

Sector Report: Battery and Critical Minerals

Electric Vehicle (EV) Revolution to Drive Demand

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Highlights

- The Electric Vehicle (EV) revolution, fueled by the pursuit for a greener planet, is expected to impact the supply chain of multiple commodities. The most commonly discussed EV-related commodities are nickel, cobalt, lithium, and graphite. In this report, we **review three relatively under-followed commodities** - Rare Earth Elements (REEs), niobium, and fluorspar. EVs are expected to be their biggest long-term demand driver.
- We are **projecting a large supply deficit for REEs and fluorspar**; both are currently used in EVs. Niobium demand is currently driven by steel, but **niobium batteries (which are under development)**, if commercialized, will push the market to a significant supply deficit. Commodity price projections are beyond the scope of this report.
- EV sales surged 168% YoY, to 2.65M, in H1-2021. **The International Energy Agency (IEA) forecasts 145M EVs on the road by 2030, up from just 11M in 2020.**
- Neodymium-Iron-Boron rare earth magnets (NdFeB or neo-magnets) are an essential component of EVs, due to their superior strength per unit weight and volume. **Each EV requires approximately 10 kg of REEs.**
- Fluorspar's use in EVs is currently a niche market. In Lithium-Ion Batteries (LIBs), fluorspar is used along with lithium as the electrolyte. **An EV battery is estimated to contain 0.9 kg of fluorspar.** There are ongoing studies for the development of Fluoride-Ion-Batteries (FIBs). Although FIBs are far from commercialization, preliminary tests indicate superior results.
- Niobium has a wide range of uses from jet engines to superconducting magnets. Studies indicate that **niobium-based EV batteries** enable faster charging times, longer range, and improved safety for LIBs.
- China is the largest producer of REEs and fluorspar. Brazil is the largest producer of niobium. China's dominance, and rest of the world's reliance on China, are prompting North America to take initiatives to improve the global supply chain of battery and critical minerals. **We believe high-quality REEs and fluorspar projects outside China will be sought after.**

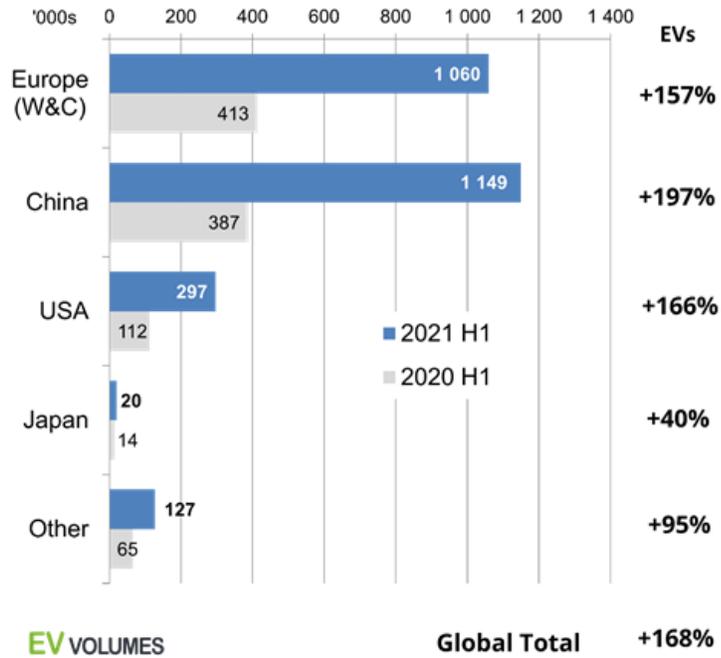
All figures are in US\$.

*See last page for important disclosures, rating, and risk definitions.

The EV Revolution

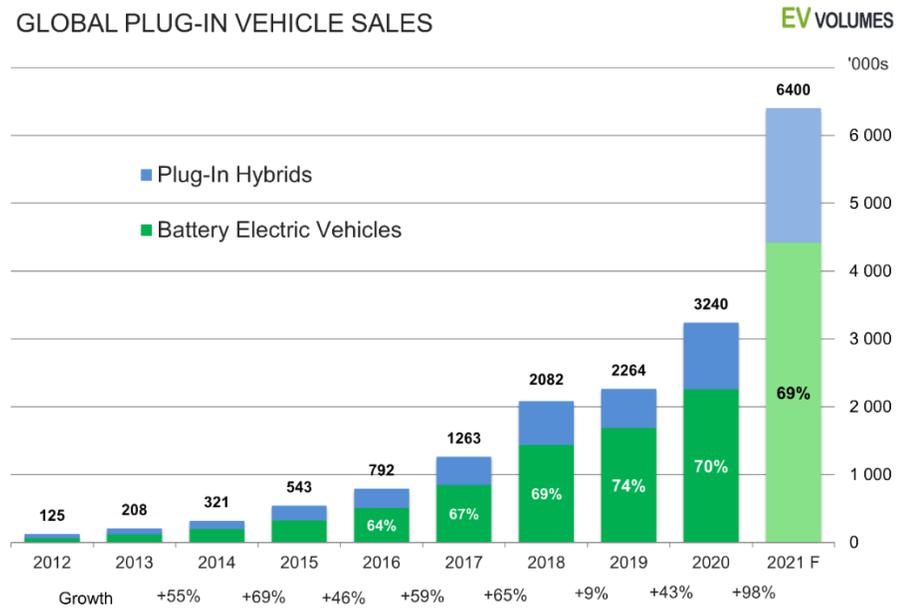
Surging EV sales

BEV+PHEV SALES AND % GROWTH



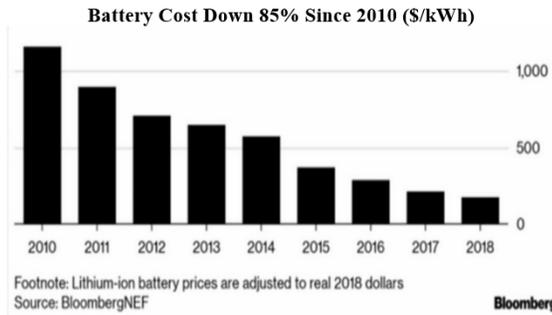
6.4M EVs are expected to be sold in 2021, up 98% YoY from 3.2M in 2020

GLOBAL PLUG-IN VEHICLE SALES

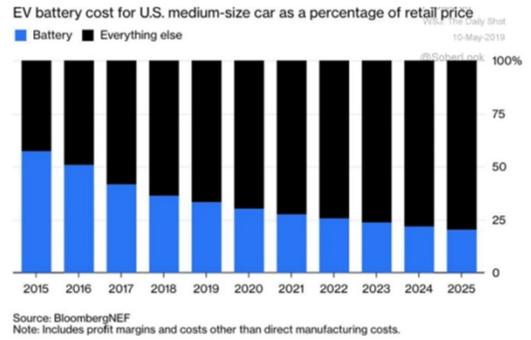


Source: ev-volumes.com

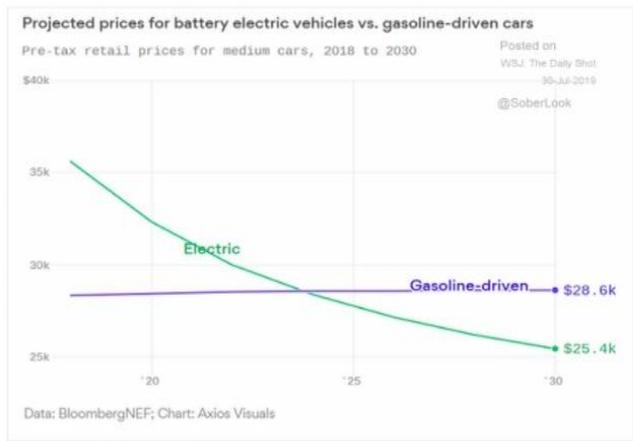
Declining battery costs is the primary driver of EV sales



Source: WSJ

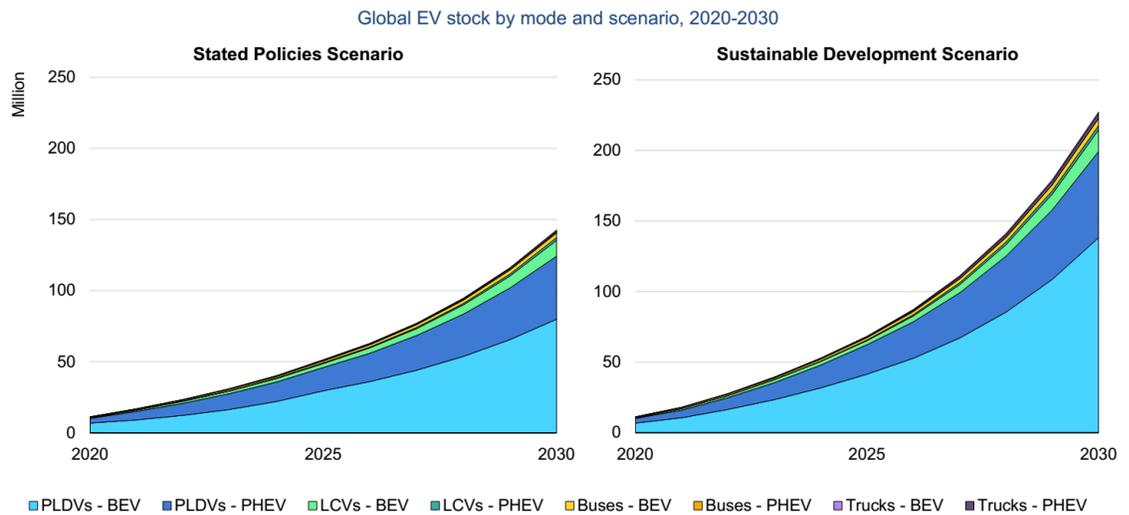


Prices of EVs are expected to be competitive starting 2024



The IEA forecasts 145M EVs on the road by 2030; annual sales are expected to increase to 30M by 2030 (consensus)

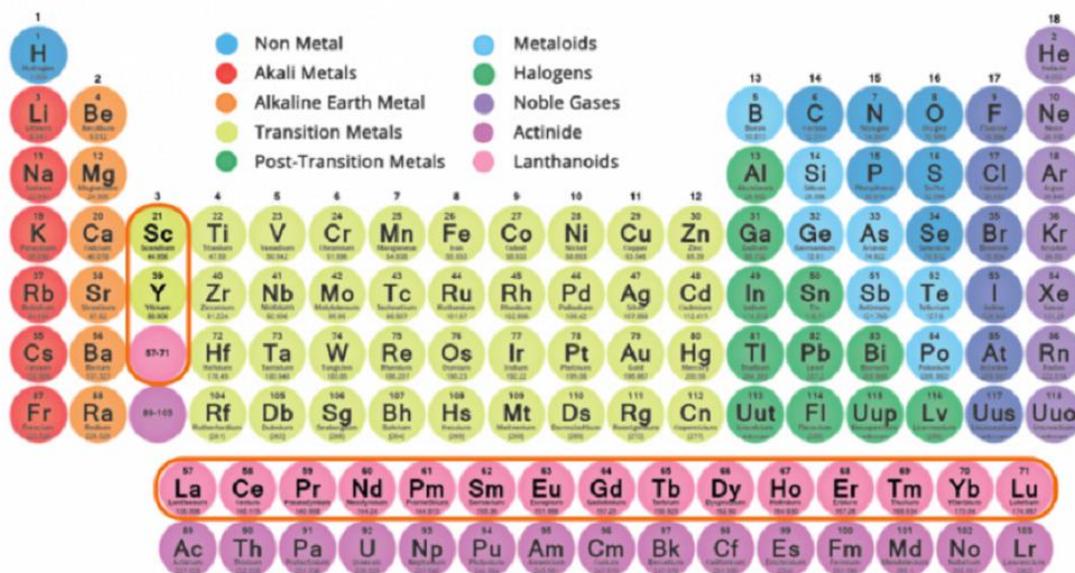
The IEA projects sales of 13M-20M by 2025, and 26M-47M by 2030



Source: IEA Global EV Outlook 2021

Rare Earth Elements (REEs)

REE Position on the Periodic Table

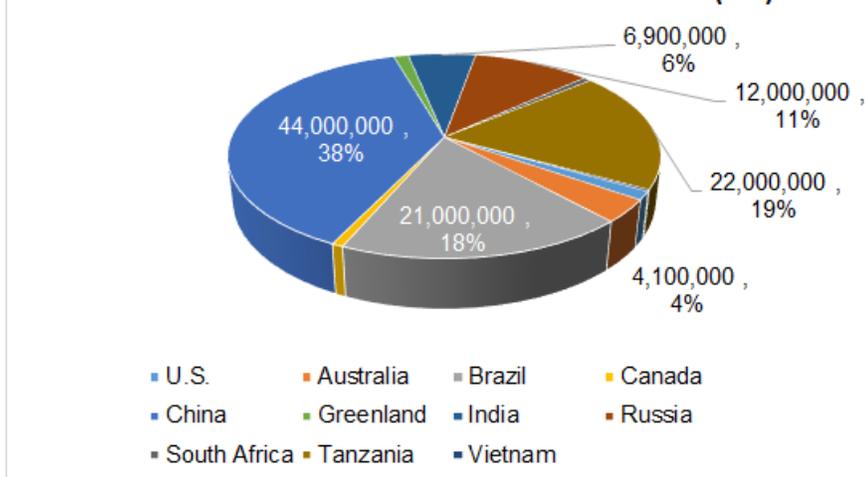


REEs are a group of 17 elements

Source: Geomega

Unlike what their name may imply, REEs are more abundant than most of the mainstream precious and base metals. **REEs are limited in supply because they are rarely found in concentrations viable for economic extraction.** Furthermore, separating ore into single elements of high purity is a challenging process due to their similar chemical properties.

Rare Earth Elements Global Reserves - 2020 (MT)



Source: USGS

China, Brazil, and Tanzania have the largest reserves, accounting for 76% of the total

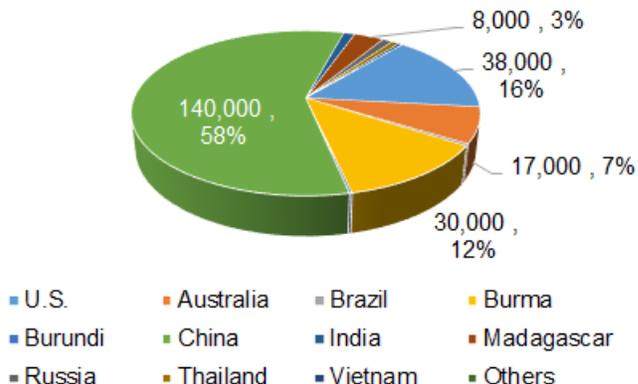
China is the leading producer, and accounted for 58% of global production in 2020

Sources indicate that China accounts for over 90% of global production, when undocumented production is included

REEs have a wide range of industrial applications

Critical importance in permanent magnets (accounting for 38% of total demand), electronics, aerospace, clean energy, electric vehicles, and wind turbines

Rare Earth Elements Production - 2020 (MT)

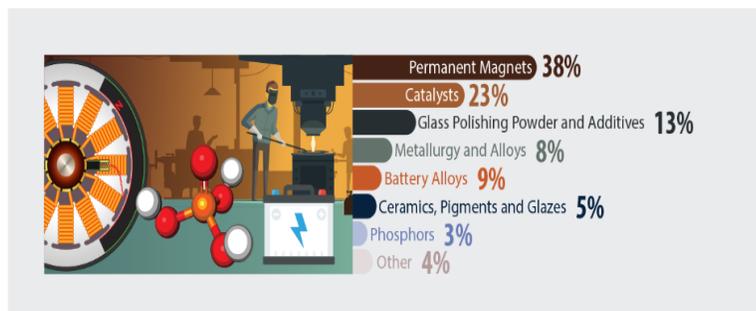


Source: USGS

Rare Earth Element	Symbol	Atomic Number	Current Applications
Scandium	Sc	21	Aerospace, sports equipment, lamps for film industry
Yttrium	Y	39	Phosphors, ceramics, metal alloys
Lanthanum	La	57	Batteries, catalysts for petroleum refining
Cerium	Ce	58	Autocatalysts, Chemical Catalyst, glass polishing, metal alloys
Praseodymium	Pr	59	High power magnets, yellow ceramic pigment, Autocat
Neodymium	Nd	60	High power magnets
Promethium	Pm	61	Beta radiation source
Samarium	Sm	62	High temperature magnets, fluorescent lighting
Europium	Eu	63	Magnetic resonance imaging contrast agent, nuclear reactor rods
Gadolinium	Gd	64	Phosphors for lighting, high power high temperature magnets
Terbium	Tb	65	High power high temperature magnets, lasers
Dysprosium	Dy	66	Highest power magnets in existence
Holmium	Ho	67	Lasers, glass colourant
Erbium	Er	68	Ceramic magnetic materials which are still under development
Thulium	Tm	69	Fibre optic technology, solar panels
Ytterbium	Yb	70	PET scanners
Lutetium	Lu	71	

Source: lynasrareearths.com

Rare earth elements uses, 2019



Source: Natural Resources Canada

Neodymium-Iron-Boron rare earth magnets (NdFeB or neo-magnets) are an essential component of electronics and automobiles. Their **superior strength per unit weight and volume** makes them an integral part of EVs and wind turbines, allowing for more efficiency and reduced energy consumption. NdFeB magnets have life cycles depending on their applications: as long as 20 – 30 years in wind turbines, and as short as 2 – 3 years in consumer electronics. Their weights vary by application, ranging from 1,000-2,000 kg in modern wind turbines, 1-2 kg in EVs, and less than 1 g in small consumer electronics. Adding all other applications, approximately 10 kg of REEs are used in an EV.

EVs will be the primary long-term demand driver; 10 kg of REEs per EV

EVs to account for 40% of demand for magnets

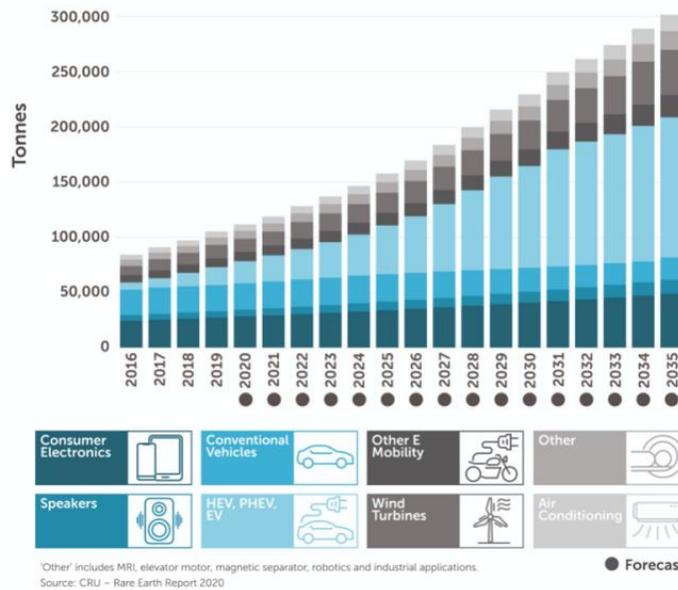
Demand for NdFeB magnets is expected to increase from 110 Kt in 2020, to 230 Kt by 2030

Hybrid and electric cars can contain 20–25 pounds¹ of rare earths
(Twice the amount found in standard gasoline cars)



Source: mineralprices.com

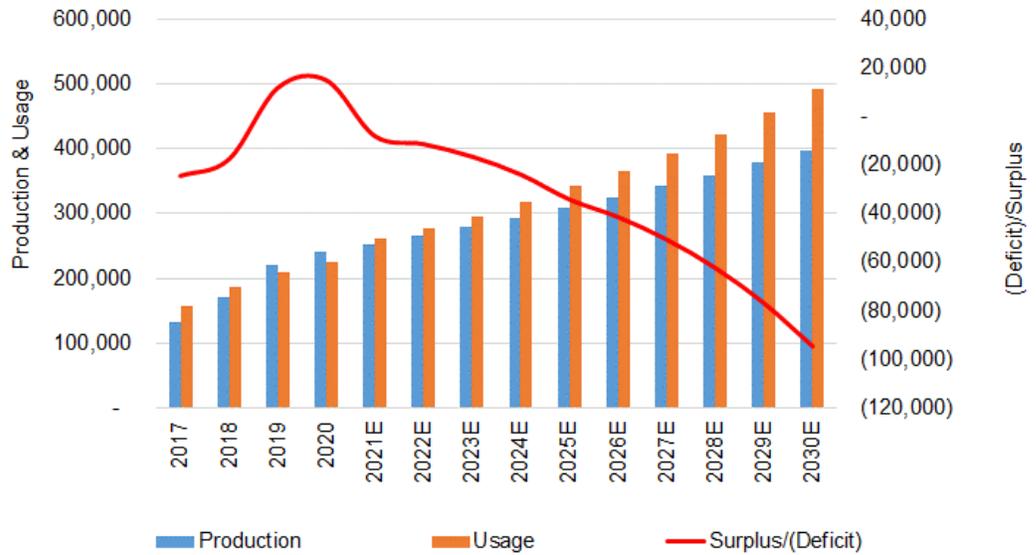
Forecast NdFeB Magnet Consumption



Applying 10 kg of REEs for each EV to consensus EV sales forecasts (presented earlier in this report), we arrived at the following demand projections. We are assuming supply to grow at historical rates.

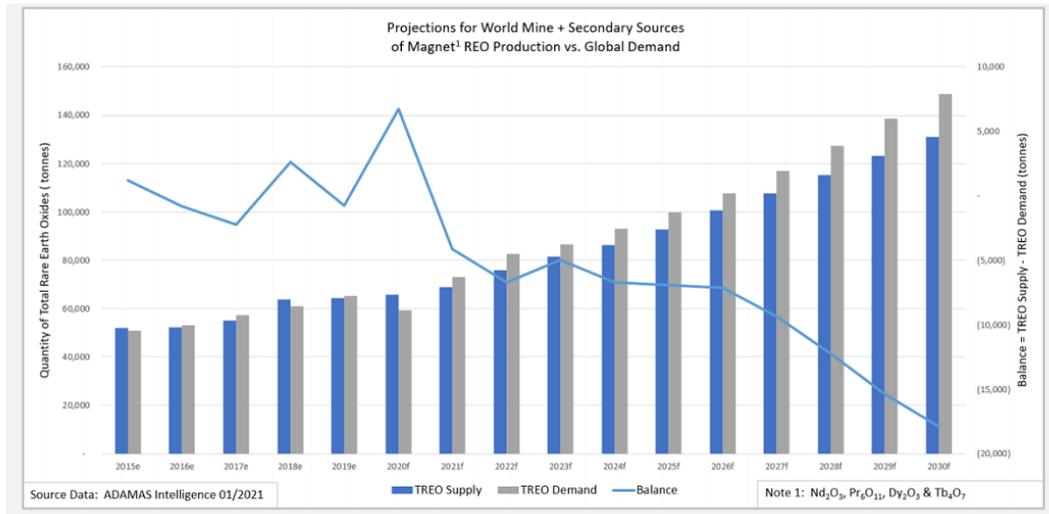
Long-term supply deficit projected for REEs

Global Rare Earth Elements Supply vs Demand (Tonnes)

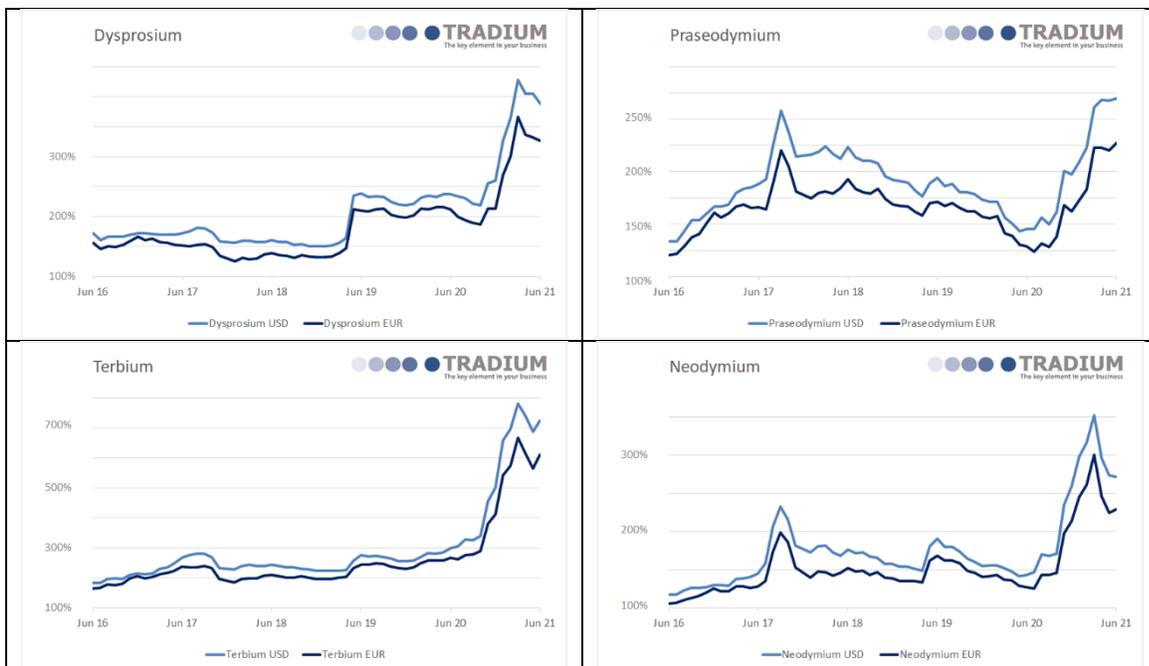


Source: USGS and FRC

Among the 17 REEs, the following four (used in magnets) are expected to experience the strongest demand growth - Neodymium (Nd), Praseodymium (Pr), Terbium (Tb), and Dysprosium (Dy)



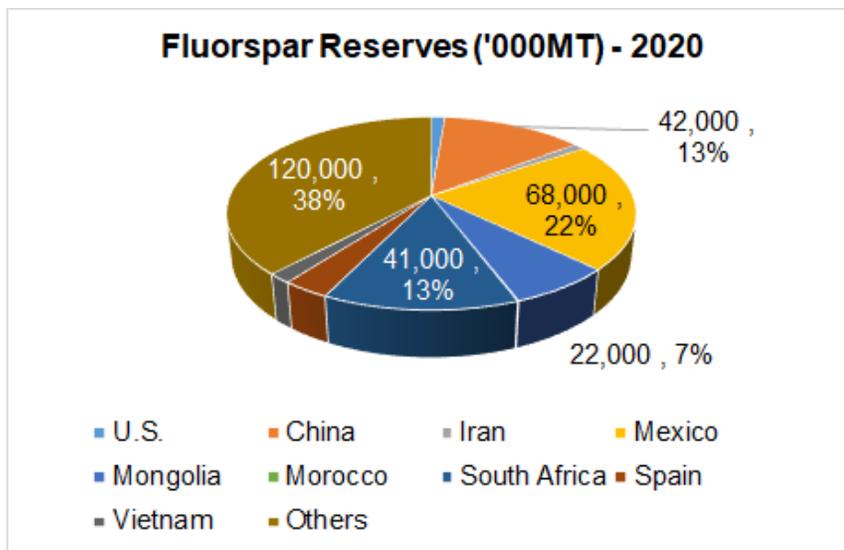
Prices of these four REEs are up significantly YoY, due to supply disruptions (induced by the pandemic), the trade war between the U.S. and China, and rising demand for magnets



Fluorspar

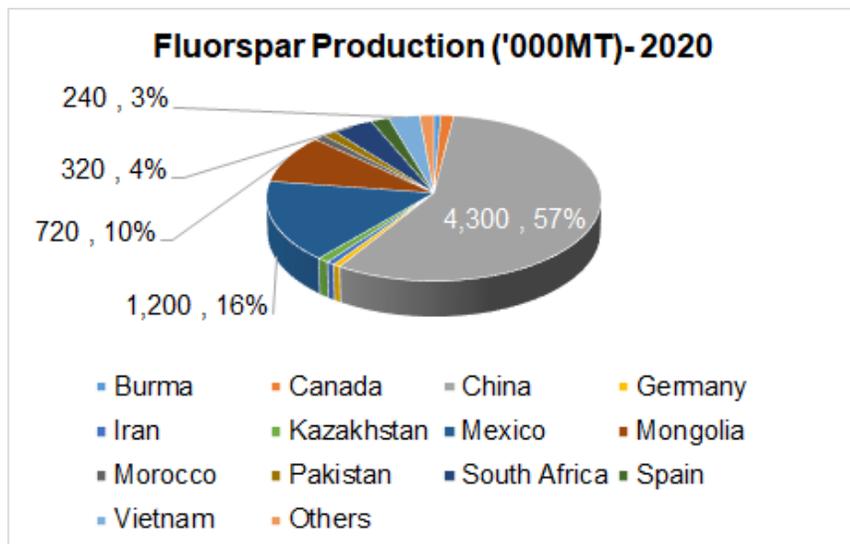
Fluorspar or fluorite is an important industrial mineral composed of calcium and fluorine.

Mexico has the largest fluorspar reserves



Source: USGS

China is the largest producer, followed by Mexico and Mongolia



Source: USGS

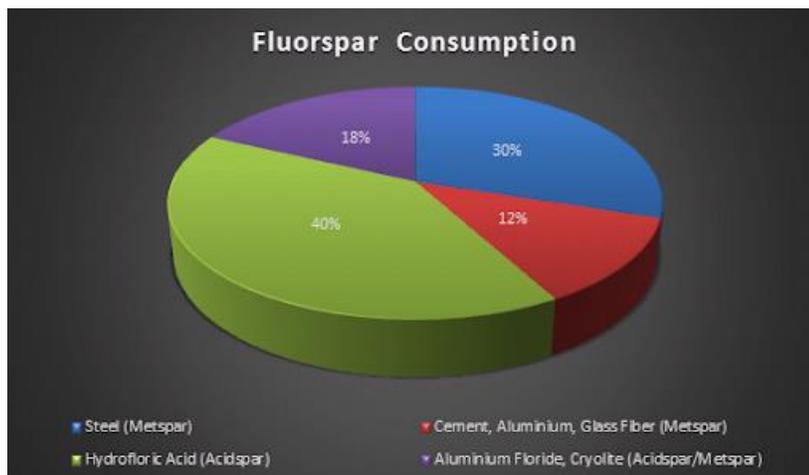
Fluorite is a common mineral in hydrothermal and carbonate rocks worldwide, and has a wide range of applications based on its purity.

Wide range of applications

Types and Uses of Fluorspar		
Grade	Fluorine Content	Uses
Acid	97% and more	production of hydrofluoric acid for foam, refrigerants, fluoride
Ceramic	85-96%	glass, ceramic, teflon production
Metallurgical	60-85%	20-60 lbs fluorite per ton of iron, steel, metal produced
Optical	Below 60%	lenses
Lapidary	Below 60%	ornamental

Source: geology.com

A key component in LIBs (acidspar)

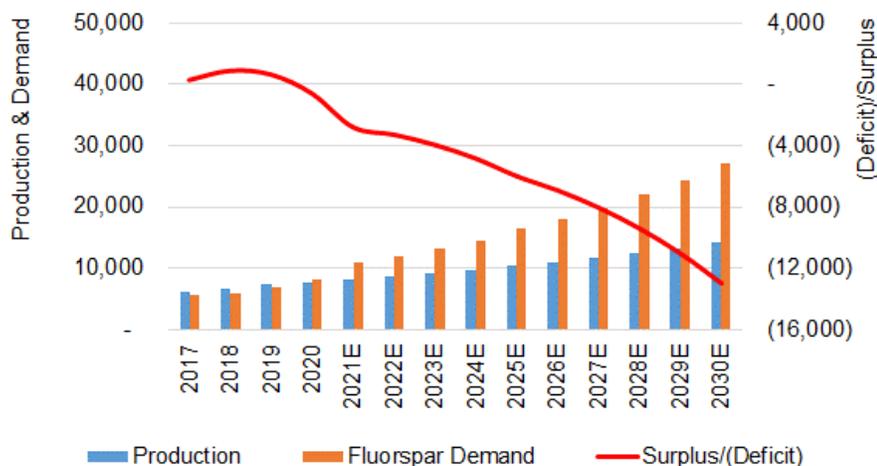


Source: mahamines.com

Fluorspar’s use in EVs is currently a niche market. In LIBs, fluorspar is used along with lithium as the electrolyte - the medium that connects the cathode and the anode. There are ongoing studies for the development of Fluoride-Ion-Batteries (FIBs) – wherein lithium is replaced by fluoride. Although we believe that FIBs are far from commercialization, studies to date have indicated that FIBs can offer up to 10x the energy density vs LIBs.

An EV battery is estimated to contain 0.9 kg of fluorspar. Applying this to consensus EV sales forecasts, we arrived at the following demand projections (shown in the chart below). We are assuming supply to grow at historical rates. Our demand forecasts will be significantly higher if FIBs replace LIBs, as FIBs require significantly higher quantities of fluoride.

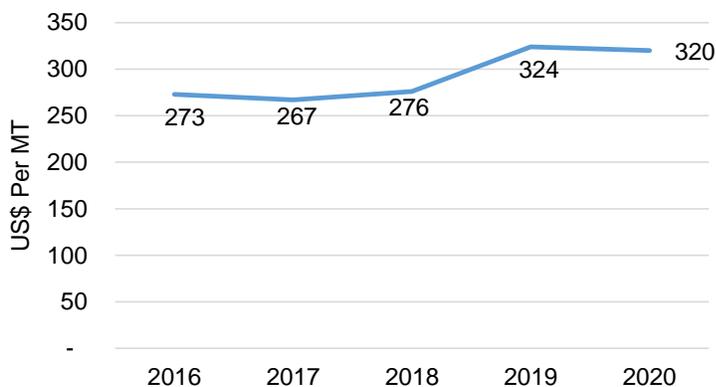
Global Fluorspar Supply vs Demand (Tonnes)



Long-term supply deficit projected for REEs

Source: USGS and FRC

Global Fluorspar Prices

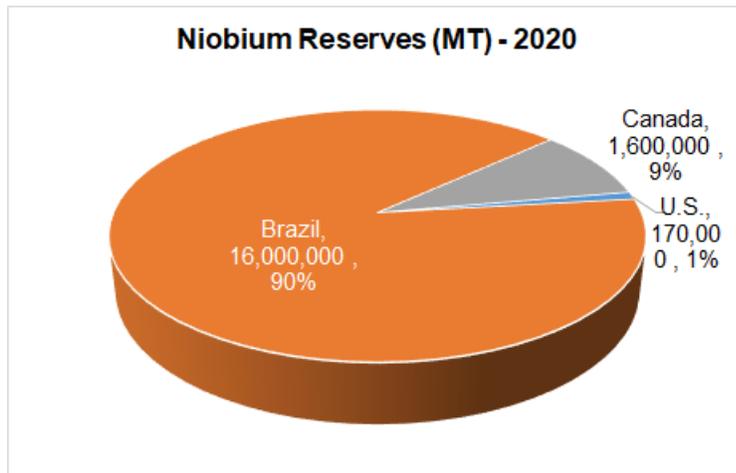


Fluorspar prices have increased on rising EV sales

Source: USGS

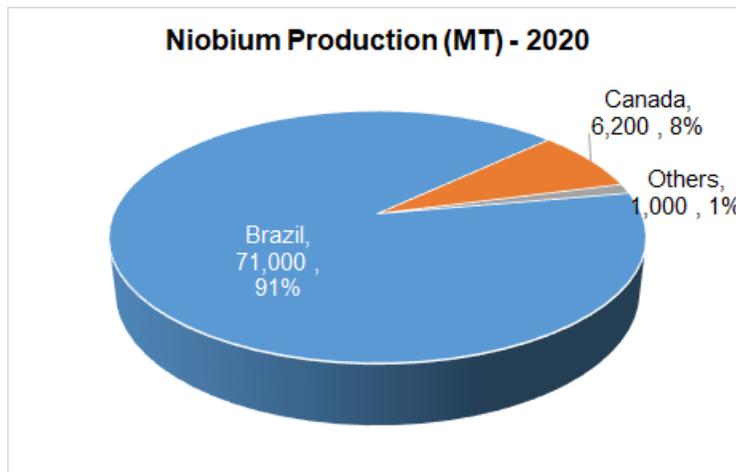
Niobium

Niobium is a soft, gray-white metal with a high melting point, and relatively low density. Niobium is classified as a 'strategic metal' by the U.S. due to its applications in aerospace and defense.



Brazil is the largest producer, and holds the largest reserves

There has not been any new niobium project since 1976



Source: USGS

Uses

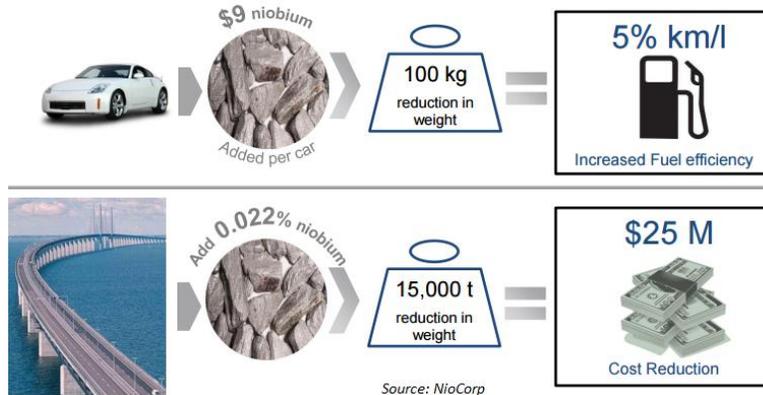
90% of niobium is used for manufacturing High-Strength, Low Alloy steel (HSLA). Niobium steel is used for pipelines, transportation, and structural applications, such as bridges and buildings.

~90 % of Niobium goes into steel

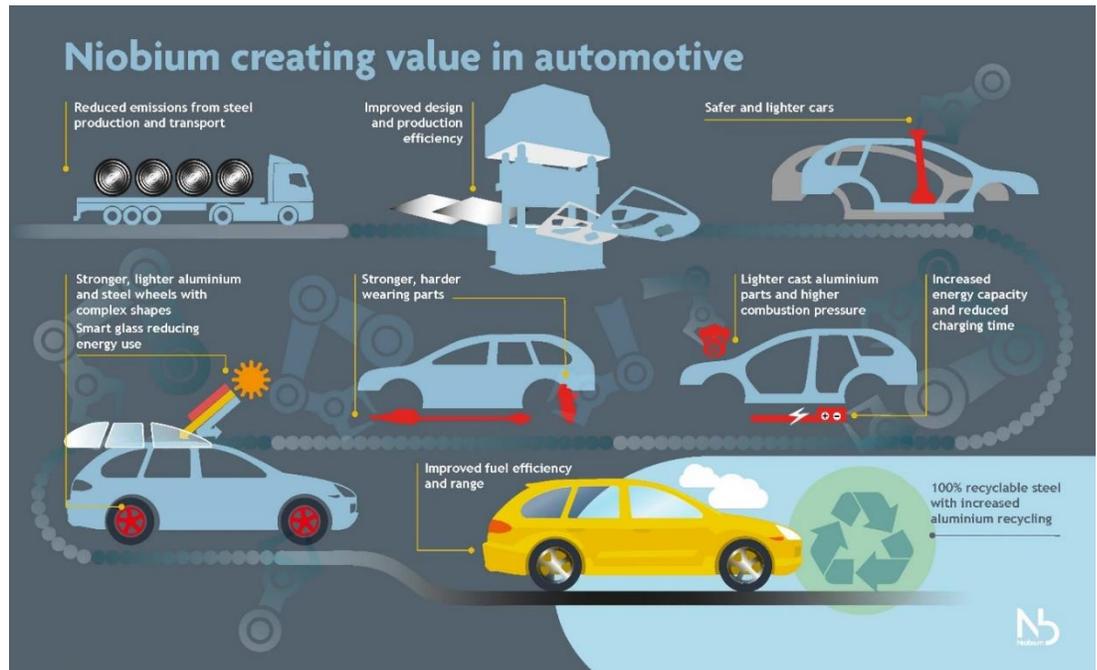


Source: www.cradleresources.com

Niobium Provides Significant Cost Benefits



According to the World Steel Association, 500 g of niobium reduces a car's weight by 100 kg, and increases fuel efficiency by 5%



Source: cbmm.com

Niobium-based batteries under development

Due to its high-temperature applications, niobium super-alloys are used in jet engines, gas turbines, rocket sub-assemblies, turbocharger systems, and combustion equipment. Niobium alloys are also used to manufacture superconducting magnets for medical and scientific applications.

Development of Niobium Batteries – Toshiba (TSE: 6502) is developing a new battery using titanium-niobium as the anode. Preliminary studies indicate that niobium-based materials can lead to faster charging times, longer range, and improved safety. EV start-up Bender Motors from Brazil estimates that an EV battery pack will consume at least 2 kg of niobium.

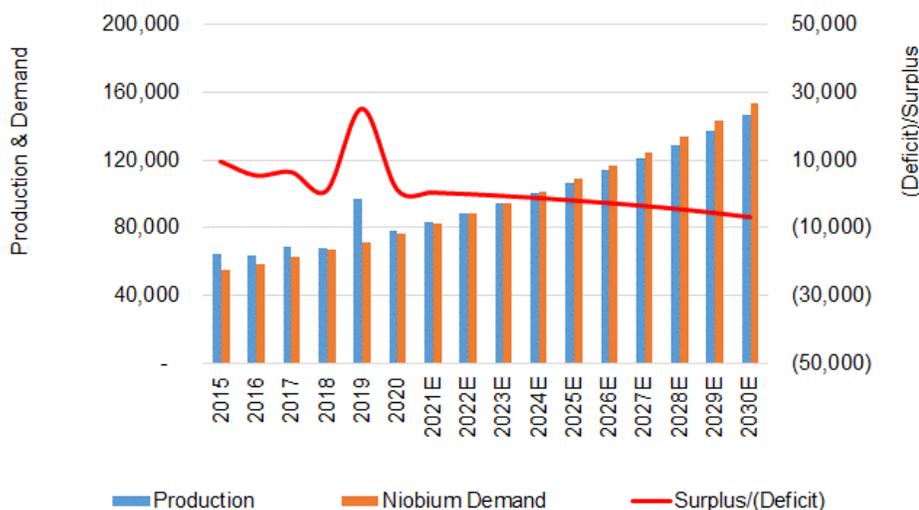
Niobium Demand

Although niobium batteries are under development, sources indicate that an EV currently requires 200 g of niobium. Applying this to consensus EV sales forecasts, we arrived at the following demand projections (shown in the chart below). Note that the primary demand driver is steel. Our forecasts will be significantly higher if niobium batteries are commercialized. We are assuming supply to grow at historical rates.

The market is expected to be in a small deficit

Demand will be significantly higher if niobium batteries are commercialized

Global Niobium Supply vs Demand (Tonnes)



Source: USGS and FRC

Niobium Prices

Niobium prices have been relatively stable as production is dominated by a single producer (CBMM) in Brazil

Global Niobium Prices



Source: USGS

In conclusion, we believe high-quality REEs and fluorspar projects, located outside China, will be sought after. China’s dominance, and rest of the world’s reliance on China, are prompting North America to take initiatives to improve the global supply chain of battery and critical minerals.

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