“DYNAMICS OF THE GLOBAL BATTERY ELECTRIC VEHICLE MARKET”

Ronald L. Miller, P.E., CEM, REP, MBA

ABSTRACT:

The de-carbonization of our modern global society is moving forward at a rapid pace, with increased renewable energy supplies and the replacement of internal combustion engines (ICE) with battery electric vehicles (BEV).

The BEV market will be driven by: 1) EV power demand, 2) capacity planning for generation and grid improvements, 3) market leader advantages, 4) key minerals required and their location, and supply chain constraints, and 5) the advantages for one country to lead BEV development.

Identifying the what, why, and how of this dynamic changeover will be key for business leaders as they anticipate, understand, and exploit to improve their business during the future acceleration toward BEVs.

BEV POWER DEMAND MODELING:

As governments and businesses evaluate the changeover from ICE to BEVs, the impact of this energy transition must be modeled and identified. If every car and truck using petroleum products in the U.S. were converted to an BEV, the country would see a huge spike in electricity demand, along with the attendant spike in generation, transmission, and distribution capacity, all at a huge capital cost.

In 2019, the U.S. used 12.091 million barrels of oil per day for gasoline and distillate demand, or an equivalent of 2.8 million gigawatt-hours (GWh) of electricity as shown in Figure 1.

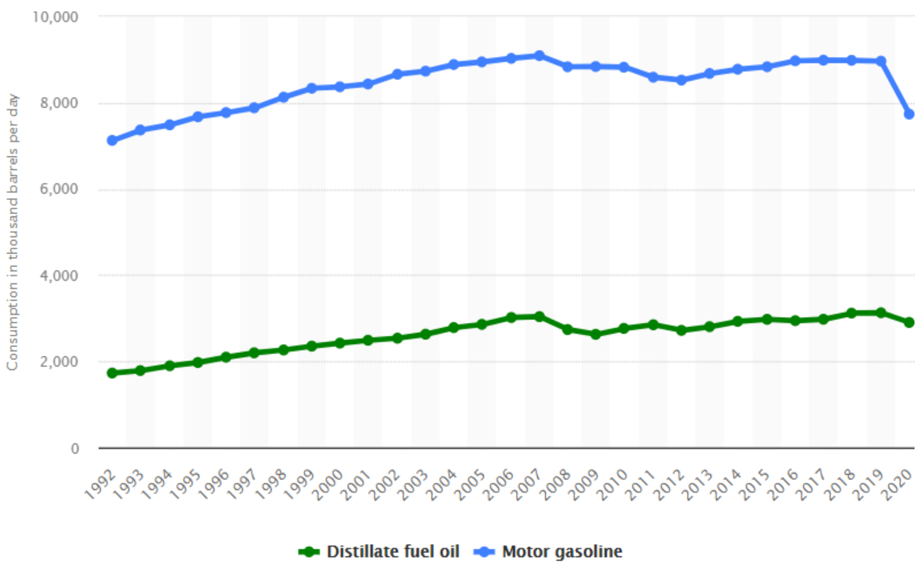

FIGURE 1 – U.S. GASOLINE AND DISTILLATE DEMAND HISTORY 1992-2020

Source: https://www.statista.com/statistics/189410/us-gasoline-and-diesel-consumption-for-highway-vehicles-since-1992/

CAPACITY PLANNING FOR GENERATION AND GRID IMPROVEMENTS:

Comparing the last representative electricity demand year (2019), the U.S. used 3.9 million GWh of electricity for industrial, commercial, and residential demand as shown in Figure 2.

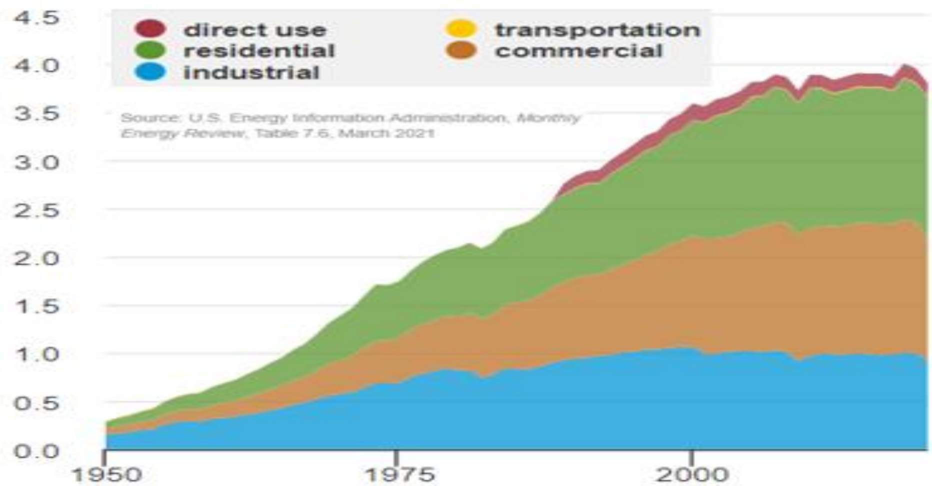

FIGURE 2 – U.S. ELECTRICITY DEMAND HISTORY 1950-2020

To facilitate the electrification of our transportation fleet, an additional 72% of incremental electricity generation must be created, along with the attendant 72% increase in transmission and distribution infrastructure. As the U.S. moves toward more renewable energy in its energy mix, and additional capital expenditure will be required for energy storage to bridge the timing of renewable energy production and energy demand.

This estimate does not include the electrification of our current heating infrastructure whereby natural gas combustion for heating at home and businesses would be replaced by electrical heat.

MARKET LEADER ADVANTAGES:

The key advantages China currently enjoys in its quest for world BEV production and cost leadership are the following:

1. Economies Of Scale
2. Swift, Autocratic Policy Decisions
3. Battery Raw Materials Control
4. Domestic Coal Supply & Low Cost Coal Electricity Production

Economies Of Scale

China's economy has seen tremendous change over the last 20 years, averaging a compounded annual 14.2% growth rate. With this domestic growth engine for a large population of 1.4 billion, average per capita incomes have increased by a 20-year compounded annual rate of 10.72%. Increasing prosperity with more of its people wanting greater mobility, has provided China with a huge domestic market for BEVs. In 2021, over half of the global BEVs were sold in China, as shown in Figure 3.

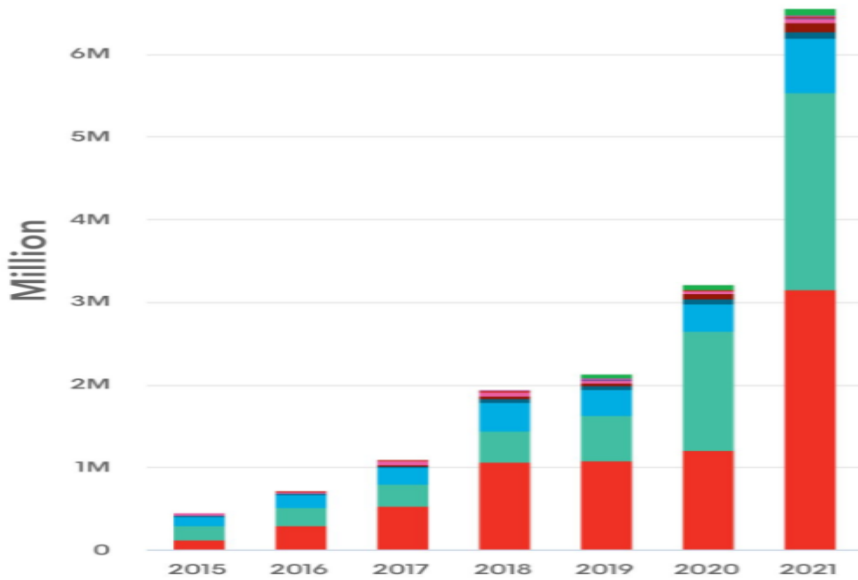

FIGURE 3 – GLOBAL PLUG-IN ELECTRIC CAR SALES, 2015-2021

Swift, Autocratic Policy Decisions

The Chinese government is mandating more BEVs at the expense of ICE vehicles compared to Western democracies, while reducing the number of licenses available for gasoline-powered cars. This policy from the top, President of the Republic of China, Xi Jinping, will increase demand for BEVs leading to greater BEV production, larger economies of scale, and lower unit production costs. This will enable China to gain a world-wide marketing advantage. In the Chinese system, no Act of Congress, debate, or negotiations with the Environmental Protection Agency is necessary, so quick, decisive action to provide advantages to China are implemented.

Battery Raw Material Controls

China now has a tight grip on the global supply of the elements needed to manufacture batteries from four components: anode, cathode, separator, and electrolyte. China currently controls between 50% and 77% of the global market for the raw materials of these components, according to Yano Research Institute. A key element of an electric vehicle's price is the cost of its batteries, and China already makes more than half of the world's electric vehicle batteries, as shown in Figure 4.

Rank	Country	% of World Total
#1	China	79.0%
#2	U.S.	6.2%
#3	Hungary	4.0%
#4	Poland	3.1%
#5	South Korea	2.5%
#6	Japan	2.4%
#7	Germany	1.6%
#8	Sweden	0.6%
#9	UK	0.3%
#10	Australia	0.1%

FIGURE 4 – LI-ION MANUFACTURING CAPACITY

China controls more lithium reserves and much greater lithium production than the U.S., and in 2018, Chinese lithium production was 8,000 metric tons, third among all countries and nearly ten times U.S. lithium production. Researching the capital devoted to lithium over the past few years, over 50% has been by the Chinese.

Domestic Coal Supply & Low Cost Coal Electricity Production

A key for EV production is cheap energy for manufacturing of the BEV's components. China has a large, low-cost domestic coal supply, yet it also imports significant amounts of coal to supply its electricity generators to produce electricity very inexpensively, a key cost advantage for its heavy industry.

Chinese electricity generation by source in 2017 is shown below in Figure 5.

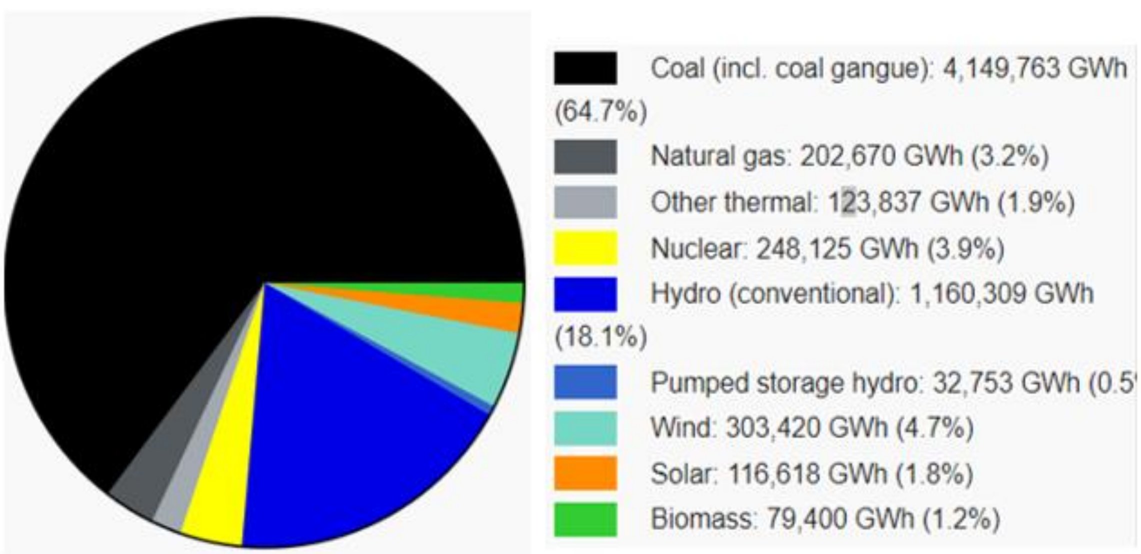

FIGURE 5 – CHINESE ELECTRICITY GENERATION BY SOURCE IN 2017

In contrast to Chinese dependence on coal for electricity (64.7%), the U.S. gets 27.61% of its electricity from coal-fired generation, a much more environmentally-favorable position, albeit at a higher cost of energy.

To put China's coal use in perspective, from 2005-2009, China added the equivalent of the entire US coal generation capacity. From 2010-2013, it added 50% of the entire US coal generation. China burns 4 billion tons of coal a year; the US burns less than 1 billion; EU burns about 0.6 billion. This volume of coal consumed in China represents about 9.12 billion tons of CO_2e emissions per year.

As China is building 250 GW of new coal plants in the 2020s decade, according to data from the U.S. Energy Information Administration, from the end of 2010 to the end of 2019, 49 GW of US and EU coal plants were retired. As U.S. / EU air gets cleaner, China's air gets more polluted.

KEY MINERALS REQUIRED FOR EVs AND LOCATION:

A typical BEV requires six times the mineral inputs of a conventional car, while the electrification of vehicles will require a doubling of electricity production and infrastructure to deliver this increased energy to the distributed demand points for BEV recharging.

In addition to BEV-driven energy demand, since 2010 the average amount of minerals needed for a new unit of power generation capacity has increased by 50% as the share of renewables in new investment has risen.

The key minerals needed in huge future quantities for BEVs include: copper, lithium, nickel, manganese, cobalt, graphite, zinc, and rare earths. Figure 6 delineates the growth in demand for these key minerals.

The types of mineral resources used vary by technology. Lithium, nickel, cobalt, manganese and graphite are crucial to battery technology. Rare earth elements are essential for permanent magnets in wind turbines and electric vehicle motors, while copper is a "cornerstone" for all electricity-related technologies.

"If the world is to reach net zero by 2050, overall demand for critical minerals will increase by a factor of six", IEA Executive Director Fatih Birol said. "The question is whether or not this can be met by production, our analysis shows there is a looming mismatch between the world's climate ambitions and the availability of critical minerals to realize those ambitions."

"Many of the technologies the world will need to reach net zero require significantly more critical minerals than their fossil-fuel counterparts", Tim Gould, head of IEA's Division for Energy Supply, Outlooks and Investment, said.

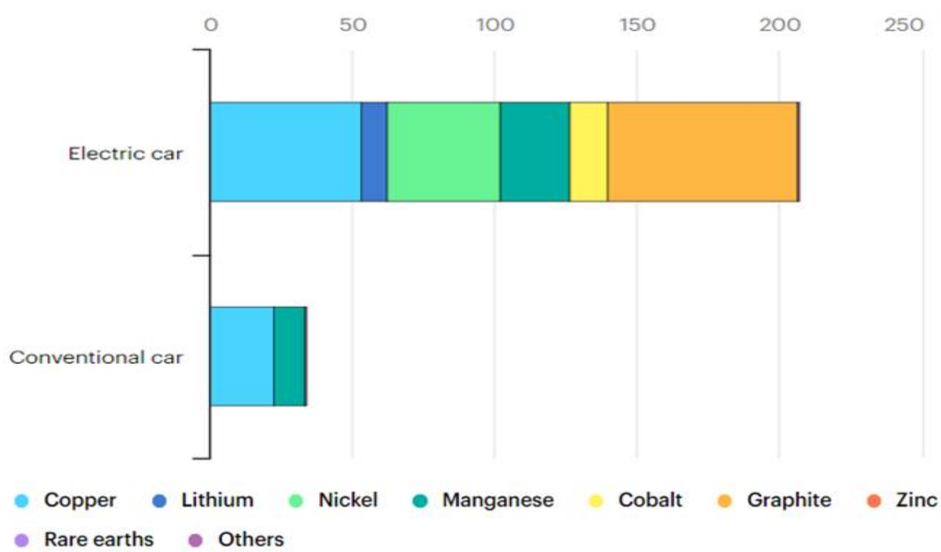

FIGURE 6 – MINERALS USED IN BEVs COMPARED TO CONVENTIONAL CARS (KG/VEHICLE)
Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary

In order to achieve the 2040 Sustainable Development Scenario as described in the IEA report, four times the minerals will be required than are currently produced.

Of that amount an almost doubling of minerals for EVs and battery storage will required from present supply as shown in Figure 7.

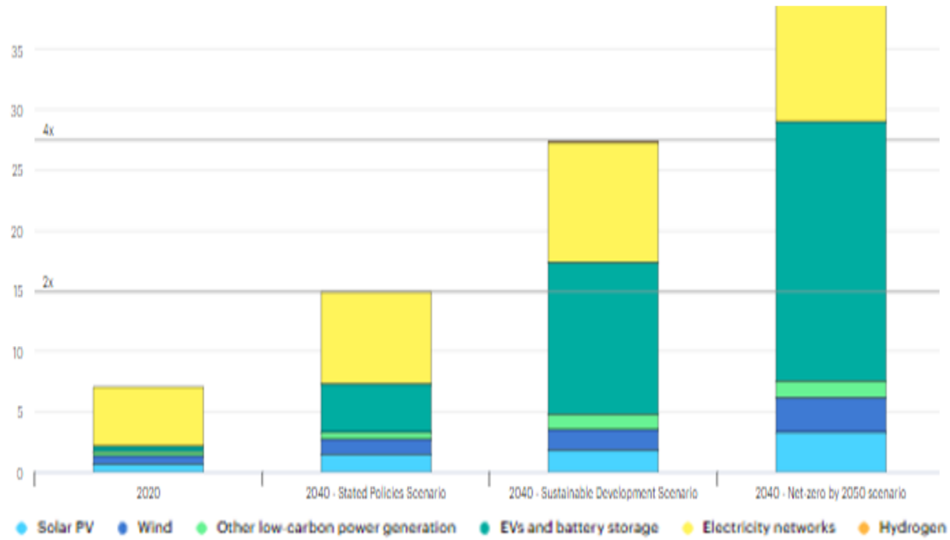

FIGURE 7 – TOTAL MINERAL DEMAND FOR CLEAN ENERGY TECHNOLOGIES BY SCENARIO, 2020 COMPARED TO 2040

Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary

Additionally, the incremental minerals are those that are not now in scaled-up production and in areas of the world where political stability could be an issue as shown in Figure 8.

Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary

One of the key drivers for BEV market development is the reduction in Greenhouse Gas (GHG) over the vehicle lifetime as shown in Figure 8. The ICE car generates about twice the emissions over its lifetime as does a similar BEV.

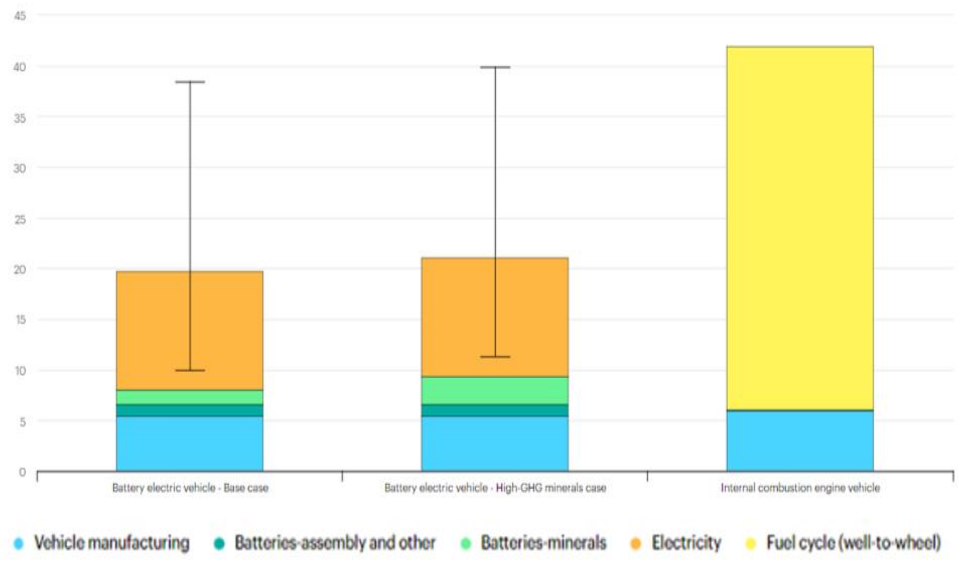

FIGURE 8 – COMPARATIVE LIFE-CYCLE GREENHOUSE EMISSIONS OF A MID-SIZE BEV AND ICE VEHICLE (TONS CO2E PER VEHICLE LIFETIME)

Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary

In May of 2020, a World Bank Group report found that the production of minerals, such as graphite, lithium and cobalt, could increase by nearly 500% by 2050, to meet the growing demand for clean energy technologies. It estimates that over 3 billion tons of minerals and metals will be needed to deploy wind, solar and geothermal power, as well as energy storage, required for achieving a below 2°C future.

Batteries for BEVs and renewable energy storage are the biggest factor driving the potential mineral shortage. A BEV requires six times more mineral resources than a car that runs on fossil fuels. Cobalt, nickel, graphite, and manganese are essential for batteries, too.

Although BEVs reduce emissions by 50% over its lifetime, it requires over 200 kilograms (kg) of minerals, or 6 times that for ICE, which require 35 kg, as shown in Figure 9.

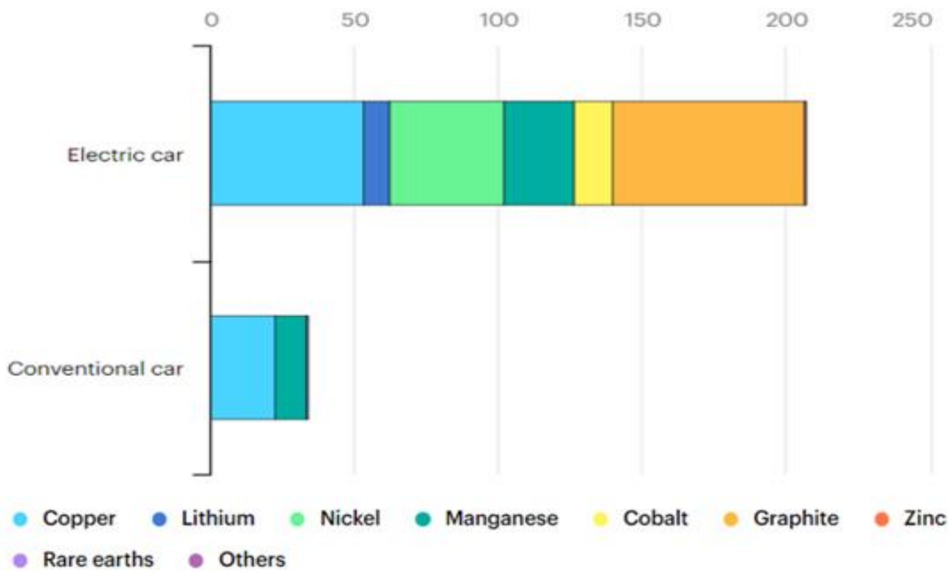

FIGURE 9 – MINERAL DEMAND FOR BEV VS. ICE VEHICLE

Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/e

As the globe embraces clean energy and BEVs, it will see a tremendous increase in key mineral demand with multiples up to 6X than is currently produced to reach the 2050 Net Zero Scenario target as shown in Figure 10. Mineral demand is shown in millions of tons.

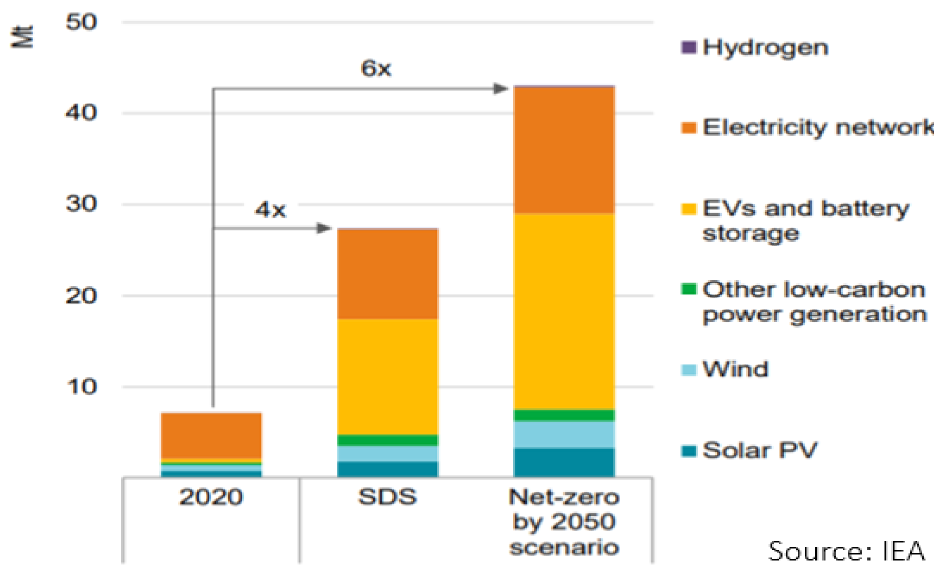

FIGURE 10 – CLEAN ENERGY MINERAL DEMAND GROWTH TO 2040

As compared to oil and natural gas, the production of clean energy/BEV minerals will be much more geographically concentrated in the future as shown in Figure 11. This brings up potential concerns for rare earth sourcing concentration in China from both an environmental and future pricing standpoint. What impact will this concentration have on the geopolitical security of supply?

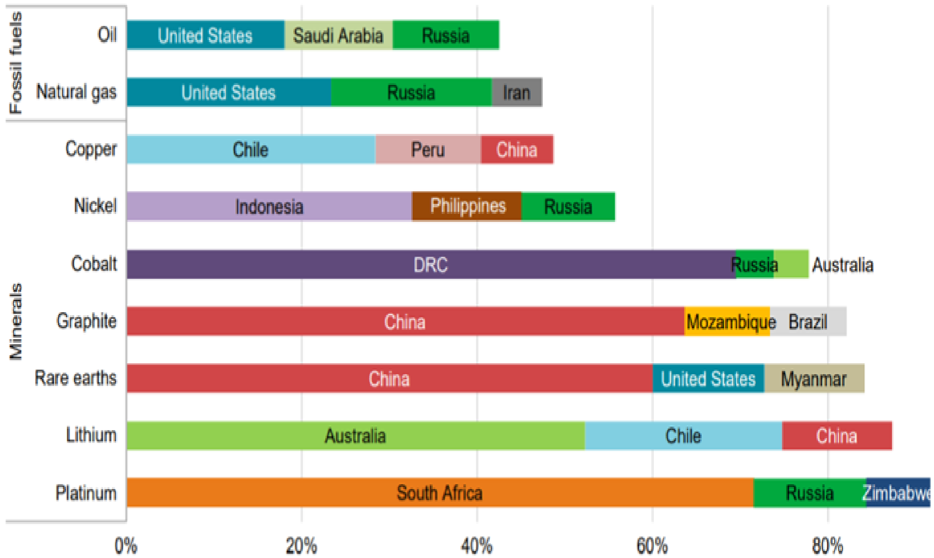

FIGURE 11 – MINERAL SUPPLY SOURCE IN 2019

Source: IEA

A graph from the U.S. Geological Survey provides a slightly different view of mineral supply concentration for clean energy/BEV as shown in Figure 12. It will be interesting in the future to gauge global comfort levels regarding reliable mineral supply source and stable pricing mechanisms from key producing countries, and whether it will be used as future geopolitical weapon like OPEC in 1970's.

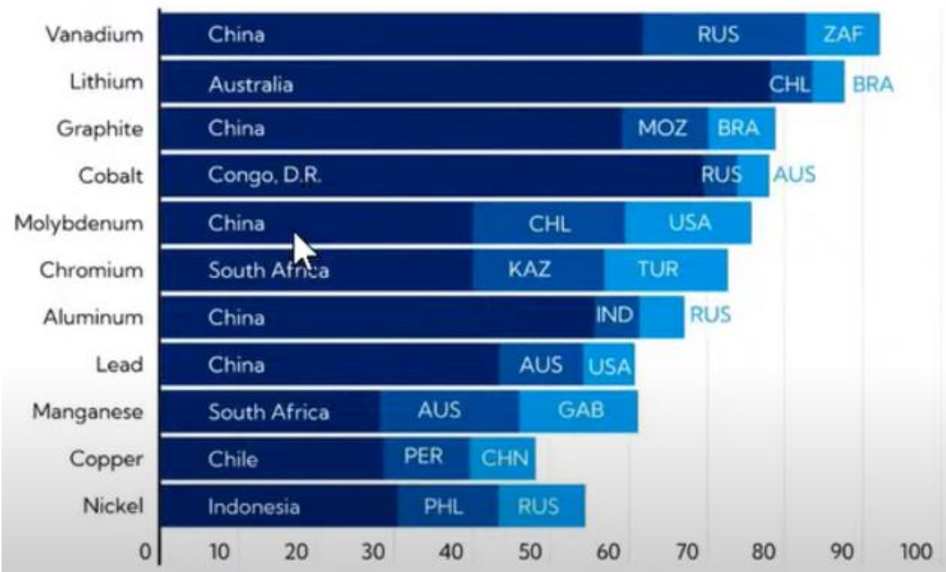

FIGURE 12 – MINERALS CRUCIAL TO CLEAN ENERGY & BEVs

Source: U.S. Geological Survey, Mineral Commodity Summaries 2021

Another way to view the geographical distribution of BEV production is shown in Figure 13 with a heavy representation from China.

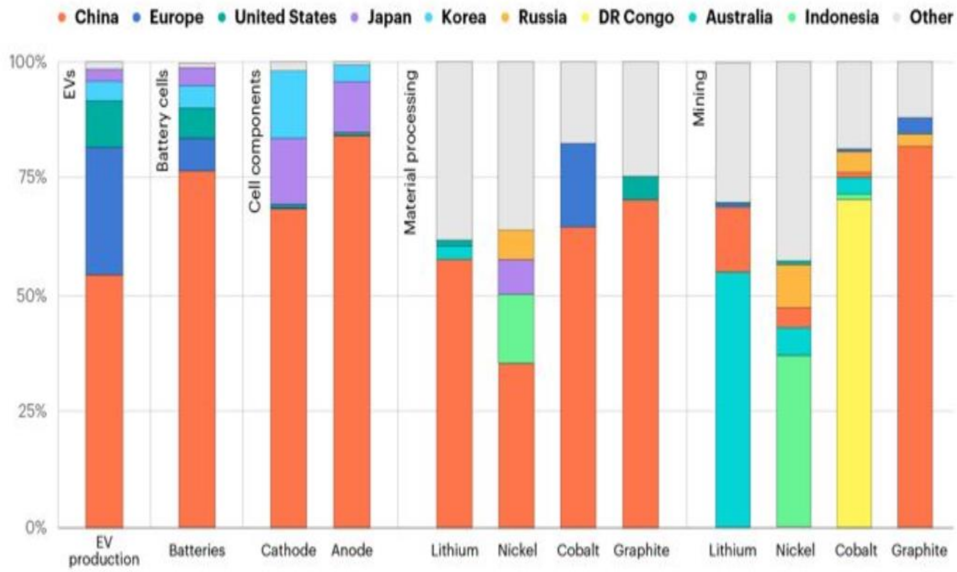

FIGURE 13 – GEOGRAPHICAL DISTRIBUTION OF BEV PRODUCTION / CAPACITY BY SUPPLY CHAIN

Source: Global EV Outlook 2022

KEY MINERALS PRICES AND PRICE VOLATILITY:

As RE and BEV minerals see increased demand, price volatility could be a key factor in the future with Figure 14 depicting the recent price volatility from January 2020 to February 2021. How will price volatility of key minerals of 25-130% impact production / adoption of clean energy/BEV products? Will BEVs remain cost competitive to fossil fuels with potential future mineral price volatility and acceleration?

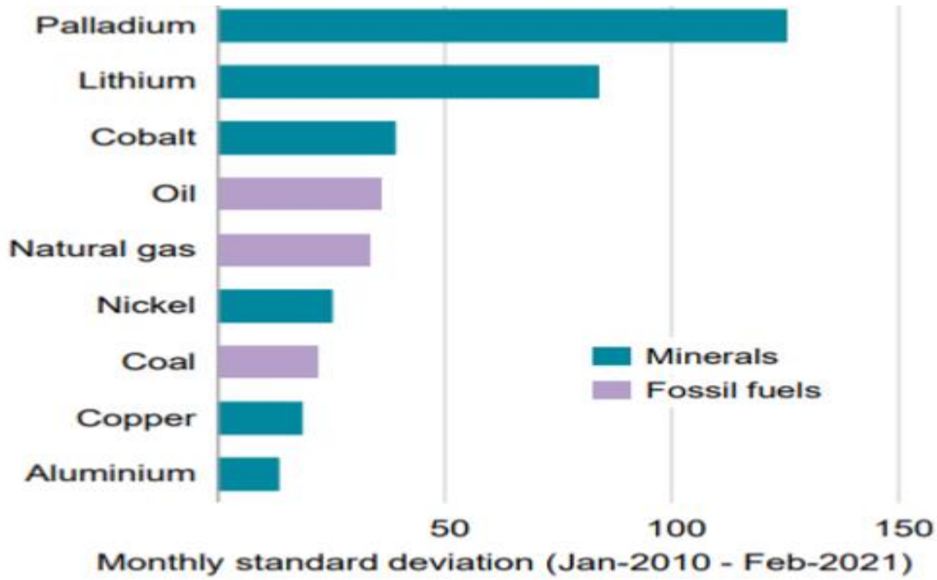

FIGURE 14 – CLEAN ENERGY MINERAL PRICE VOLATILITY

Source: IEA

To calibrate the RE and BEV mineral price volatility, Figure 15 shows how key metal prices performed in 2021.

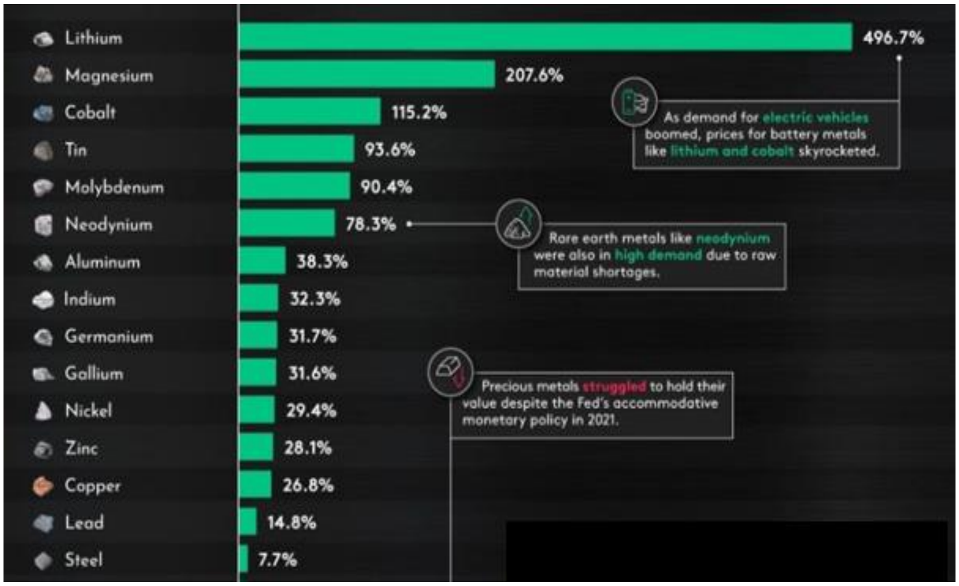

FIGURE 15 – HOW METAL PRICES PERFORMED IN 2021

Source: elements.visualcapitalist.com

BEV demand boomed, prices for battery metals (lithium skyrocketed by almost 500%).

KEY DRIVER FOR CHINA TO LEAD IN BEV PRODUCTION:

China Is A Major Petroleum & LNG Importer

The country is experiencing increasingly high domestic demand for petroleum and LNG, yet the domestic upstream industry is unable to satisfy it. One of the reasons is that China's upstream sector is dominated by its national oil companies (NOCs) and private sector participation in China's can only happen with contracts with the NOCs. Operating costs for domestic Chinese production have remained relatively high in comparison to the United States.

Another reason limiting domestic gas production is that China's shale gas resource lies at depths greater than 3,500 meters, and available technology is not easily adapted for this depth.

China will continue to import large amounts of crude and petroleum products to meet demand as shown in the Figure 16 below.

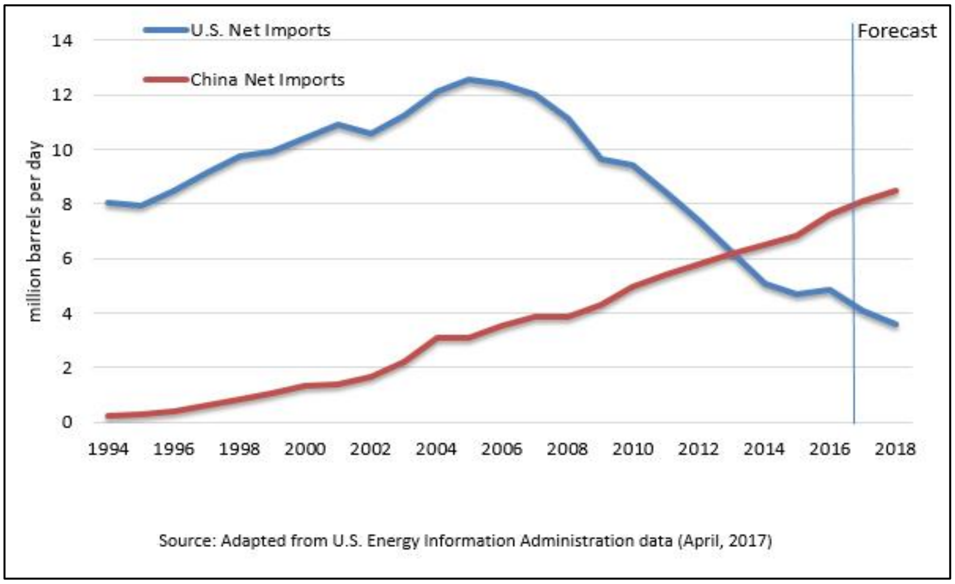

FIGURE 16 – NET IMPORTS OF PETROLEUM AND OTHER LIQUID FUELS COMPARING CHINA AND U.S.

Additionally, since Chinese shale gas is currently inaccessible, it continues to import natural gas via pipeline and LNG terminals. Natural gas and LNG imports are both increasing due to China's continued need for more energy.

China imported 54 million metric tons of LNG in 2018, a year-on-year increase of 42 percent. LNG imports from the US stood at 2.1 million tons, accounting for 4 percent of the total. Figure 17 below provides an LNG import history.

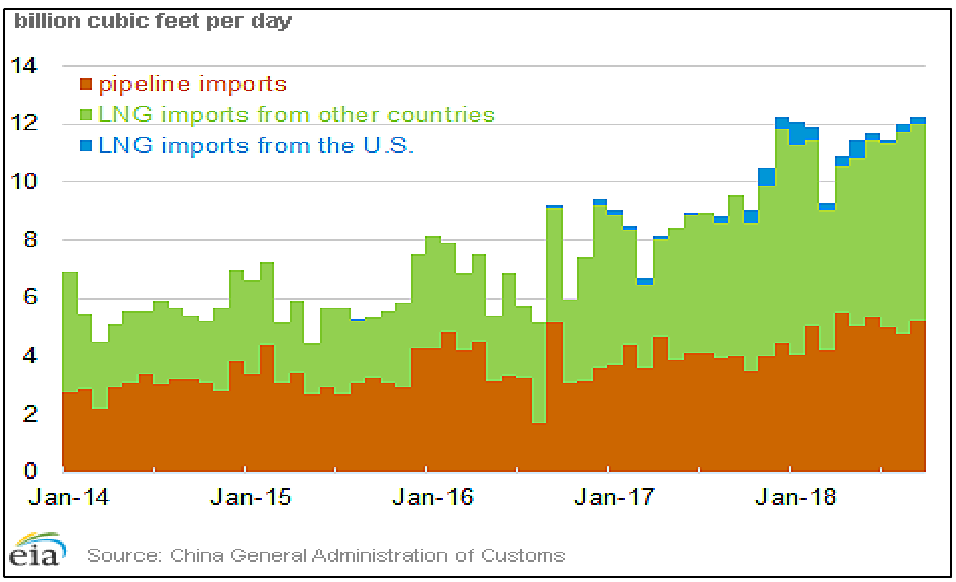

FIGURE 17 – CHINESE NATURAL GAS IMPORTS BY PIPELINE AND LNG, 2014-2018

Therefore, being short of both petroleum and natural gas, the Chinese must import and give up hard currency. By reducing fossil fuel imports, China could reduce its balance of payments, however, the type of fossil fuel imports matters greatly when the prices of energy in fossil fuels, shown as United States Dollars (USD) per British Thermal Unit (BTU) are compared.

Evaluating the imported fossil fuels China has at its disposal of coal, LNG, and crude/diesel, and spot prices in April 2022, the summary of China's fossil fuel consumption is as follows:

1. 4 billion metric tons of coal/year for electricity and steam generation, a spend of ~**$1,300 billion per year** with coal @ $14.57 per MMBTU

2. 92 million tons of LNG each year, a spend of **$90 billion per year** with LNG @ $18.93 per MMBTU

3. 8.6 million barrels of crude oil and refined products (diesel) per day, an expenditure of **$322 billion per year** with Brent at $102.50/bbl.

4. ***Total annual fossil fuel value of $1.7 trillion***

Imported Fuel Switch Impact From Crude/Refined Products to LNG

Replacing 8.6 million barrels of crude oil/refined products per day with LNG would breakeven on cost between crude/refined products and LNG, but ***saves China ~400 million metric tons of CO_2e per year***

Converting LNG to electricity for transportation energy demand is more efficient than the ICE alternative with crude/refined products/diesel for the import dollar expended.

The probability for conversion of coal-fired electricity generation plants to LNG appears remote, even if the environmental prize is eliminating 9.12 billion tons of CO_2 per year.

THE CLEAN ENERGY MINERAL CHALLENGE:

Quoting Daniel Yergin's new book, "The New Map: Energy, Climate, and the Clash of Nations":

1. ~0.5 million pounds raw materials mined / processed to make a battery for an electric car."
2. Demand for lithium up by 4,300%, cobalt and nickel by 2,500%.
3. For lithium, the top three producers control over 80%.
4. China controls 60% of rare earth output for wind turbines.
5. DRC controls 70% of the cobalt required for EV batteries.

SUMMARY:

1. BEVs will require 6 times the minerals than for ICE cars, while generating half the emissions.
2. BEV mineral supply key, new mines needed/new emissions, and long lead times for development
3. Supply sourcing countries may not be friendly to the West, or have unstable governments
4. Supply availability to match global demand will induce increased mineral price volatility
5. BEVs in U.S. will double electricity generation, transmission and distribution infrastructure
6. China has huge incentives: replacing 8.6 million barrels of crude oil/refined products with LNG to save ~400 million metric tons of CO_2e per year
7. BEV mineral supply dependency to replace current oil/gas dependency

BIOGRAPHY

Ron Miller is an energy industry expert creating value by analyzing assets, markets, technologies, and power usage to identify, monetize, and implement profitable energy and de-carbonization projects. He is a Professional Engineer / MBA / Certified Energy Manager / Renewable Energy Professional experienced in developing and leading global energy projects in the renewable energy, conventional power, and fuels industries, before founding Reliant Energy Solutions LLC. His global energy consultancy provides analysis for energy supply and demand, energy reliability, feasibility, fuel and energy efficiency, and de-carbonization. He has led energy project development at ExxonMobil, Xcel Energy, AECOM, Rio Tinto, and Newmont Corporation. Ron holds a BS in Civil Engineering from Virginia Tech and an MBA in Finance from the Terry College of Business at the University of Georgia.

ron@reliantenergysolutions.com
+1 720-381-9452