changes in the Time-to-Permit Approval, 2004 to 2014.



Source: Jackson and Green, 2015: 5.

for the mine were requested in 1990, and production was anticipated to commence in 1993; however, a series of permitting issues resulted in the mine only beginning commercial production in 2010 (a delay of 17 years). Litigation concerning a key permit that had been issued went all the way to the U.S. Supreme Court before being upheld. At the outset, the Kensington gold mine was estimated to cost US$195 million to build. The final cost for construction was US$290 million. At the beginning of the project, production costs were estimated to be US$225 per ounce of gold. At the end, production costs had increased by 34 percent per ounce and the company reduced its anticipated production of gold by almost a third" (Shaw and Whitmore, 2020).

Shaw and Whitmore described another US mining project, the Rosemont Copper project, that was submitted to the US Forest service for approval in 2007, but litigation and opposition by indigenous groups delayed the project for over 13 years (Shaw and Whitmore, 2020).

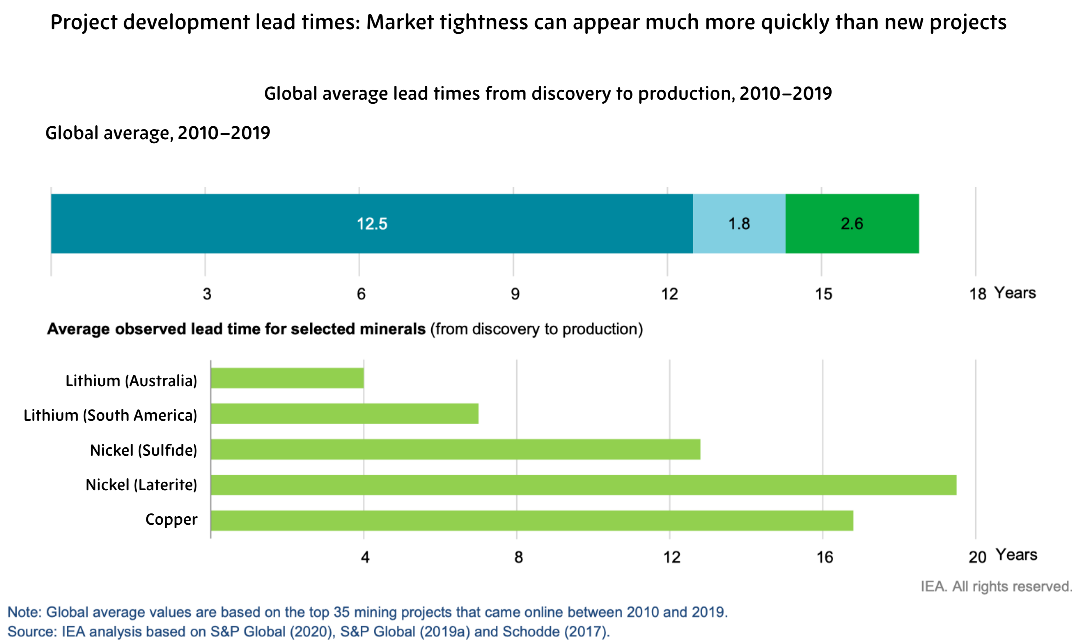
A 2016 report by the United States Government Accountability Office (GAO) is somewhat dated, but its key findings are still revealing:

> From fiscal years 2010 through 2014, BLM [Bureau of Land Management] approved 66 mine plans, and the Forest Service approved 2 mine plans for hardrock mines that varied by mineral type, mine size, and location. The length of time it took for the agencies to reach the third step of the five-step mine plan review process—the step in which the mine plan is approved—ranged from about 1 month to over 11 years and averaged approximately 2 years. (GAO, 2016)

In figure 10, the International Energy Administration also offers data regarding the timelines for development of lithium and nickel mines, both globally and in select jurisdictions. As a reminder, lithium, the component most crucial for electric vehicle batteries, is likely to be the rate-controlling metal needed for the EV transition to unfold according to the various ambitious governmental timelines.

The IEA also discusses the importance of investment lead times in the production of various elements and stages of EV battery production.

Figure 10: Mining Project Development Lead Times (in Years)

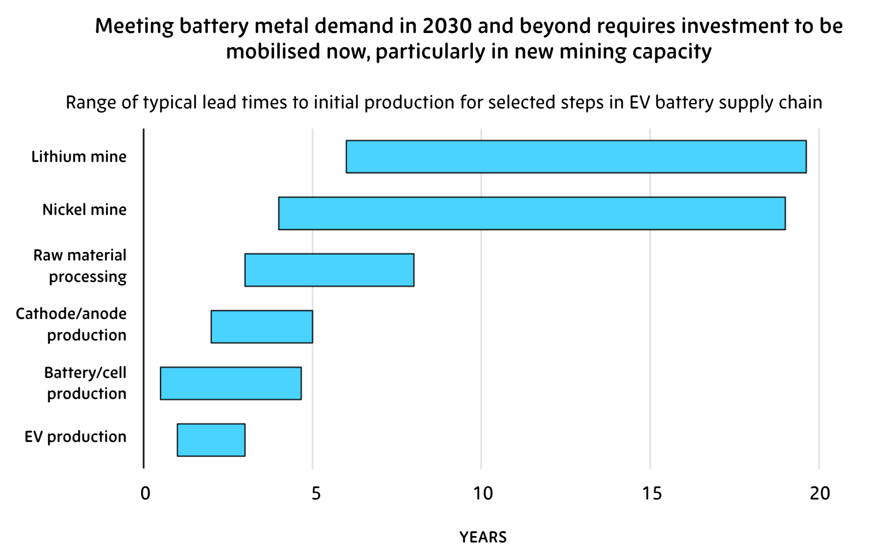


Source: IEA, 2021b: 122.

Figure 11 shows what IEA considers "typical" lead times to initial production (i.e., mining) of lithium, nickel, and battery cathode ingredients (such as cobalt and magnesium), production of the batteries themselves, and production of electric vehicles. As can be seen, the lead times—the time before production begins—are relatively short for the actual manufacturing and building of products (EVs and batteries), but significantly longer for the metals and minerals that go into them. While the lead time for manufactured aspects of EV production, such as EV production itself, is only estimated at about three years in this figure, and battery production at about five years, lithium and nickel lead times are upwards of 15 years.

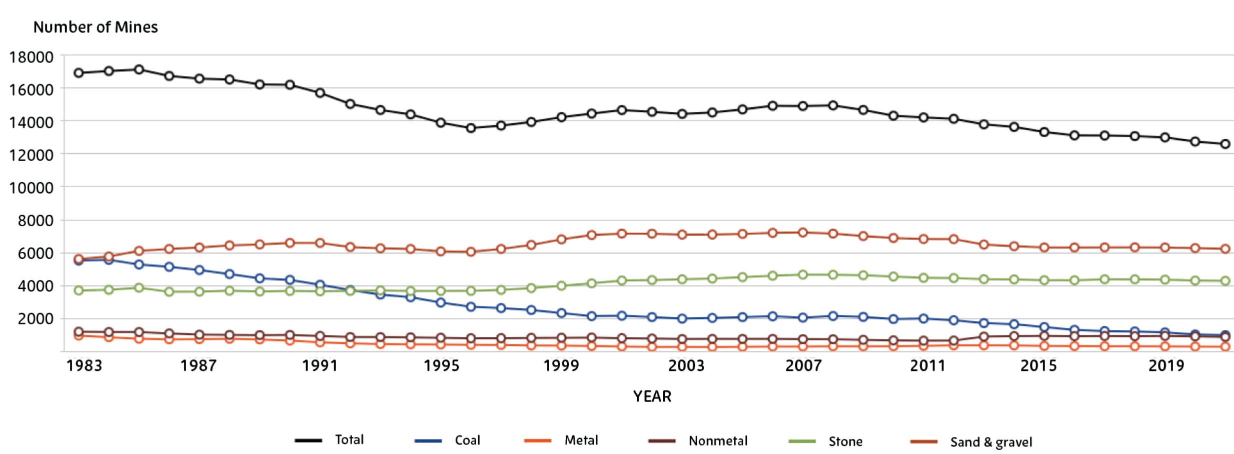
Finally, historic trends in mining, at least in the US, do not lend much confidence to the idea of a massive, rapid increase in the production of EV metals or other mined materials. The US National Institute of Occupational Safety and Health (NIOSH) data shows that in the US at least, the number of active mines has declined steadily since 1983, with metals production peaking slightly from 2000 to 2010, then leveling off through 2021 (figure 12). Note that as of 2021, the US had only 270 metal mines in operation and Canada, according to data-aggregator Statista, had 70 metals mines and 931 non-metals mines in production that year, for a total of 1,001 active mines (Statista, 2023).

Figure 11: Typical Lead Times to Initial Production for Selected Steps in the EV Battery Supply Chain



Source: IEA, 2022: 178.

Figure 12: Number of Active Mines in the United States by Sector and Year, 1983 to 2021



Source: Centers for Disease Control and Prevention, 2023.

DISCUSSION AND CONCLUSION

Global governments, including the governments of Canada and the United States, have adopted ambitious targets for the electrification of transportation in furtherance of climate policies adopted by those same governments.

To summarize, both Canada and the United States have adopted aggressive targets for the adoption of electric vehicles. In Canada's case, the current goal is to "reach 35% of total new medium- and heavy-duty vehicle sales being zero-emission vehicles by 2030. In addition, the government will develop a medium- and heavy-duty zero-emission vehicle regulation to require 100% of new medium- and heavy-duty vehicle sales to be zero-emission vehicles by 2040" (Canada, 2022: 1). For the United States, the goal is "that 50 per cent of all new passenger cars and light trucks sold in 2030 be zero-emission vehicles, including battery electric, plug-in hybrid electric, or fuel cell electric vehicles." (United States Federal Register, 2021) Internationally, the International Energy Agency finds that "the collective target of the EV30@30 signatories [a coalition of city governments and EV industry groups] to achieve 30% sales share in 2030 for light-duty vehicles, buses and trucks is surpassed at the global level (reaching almost 35%), which reflects increasing ambitions for widespread EV deployment" (IEA, 2021c).

With these highly ambitious timelines comes increased demand for the metals and minerals needed to produce electric vehicles and batteries. The International Energy Agency estimates that "Mineral demand for [EV battery] storage in the SDS [Sustainable Demand Scenario] grows by over 30 times between 2020 and 2040, with demand for nickel and cobalt growing by 140 times, and 70 times respectively" (IEA 2021b: 104).

Experience with mining production lead times, as discussed above, suggest that for metals such as lithium and nickel, lead times of close to 15 years are common. In turn, this suggests that IEA's predicted aggressive growth rates are unlikely to be feasible over such short time horizons. In the case of the 2030 scenarios, there are only 7 years remaining to achieve a significant expansion of metals production.

As mentioned in the *Globe and Mail* article cited earlier, "It can take up to 25 years to get a minerals mine into production [in Canada]—far slower than international competitors such as Australia. Speaking to reporters after the panel, Mr. Wilkinson [Canada's Minister of Natural Resources] said the average time it takes is about 12 to 15 years, but added that even that is too long. 'If it takes us 12 to 15 years, we are going to have a real problem,'" he said (Walsh and Graney, 2023).

Finally, plans for a rare earth elements mine in Kiruna, Sweden, also suggest that the timeline to production is lengthy. In a press release from mining company LKAB, the company president observes:

> "If we look at how other permit processes have worked within our industry, it will be at least 10-15 years before we can actually begin mining and deliver raw materials to the market. And then we are talking about Kiruna, where LKAB has been mining ore for more than 130 years. Here, the European Commission's focus on this issue, to secure access to critical materials, and the Critical Raw Materials Act the Commission is now working on, is decisive. We must change the permit processes to ensure increased mining of this type of raw material in Europe. Access is today a crucial risk factor for both the competitiveness of European industry and the climate transition," says Jan Moström. (LKAB, 2022)

Government's history with picking winning and losing technologies, and executing on those choices over longer timeframes that involve high levels of uncertainty is not particularly encouraging. In the case of vehicle electrification, it may seem different this time—that the transition is inevitable, and that all of the investments, and planning, and development of new mines and refining facilities may bear fruit. But if it does, in this electric vehicle space, it will be a surprising result. Previous efforts to enshrine electric vehicles dating back to the mid-1900s have failed repeatedly, leaving behind the economic wreckage of those who, in good faith, dove headlong into government's plans, along with unwitting and sometimes unwilling taxpayers who were tapped to fund the effort.

> "Because the conceit of planners vastly outstrips their knowledge of the fine workings of the economy… government technology-choosing initiatives offer far more bust than boom."

Fossil fuels may be derided for their notorious boom and bust cycles, but government's picking and choosing what they think will be winning technologies in the market and in society also has boom and bust cycles. However, because the conceit of planners vastly outstrips their knowledge of the fine workings of the economy, as economists like Milton Friedman and others have repeatedly observed, government technology-choosing initiatives offer far more bust than boom. This is the most likely prospect for the global government push to mandate vehicle electrification at massive scale and at prohibitively high speed.

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