NEODYMIUM ($USD/MT)
OVERWEIGHT

BLOSSOMING DEMAND; SUPPLY CONSTRAINTS; OVERWEIGHT RATING

10/10/2021

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THESIS

The combination of increased global demand and supply constraints in the market for Neodymium will likely lead to substantial price increases for the rare earth metal in the next 3-5 years. We believe that fiscal stimulus from multiple countries, a growing emphasis on green technology, and inflationary pressures will force the demand for Neodymium to rise substantially. Neodymium will play an instrumental role in the renewable energy and electric vehicles industry because it is used to create the world's strongest magnets, a key component in electric motors and electricity generators (e.g., generators used in windmills). Unfortunately, China currently controls more than 80% of the world's supply of Neodymium and developing regulations and an unpredictable CCP is likely to constrain supply while demand begins to blossom.

KEY DRIVERS

Reflationary policies leading to increased demand and inflationary pressure. International governments took extreme measures to minimize the economic impact of the COVID-19 pandemic. In the United States alone, the Federal Reserve reduced the short-term benchmark interest rate to near-zero, stimulating the investment of capital and promoting economic growth. The Federal funds rate was lowered to between 0-25 bps during the pandemic to encourage banks to lend more and restructure debt. The United States also unloaded a total of 5.6 trillion dollars of stimulus since April 2020 and the rest of the world collectively injected far more into the global economy. Global reflationary policies will likely elevate commodity prices in the near term and spark demand for important inputs like Neodymium as global production returns to normalcy.

Emergence and growth of China's supply monopoly. China's disruptive emergence into the REE (Rare Earth Elements) market in the 1980s caused a sharp decline in the price of these metals, which forced international competitors, like the US, to curb production dramatically. Since then, China has created a supply monopoly with preferential policies and lax environmental standards in its metal industries. The Chinese government introduced export quotas in 2010, which cut the world supply of rare earth metals by 40% and elicited a sharp increase in these prices (with some by as much as 1,000%). Even after the WTO forced China to lift these quotas, China's lax environmental regulations have become advantageous for maintaining high production levels as other countries are hindered by stricter policies. Countries that attempt to enter the neodymium production industry struggle because of the costly capex required in the refining process and the difficulties associated with building and maintaining refinery infrastructure.

Increasing demand for renewable energy and electric vehicles. Renewable energy and electric vehicle markets are expected to grow dramatically. The off-shore wind-power market is forecasted to grow at a CAGR of 19.3% to reach a capacity of 94 gigawatts (GW) by 2026. The recent $2 trillion US infrastructure plan includes a $174 billion investment to boost the domestic electric vehicle market. The EV market is projected to grow at a 33.6% CAGR to be worth $2.5 trillion in 2027. J.P. Morgan conservatively predicts EV sales to rise from just under 5% of all vehicle sales in 2020 to at least 30% by 2025. This growth can be attributed to a universal push towards clean energy and advancements in green technology as countries like the US and members of the EU have set hard goals to reach net-zero emissions by 2050. Given neodymium's application renewable energy generation and EV motors, its future demand is promising considering the growth outlook for these industries.

PRICE:
$95,583
(Pricing as of 9/29/21)

TARGET:
$142,000

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SUMMARY

Rating	Overweight
Price	$95,583
Price Target	$142,000
52 Week High/ Low	107,650/ 60,983

5 Year Price of Neodymium

All pricing data is in relation to the NDCNDLXH China Neodymium Oxide Index measured in USD/ metric tonne

COMMODITY OVERVIEW

Neodymium is one of seventeen chemical rare earth elements (REEs) and is most commonly used in the production of powerful permanent magnets and specialty glass products. The metal belongs to the lanthanide series of elements and is a hard, slightly malleable, silvery metal. It is extremely susceptible to degradation when exposed to open air and moisture. The metal is commonly sold as Neodymium oxide Nd_2O_3 which is then converted into different final goods such as magnets which make up the largest use of Neodymium. Neodymium magnets are frequently made from a combination of Neodymium (Nd), Iron (Fe), and Boron (F) and make the chemical composition $Nd_2Fe_{14}B$. Neodymium is the largest input making up 27% of the final product by weight. Neodymium magnets are considered the most powerful permanent magnets available. These magnets have the highest resistance to magnetism and the strongest power-to-volume ratio compared to alternative magnets. These high-powered neodymium-iron-boron magnets are commonly used in electric vehicles, electronics, wind turbines and microphones. Neodymium magnet's weight-magnetism ratio makes it the ideal choice in products where lightweight and high-performance is a necessity.

Extraction and refinery for rare earth elements like Neodymium is more complex than oil or natural gas and deposits are more difficult and expensive to mine. While rare earth elements are not scarce and are about 50% as abundant as copper, mining and refining these products are expensive and are highly pollutant processes. REE's must be extracted and refined together since Neodymium exists alongside all other REEs in mineral deposits making it difficult to substantially decrease mining costs through scale.

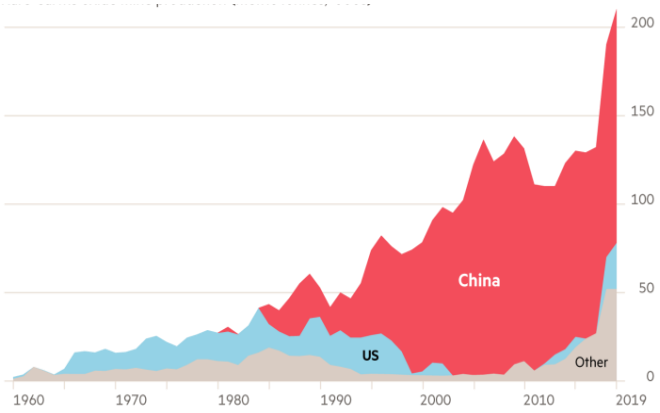
The refining process of REE's typically starts with a grinding process which turns raw ore into a powder that can more easily be separated. The REE mixture is then passed through a flotation process where it is mixed with various solvents and elements are separated based on weight. Some refining processes include electrochemical or electrolytic refining processes which include a complex process of ion manipulation through the introduction of charged compounds or electricity. The remaining mixture is usually a solid mixture which is then smelted to remove unusable mixtures from the valuable refined element. In the specific case of Neodymium, the process yields a mixture of Neodymium and Praseodymium. These elements are so chemically similar that it is very difficult to efficiently separate the two elements. However, in general, the elements are so similar that they can be used practically interchangeably. This mixed metal output is commonly sold and listed under Praseodymium-Neodymium or just Neodymium.

GEOGRAPHIC OVERVIEW

In 2020 alone, over 240 metric tons (MT) of rare earth metals were produced globally. Of the identified rare earth metals taken out of the ground, about 95% are produced by mines in just five countries – China, United States, Burma, Australia, and Madagascar. Note that, neodymium is typically 10 to 18% of the rare earth deposit composition. Although it belongs to the rare earth metals, neodymium is not rare at all. Its abundance in the Earth's crust is about 38 mg/kg, which is the second highest among rare earth elements. Furthermore, the reserves of neodymium are estimated at about 8 million tonnes. According to the US Geological Survey, Greenland holds the largest reserves of undeveloped rare earth deposits, particularly neodymium.

China not only dominates the supply of neodymium products but also demand, with 70% of global rare earth production consumed within the Chinese domestic market. In the United States, neodymium is critical to the Defense sector. Globally, there is a growing demand for neodymium in the manufacturing of permanent magnets used in wind turbines, the drive train of hybrid and electric vehicles, and energy-efficient applications, and these currently account for 29% of the total global demand for all rare earth elements. Also, It is important to note that market price dynamics can escalate so quickly that companies without an extensive supply chain will bid aggressively as materials get scarce, causing the prices to go up. For example, in 2011, neodymium prices skyrocketed when China restricted exports to maintain supplies for domestic industries.

Figure 1.0: Global Supply of REE by Largest Players



Source: US Bureau of Mines, US Geological Survey 2011-2019 data

The key to supplying neodymium is not that it is rare to find, but that it is difficult and expensive to extract, and the refining process is extensive. China developed its neodymium production capabilities as a strategic national priority because it gave the CCP monopolistic control over global supply. China is currently the global leader in this space, producing over 80% of the global supply of neodymium. Specifically, Chinese production at both the mining and refined stages is controlled by quotas assigned to six state-owned enterprises, which are highly integrated throughout the neodymium supply chain.

In the United States, companies like MP Materials are aiming to restore the domestic supply chain from mines to magnets by 2025. This includes refining, separation, and magnet-making, as the domestic electric vehicle market ramps up production. Also, the Department of Energy is investing $25 million per year in the Critical Materials Institute, focusing on securing neodymium and lithium supply chains for battery manufacturing. Moreover, Australian mining company Lynas Corporation is another key player in the large-scale processing of neodymium outside of China. They recently received $30.4 million in funding from the Pentagon to build a neodymium and light rare earth processing facility in Texas. New facilities such as these are an "essential foundation" for renewing downstream metal making and implementing magnet manufacturing into the U.S. Diversifying outside the Chinese magnetic materials supply chain is important to create competitive markets and meet the growing demand for 21st-century technologies. Unfortunately, the Neodymium refining process requires large capex and complex infrastructure. These facts make it unlikely that the United States and other

well-positioned nations will be able to substantially contribute to global supply for the next 5-7 years, and possibly longer.

GLOBAL REFLATIONARY FISCAL POLICY

Governments around the world took extreme measures to minimize the economic impact of the COVID-19 pandemic. These measures included providing emergency financial assistance to individuals and businesses, enhancing unemployment benefits, and mandating industrial actions. Expansionary fiscal and monetary operations were aimed at boosting aggregate demand and employment.

On March 11th, 2021, President Biden signed the American Rescue plan to provide 1.8 trillion dollars or 8.8% of the 2020 U.S. GDP in the form of direct stimulus payments, PPP loans, aid to local and state governments, and funding to support vaccinations. The U.S. Federal Reserve reduced the short-term benchmark interest rate to near-zero, in the wake of the pandemic, to lower the cost of financing and stimulate economic growth. The Federal Funds rate was lowered by 150 basis points to 0-0.25 basis points during the pandemic. More than 6 trillion dollars, or roughly a quarter of the US GDP, has been injected into the US economy since the start of the pandemic. Since July 2021, the Fed continues to purchase 80 billion dollars' worth of Treasury securities monthly. The global fiscal support remains upwards of 15 trillion dollars and counting.

International governments reacted similarly to the United States during the economic recourse of the pandemic. China announced discretionary fiscal policy measures of RMB 4.9 trillion or 4.7% of their GDP. The Chinese authority disbursed unemployment insurance, provided tax relief and additional public investment, and provided funding to key business operations. People's Bank of China provided monetary policy support to safeguard financial markets through liquidity injection into the banking system through reverse repos, medium-term lending facilities, and the reduction of their interest rates by 50 basis points. The European Central Bank had its main interest rates at 0.0% and -0.5% respectively. The ECB's quantitative easing, bond purchasing program is projected to reach 1.85 trillion pounds by March 2022. India's Reserve Bank of India reduced the repo and reverse repo rates to 4.0 and 3.35 percent and conducted open-market operations resulting in a total liquidity injection of 5.9 percent of the Indian GDP.

These reflationary pressures will likely artificially elevate commodity prices in the near term. The injection of liquidity will increase demand for all goods, including the demand for commodities as inputs and raw materials. Neodymium prices have already increased close to 25% since the beginning of 2021.

GLOBAL COMMODITY SUPERCYCLE

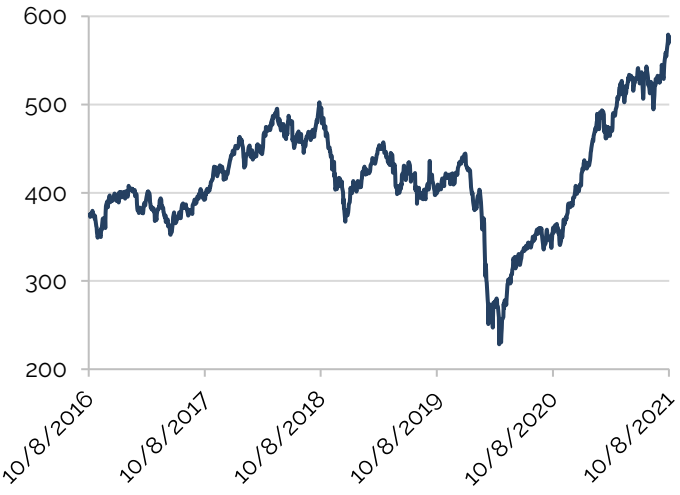
Analysts at Goldman Sachs predicted earlier this year that macroeconomic conditions at the start of 2021 could promote a global commodity super cycle. These conditions are very similar to those existing in the early 2000's which caused metal prices to surge following a huge demand boost. At the turn of the century, accelerated industrialization and urbanization in emerging economies was sucking all kinds of commodities from global markets. Emerging economies were investing large amounts of capital in capex to support their growth. Goldman believes that the demand and supply dynamic in the near future is likely to create a capex cycle like the one that existed in the early 2000's. Goldman's prediction for a commodity supercycle in the immediate future Is supported by how the world will likely recover from COVID-19. Pent up consumer demand, an emphasis on green energy technologies, and international fiscal policy will cause demand for commodities to skyrocket. This combined with supply-chain challenges, that are likely to persist for the next 3-5 years, will cause prices to increase substantially across all commodities.

In addition to general commodity market conditions, two of the world's largest governments are pushing policy that will heavily Impact the demand and supply for raw materials. The United States Senate recently passed a 1 trillion-dollar infrastructure package to update the nation's aging roads, bridges, railroads, and more. On the other side of the world, China Is enacting serious regulations on Its refining Industries that are likely to severely constrain supply. The combination of these policies and the existing conditions for a commodity supercycle will likely cause Immense strain on commodity markets and force the price level of all commodities even higher.

In the month of September, the S&P GSCI Commodity Index rose 6% and sits at near all-time highs. This index serves as a broad commodity benchmark and indicates that commodity prices throughout the market are elevated. Although the increase in the index's price level is due in part to extremely high energy prices, the prices of metals and other commodities remain far above normal levels as well. These price levels are likely to continue as demand booms coming out of the pandemic.

During a supercycle, prices for commodities are especially vulnerable to a "hype factor", defined as an extra increase in price level due to heightened investor attention, confidence, and/or speculation. As economies experience consistent growth and stability coming out of the pandemic, general confidence in all kinds of markets will also elevate the price for commodities. Specifically, regarding neodymium, once electric vehicles and renewable energy gain more momentum, neodymium will likely become an extremely important commodity for many companies and consumers. This novel attention combined with economic confidence and a general rise in prices throughout markets will likely amplify the already elevated commodity price.

Figure 1.1: S&P GSCI Global Commodity Index



POLITICAL CONCERNS IN CHINA MAY LIMIT SUPPLY

China controls 70% of the world's total rare-earth metal supply and plans to further accelerate mining quotas by 30%. Demand continues to outstrip efforts to expand supply and break China's dominance in the market. Moreover, China's pursuit of a carbon neutral economy and continual focus on its environmental efforts complicate China's aggressive control over commodity markets. China has already expressed plans to curb steel production, an industry that contributes between 10% and 20% of China's annual carbon emissions. Recently, state-owned aluminum factories have faced production challenges due to the government's strict energy consumption regulations. The rare earth's mining and refinery processes require large amounts of toxic chemicals and pollutants that are likely to force the Chinese government to begin heavily regulating this industry as well. As the main producer of Neodymium, any regulation that will decrease China's production will massively impact the neodymium markets globally.

Post-pandemic, the U.S. and other countries face many barriers to entry and are reminded that secure supply-chains are key for strategic metals, like rare earths. China's interference with the commodity production firms may negatively impact their efficiency, as regulators enforce measures that will force firms to curb production. As most of the world's rare earth supply originates from China, increased regulations may cause inefficiencies and issues in the supply chain that elevates prices globally.

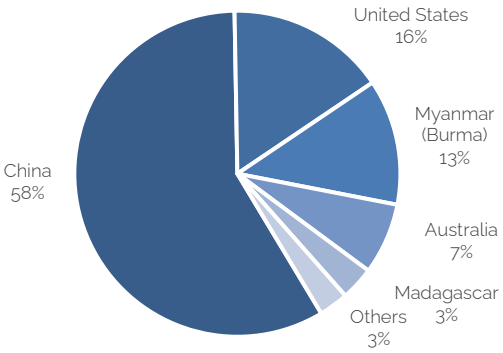
Chinese production at both the mining and refining stages are constrained by quotas assigned to six state-owned enterprises. China has regulations that prohibit the purchase and sale of rare-earth products that are exploited and extracted illegally to ensure that the government maintains tight control over the rare-earth market. However, industry officials argue that this is expected to help stabilize the market, as well as protect industrial security and the environment. China is also tightening regulation over the rare-earth metals industry, from mining to exports, by enforcing stricter export controls, in what some see as its latest response to ongoing foreign geopolitical tensions. Experts agree that the possibility of conflict between the United States and China in the South China Sea and over claims to Taiwan could materialize within the next decade. Given China's supply monopoly over the rare-earth market, if major geopolitical issues do materialize, China is likely to constrain supply significantly.

REFINING BARRIERS TO ENTRY

China was responsible for 80% of rare earth imports into the United States, according to the 2019 U.S. Geological Survey. Past efforts to rival China in the neodymium market to rebuild a domestic industry have been stymied. In the decades before the 1980s, the U.S. used to be a leader in mining and refining neodymium and other REE's. That changed as production grew abroad and environmental pressures tightened domestically. Cheaper labor, decreased regulation, and government support ultimately shifted production to China. As a result, China was able to "strategically flood the global market" with rare earth elements like neodymium at cheaper prices to drive out and deter competitors. Even though annual production of rare earth metals from non-Chinese sources is forecast to rise from 20,000 tonnes in 2020 to about 70,000 tonnes by 2030, experts say that there is a very limited connecting supply chain to maintain the demand from production, so much of this material will likely end up being refined and processed in China anyways.

The 17 rare earth elements are chemically very similar, which is why separating and purifying them is so difficult. Once extracted from the mines, ores such as monazite and bastnaesite are shipped to refining facilities, where neodymium is separated from the rest of the ore. This is a complex process that involves many steps, but it begins with the ore being crushed and milled. Then, the ore goes through a flotation process where it is mixed with water and special reagents to separate neodymium from the tailings. The resulting concentrate can be refined and extracted electrochemically, by distillation, or ion exchange techniques. The refined ore is then smelted, so the valuable neodymium metal can be separated from unusable materials in the ore.

Figure 1.2: REE Supply by Region



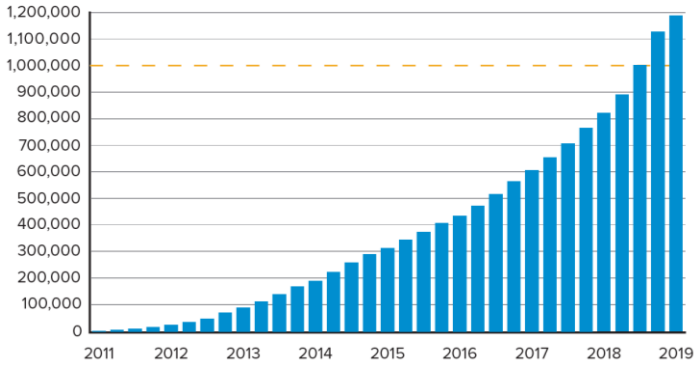
To overcome the barriers in the refining process of neodymium, the U.S. Department of Energy (DOE) is funding research to make separating rare earth metals easier and more efficient. Its office of Basic Energy Sciences is adding five laboratory-led projects focusing on separation science totaling $6.7 million per year. Similarly, the Russian government plans to invest $1.5 billion across 11 rare earth projects by 2030 and is offering reduced mining taxes and cheaper loans to investors. Furthermore, the Japan Oil, Gas and Metals Corporation signed a $20 million agreement to develop and refine mineral products including neodymium in north-western Namibia. Considering the rising demand for neodymium in battery manufacturing and green energy applications, it is essential for countries to adopt projects to overcome the barriers of entry in neodymium refining and manufacturing supply chain space outside China. Nevertheless, reentering the neodymium mining and refining industry will require a large amount of time and capital. Therefore, it is very unlikely that any country will rival China's supply dominance for at least the next 5-7 years.

INCREASED DEMAND FOR RENEWABLE ENERGY AND EV'S

Utility-scale renewable energy makes up one of the largest end uses for neodymium-iron-boron magnets. Renewable energy is growing rapidly around the globe in the wake of demands to reduce greenhouse gas emissions and improving technology which has brought the levelized cost of energy (LCOE) of renewable alternatives in line with traditional oil, coal, and natural gas energy generation on an unsubsidized basis. This metric analyzes the cost of producing one megawatt hour of energy including plant depreciation, maintenance, fuel, and other associated costs. The United States has increased the amount of energy produced from renewables by 122% from 1990 - 2020 and now produces nearly 20% of all energy through these sources which has been a dramatic increase from 11.7% in 1990. China produces 19% of their total energy from renewable sources and 54% from coal but the CAGR of solar energy is 74% from 2012-2018 whereas coal has only grown at 3.6%. Energy networks are unlikely to replace base load capabilities with renewable alternatives because of the variability in energy output caused by weather abnormalities; however, this is only about 20% of total energy capacity. This leaves an enormous amount of energy capacity that governments around the world intend to convert to renewable energy. These plants also have a 25 - 35-year lifespan which will provide a perpetual need for rare earth elements as energy plants are replaced.

The Neodymium magnets that are used in wind turbines cost between $50 - $115 per kilogram and can require several tons of the magnet in larger offshore turbines. The higher magnetic output of these magnets relative to their alternatives makes it the superior choice in these projects, solidifying the demand for neodymium in wind turbines. The accelerating construction of renewable energy projects across the globe translates to a significant demand increase for rare earth elements.

Figure 1.3: Number of EV's in Operation in US



Source: Edison electric Institute EV data from 2011-2019

Electric and hybrid vehicles represent another one of the largest end uses of neodymium magnets. These magnets are required to power the rotor of the drivetrain and require between 2 - 5 kilograms of magnet per vehicle. Electric vehicles can be produced without these magnets instead utilizing induction motors but are less efficient resulting in a shorter driving range per charge. Governments and corporations across the globe have announced plans to significantly increase their adoption of electric vehicles or phase out internal combustion engine vehicles entirely. General Motors intends to solely produce electric vehicles by 2035 and the European Union announced their policy for vehicles to produce zero emissions by 2035. In 2010 10% of all vehicles sold in the EU were electric vehicles, up from 2.2% in 2018. There has been hesitation for many consumers to replace their traditional vehicles with an electric vehicle because of driving range concerns and a lack of rapid charging infrastructure. The U.S. $550 billion Bipartisan Infrastructure Bill includes $7.5 billion which will be spent on building up the country's electric vehicle charging infrastructure which should quell some of these reservations amongst consumers. Given these factors, the global EV market is projected to grow at a 21.7% CAGR through 2027 before continuing to grow faster on a per vehicle sold basis. The increasing adoption of electric vehicles coupled with the steady creation of renewable energy will result in an increase in demand for Neodymium.

EMERGING DIVERSIFICATION IN NEODYMIUM USES

Neodymium has special properties that are useful beyond just magnet technology. The scientific world is finding numerous ways to integrate neodymium in revolutionary new technologies which will also help spur demand. Our group outlines some below:

MILITARY APPLICATIONS

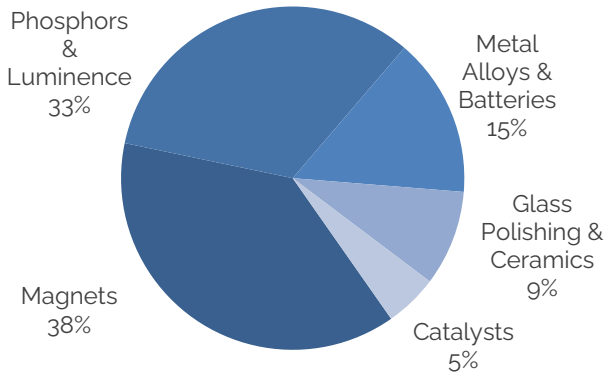
In recent years, neodymium magnets have experienced a surge in military applications, which is in large part due to the U.S.'s effort to remain the world leader in advanced military technology. Because of the high power-to-weight ratio of neodymium, there is heightened demand for utilizing hard drive magnets in aircrafts, tanks, and satellites. More relevant to the military weapons race today, the NdFeB magnet and Nd:YAG laser have become increasingly popular for guiding advanced missile systems as well as planting and detecting mines. Pentagon documents recently revealed that the US military has been stockpiling rare earth magnets, such as neodymium, for uses in F-35 fighter jets and Javelin missiles. However, if China continues to garner leverage over the supply of rare earth metals, they could implement trade restrictions that would threaten the US' ability to maintain its military equipment levels and technological edge. Until there is any success from stockpiling REEs or opening new mines to alleviate Chinese pressure, the DOD will still be at risk from any drastic changes to the neodymium supply chain.

MEDICAL USE CASES

There is an emergence of neodymium as part of surgical exams and as a component of high-functioning medical devices. In the past, Neodymium has been used as an additive to glass to add a lavender or wine-red tint. When added to glass, neodymium helps filter specific, unwanted wavelengths of light. Neodymium glass in lasers has superseded other techniques in treating eye issues and removing skin cancers. Noedymium lasers emit a very specific wavelength of radiation that has the capability to safely reach deeper layers of skin tissue compared to other medical lasers. Moreover, neodymium magnets are an important component in magnetic resonance imaging (MRI) devices used to diagnose a variety of diseases and medical conditions. The

ability to generate a static magnetic field allows doctors to remove certain foreign bodies from patients who undergo surgical operations. This treatment, known as magnetic therapy, is valuable for inhibiting the growth of both benign and malignant tumors early on. As cancer incidence rates are expected to rise in the coming years, neodymium magnets can serve as a powerful mitigation tool

Figure 1.4: Current Uses of Neodymium



PRICING MODEL

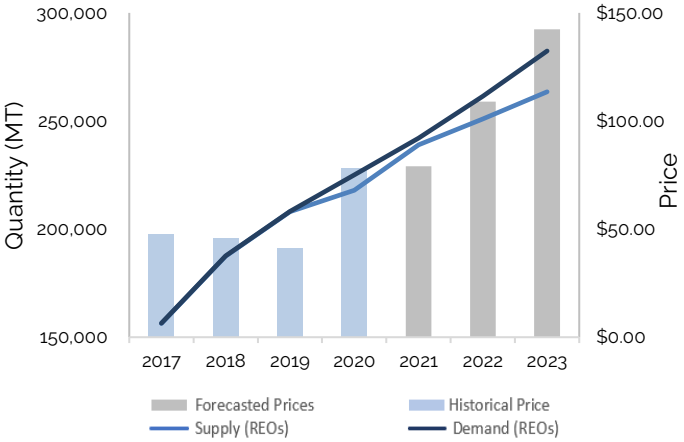
We establish a price target for neodymium oxide of $142 per kilogram by FYE 2023. Our neodymium pricing model is a multiple linear regression analysis which accounts for historical global demand and supply for rare earth elements to identify a relationship between these independent variables and neodymium price. Through our research, we discovered that the percentage of neodymium to total rare earth elements supplied globally remained relatively constant throughout time between 10-18%. We used the average of this statistic (14%) to estimate the historic level of supply and demand for neodymium globally. We then ran these data points through a regression model to generate a multivariable equation we could use to forecast price. Using this data, a preliminary list of price forecasts was found.

For our supply and demand forecasts beyond historical data, we used a supply growth rate of 5% and a demand growth rate of 8%. Considering that China controls a majority of Neodymium supply, we believe that their capabilities are the most important determinant of supply in the future. The historic growth rate of supply in our model is averaged at 8.68%. However, given geopolitical and regulatory uncertainty in China, we believe that this number is unsustainable moving forward. We also believe that it will take at least 5-7 years for the rest of the world to establish necessary infrastructure to substantially add to neodymium supply. Considering these factors, we estimate that the global supply of neodymium will likely grow at a 5% growth rate moving forward. Even if China is unable to meaningfully increase their production capabilities, they likely have enough inventory to support this lower growth rate in the future. As for demand, our model yielded a 12% historical growth rate for Neodymium demand in the past 4 years. We believe that this time horizon is not long enough to confidently establish an average demand growth rate. According to Markets and Markets, a market research firm, global demand for Rare Earth Element based magnets is likely to grow by 10-14% until 2025. We believe that over 50% of global neodymium will be used towards creating magnets for electric vehicles and electricity generation in the near future. Given the metrics proposed by Markets and Markets and our historic average demand growth rate, we established a conservative estimate that demand for Neodymium will likely grow by a 8% CAGR into the future. We used this figure to estimate demand.

Our regression model used supply and demand data points from the end of each year starting in 2015 and projected supply and demand to 2025. Our model had a correlation coefficient of 0.83 and an R-squared of 0.69. Based on the numbers, we are confident that our model establishes a fairly strong relationship between price, supply, and demand.

Even though our model projects pricing up to FYE 2025, we decided to use our forecast up until FYE 2023. We believe that the possibility for a commodity super cycle creates significant volatility and uncertainty in commodity markets that our model cannot predict for. Commodity cycles follow a periodic distribution, which can be modeled via a trigonometric function to estimate how supercycles affect pricing. However, these functions are too complex to regress and beyond the scope of our analysis. As a simpler alternative, we used our regression model to predict over a shorter time horizon. Beyond the next 2-3 years, we believe that complicated factors, including the interaction of global inflation and uncertain investor sentiment, will affect supply and demand, as the world continues to proceed through an unprecedented period of economic recovery.

Figure 1.5: Pricing Model for Neodymium



RISK FACTORS

There are three main risks that could affect our investment thesis.

Substitutes and emerging magnet technology. Unlike Neodymium based magnets, ALNICO (composed mainly of an aluminum, nickel, and cobalt alloy) magnets rely on more abundant and consistent commodity markets. Before the development of rare earth magnets, ALNICO magnets were the strongest type of magnet available. ALNICO magnets retain their magnetic capabilities more consistently because they are able to withstand higher heat and are more resistant to corrosion than Neodymium magnets. However, Neodymium-based magnets

continue to dominate the EV and renewable energy market because it is the strongest functioning magnet in relation to its size. Nevertheless, ALNICO magnets offer a viable alternative to Neodymium based magnets and could replace Neodymium magnets if the commodity market for the rare earth metal becomes too volatile. In high heat applications like aerospace and advanced weaponry technologies, ALNICO based magnets will likely emerge as the primary option due to its resistance to high temperatures.

In addition to ALNICO, material science researchers have placed a growing emphasis on developing alternative magnetic materials to Neodymium and Dysprosium based magnets. Currently, cerium cobalt has emerged as a possible alternative. Cerium is more abundant than other rare earth metals and researchers at the American Chemistry Society believe that cerium cobalt magnets could suck demand for Neodymium magnets in the future. Researchers are confident that their efforts could yield other viable, and even more useful alternatives, in addition to cerium cobalt, to neodymium magnets in the future.

Neodymium magnet maintenance requirements. Neodymium magnets are delicate and can shatter or break relatively easily. If they are collided with another hard material, even from just a few inches away, neodymium magnets can easily shatter or break. In addition, neodymium magnets are extremely susceptible to corrosion. The typical coating for a neodymium-based magnet consists of a coating of nickel, followed by a coat of copper, and then another coat of nickel. Maintenance on the magnet's coating is extremely important because any exposure to moisture will degrade the magnet very quickly. Like iron, atmospheric moisture can easily degrade the strength and composition of neodymium magnets. Neodymium magnets thus require a high degree of maintenance, and these input costs may reduce the overall demand for the magnets as alternatives emerge in the market.

Price volatility could constrain growth. The high price volatility of the rare earth market is likely to constrain growth in the future as alternatives become more abundant. Producers prefer the ability to consistently predict costs of production, and magnets that rely on more stable commodity markets may become preferable. Considering the effects of COVID-19 on commodity markets and the emerging dynamics of the rare earth commodity markets, the price of neodymium is likely to remain volatile for at least the next 5 years. In addition to price, the supply of neodymium will also likely remain volatile in the near future considering China's supply dominance in the neodymium market. The CCP's (Chinese Communist Party) control over neodymium mining facilities and mining companies makes their output unpredictable and unreliable over the long-term. Furthermore, the emerging concerns about China's increasing emphasis on environmental regulation may impede the production of neodymium.