MACRO POLO

The Impermanence of Permanent Magnets:

A Case Study on Industry, Chinese Production, and Supply Constraints

Damien Ma and Joshua Henderson

保尔森基金会
PAULSON INSTITUTE

Executive Summary

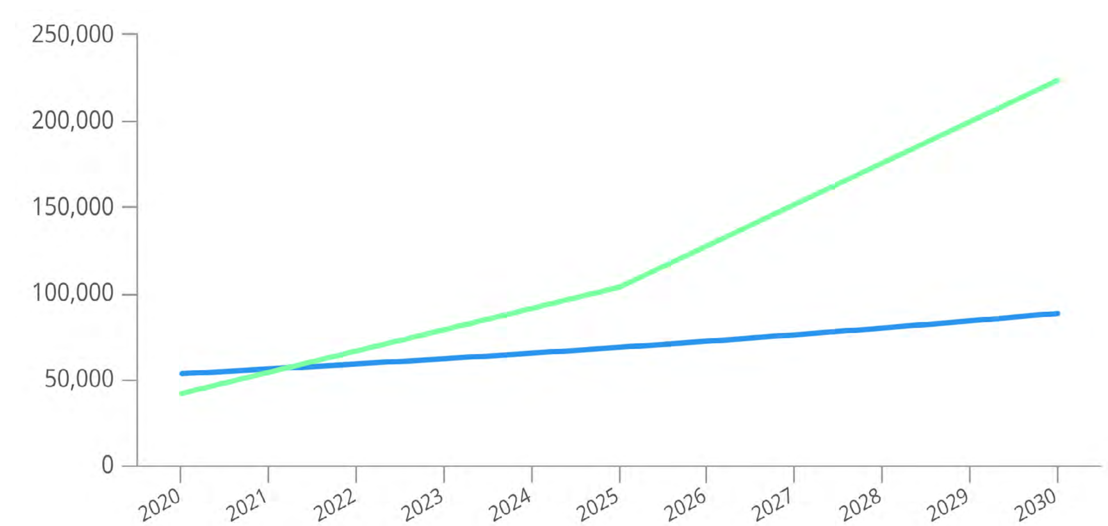
A more digitized and clean energy-driven global economy will lead to a material shift in the supply and demand of different inputs. One such input is the permanent magnet, which can be considered a "neo-commodity" product like the lithium-ion battery.

Like the li-ion battery, the clean energy transition will be the key driver of rare earth-based permanent magnet demand in the coming decade—namely the penetration of electric vehicles (EVs) and wind power.

In particular, high-performance NdFeB (neodymium-iron-boron) magnets are crucial inputs for EV motors and wind turbine generators, and their demand is likely to grow at an estimated 18% per annum through 2030.

That ballooning demand, however, will be met with an estimated <6% growth in NdFeB supply over the same period, with a demand-supply gap potentially appearing as soon as 2022.

Figure 1. High-Performance NdFeB Magnets Demand-Supply Gap Could Appear by 2022



Note: Supply is assumed to grow at a CAGR of 5.2% from 2022-2030; demand projection uses the average of the high- and low-end scenarios. Source: Authors; Deloitte; Ping An Securities; Industrial Securities; International Energy Agency; Global Wind Energy Council; Rethink Technology Research; EV Volumes; and QYResearch.

Assuming that baseline capacity expansion, by 2030, the supply deficit could reach 135,000 tons, driven largely by the growth of the EV and wind turbine industries.

With an 87% global market share, China is more dominant in NdFeB magnet production than it is in li-ion batteries and solar panels.

But that headline figure obscures an important wrinkle: for now, China is able to produce only about half of the high-performance magnets that go into EVs and wind turbines. Japan and Germany account for the remaining high-performance magnets market, with Japan's Hitachi Metals owning most of the patents for advanced sintered NdFeB magnets.

As such, several factors could exert significant pressure on the supply side:

- The patent barrier is one constraint among others that prevent Chinese manufacturers from significantly expanding high-performance NdFeB magnets production;
- Production levels in Japan and Germany may have plateaued, ushering in questions about their ability to expand capacity quickly;
- Even if China ramped up capacity, it is unlikely to export a large portion of such magnets because its own burgeoning EV and wind markets will absorb much of the supply.

Without significant expansion of capacity in these three countries, particularly China, potential NdFeB magnet scarcity in coming years will drive up prices and therefore raise the cost of the clean energy transition.

While it is tempting to focus on China's dominance of permanent magnets production, the priority may need to center on how to ensure that the clean energy supply chain remains stable. It is certainly possible to invest in manufacturing capacity in the United States, but the cost and complexity of advanced magnets manufacturing means that it will take time.

That implies the supply crunch could arrive before significant additional capacity can be built. Amid continued supply chain flux and an inflationary environment, any sensible policies in this area will need to account for this economic reality and further assess the extent and scope of the demand and supply mismatch.

In the near term, at least, securing supply chains should not come at the expense of preventing disruption in the clean energy supply chain.

Introduction

A more digitized and clean energy-driven global economy will invariably catalyze a material shift in the supply and demand of different inputs. That shift is already under way, as lithium prices are skyrocketing and semiconductor bottlenecks are inflating the cost of used cars.

If traditional commodities from copper to iron ore saw their "super cycle" in the 2000 to 2010s, a set of "neo-commodities" necessary to actualize that future global economy may be subject to similar dynamics over the next decade.

The lithium-ion battery, largely responsible for lithium market fluctuations, has lately come to symbolize this neo-commodity. The attention lavished on batteries, however, has obscured another candidate for neo-commodity status: permanent magnets.

A magnet is familiar to many, yet few realize that it is in virtually everything. From the smart phone to an infrared guided missile, permanent magnets are indispensable inputs for most power systems.

As with batteries, magnets consumption will be driven by the clean energy transition—predicated on the growth of electric vehicles (EVs) and wind turbines. The volume of permanent magnets required in a typical smart phone is miniscule compared to what an EV or a wind turbine needs.

But not all permanent magnets are made equal, and the industry preference is by far the neodymium-iron-boron (NdFeB) composition, a type of magnet that can generate more power per unit at lower cost.

Since neodymium is a light rare earth element (REE), it is no surprise that China's control of the upstream REE supplies has raised hackles in Washington and beyond. Yet that may require a rethink.

Ever since the early 2000s, Beijing has been consolidating its REE industry with the intent of supplying its own magnets manufacturing capacity. Two decades later, China now commands less than 60% of global REE supplies but produces more than 80% of the world's total permanent magnets, a share that has held relatively steady over the last decade.

This makes China more dominant in permanent magnets than it is in either li-ion battery or solar panels production, sectors often raised in the United States as candidates for reshoring manufacturing.

As such, the focus on China's control of REEs as a matter of supply chain security may be misplaced going forward. Not only are REE supplies globally distributed, these metals also can be recycled. But manufacturing permanent magnets requires building costly capacity, since it needs specialized machinery and involves somewhat complex processes.

In other words, to the extent there will be supply bottlenecks, they will likely increasingly shift from the upstream REEs to the midstream production of permanent magnets. These bottlenecks could manifest most prominently in the high-performance NdFeB segment.

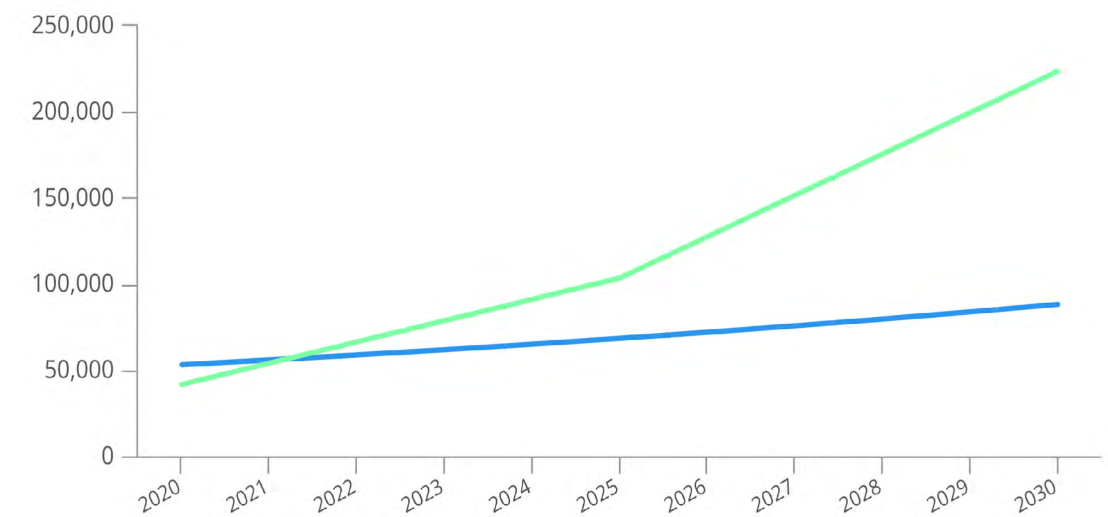
As these magnets become highly sought after by EV and wind turbine manufacturers, whether rising demand will be met with sufficient supply is an open question. For example, assuming no significant technological breakthroughs, the EV and wind turbine industries alone could drive some 80% of high-performance NdFeB magnet demand over the next decade.

A large part of that demand will be China itself, since it is expected to be one of the largest markets for EVs and wind turbines. Therefore, it is little surprise that Beijing has a self interest in integrating a domestic clean technology supply chain—from the REEs to magnets—to meet anticipated rising demand at home.

But there's more uncertainty on the supply side, in large part because just two other countries besides China specialize in high-end NdFeB magnets: Japan and Germany. Both Japan and Germany are marginal players in overall permanent magnets production, but combined they make up roughly half of the global production of high-performance NdFeB magnets.

Yet it is not clear that Japan and Germany on their own will be able to ramp up capacity to meet future demand driven by the clean energy transition. Based on public and industry data and some assumptions, our baseline projection sees high-performance NdFeB demand exceeding supply potentially as soon as 2022. By 2030, that supply deficit could reach 135,000 tons, driven largely by EVs and wind turbines (see Figure 1).

Figure 1. High-Performance NdFeB Magnets Demand-Supply Gap Could Appear by 2022



Note: Supply is assumed to grow at a CAGR of 5.2% from 2022-2030; demand projection uses the average of the high- and low-end scenarios. Source: Authors; Deloitte; Ping An Securities; Industrial Securities; International Energy Agency; Global Wind Energy Council; Rethink Technology Research; EV Volumes; and QYResearch.

The demand and supply gap in coming years could add challenges and costs to the clean energy transition. With economic security rising to the fore, however, that security component ought not come at the expense of the economic component. Exclusively considering where magnets are made may end up overlooking potentially serious production constraints that will affect prices amid an inflationary environment.

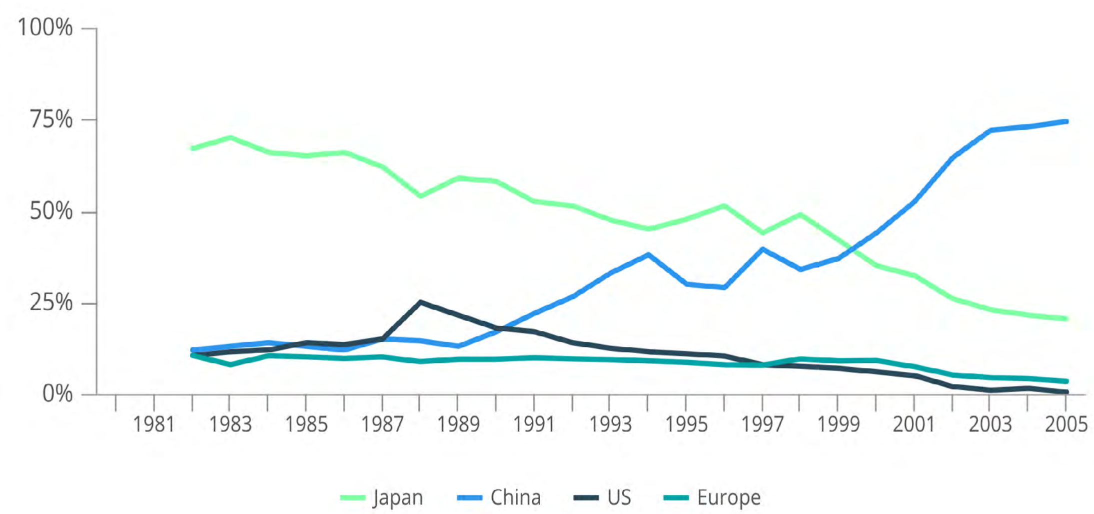
With supply chains already in flux, sensible policies for a given industry need to be based on economic reality and industry dynamics, which may require prioritizing the expansion of aggregate global supply to ensure that the clean energy supply chain remains stable.

This case study, then, aims to crystallize that economic reality. It begins by briefly examining the recent history of the permanent magnets industry, including the technology behind magnets and how China came to dominate production. It then looks at current market dynamics and future demand drivers through 2025 and 2030. Finally, it concludes with what the demand and supply pictures mean for reliable supplies and economic security.

Evolution of Permanent Magnets Production

Production of NdFeB magnets was concentrated in Japan and the United States for about a decade. Starting in the 1990s, for a variety of reasons, China began to displace both Japan and the United States as the hub of magnets manufacturing (see Figure 2). By the mid-2000s, the United States had essentially exited the magnets market, while Japan's production footprint also shrank considerably.

Figure 2. China Surpassed Japan in NdFeB Magnets Production by 2001



Source: Du, Xiaoyue and Graedel, T.E., "Global Rare Earth In-Use Stock in NdFeB Permanent Magnets," Journal of Industrial Ecology, 15 (6), 836-843.

Brief History of NdFeB Magnets

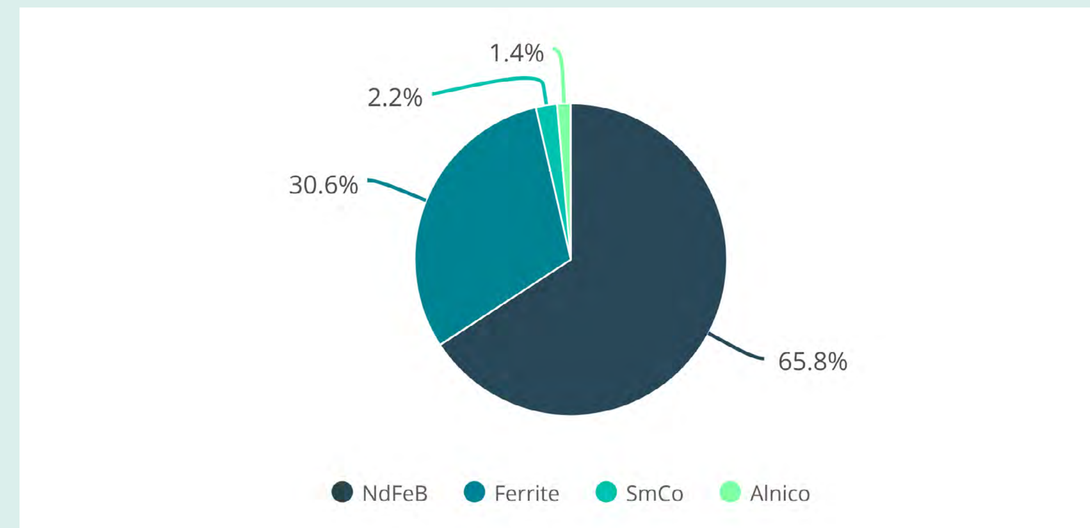
This outcome may be surprising given that both US' General Motors (GM) and Japan's Sumitomo Special Metals, out of sheer coincidence, invented the NdFeB compound in 1982. Apparently both companies were synchronized in their desire to move beyond what was then the prevailing compound, samarium cobalt (SmCo), which was powerful but very costly. NdFeB magnets, on the other hand, could generate similar power at lower cost.

In fact, the NdFeB is the most powerful permanent magnet (per unit volume) in existence, able to attract objects up to 1,000 times its own weight. This makes these magnets ideal inputs for high-energy applications where miniaturization is a key component of product design (see Box).

Permanent Magnets 101

Magnets power everything from smart phones and stereos to cars and wind turbines. Among permanent magnets, the NdFeB type is not only the strongest but is also more resistant to de-magnetization (i.e. high values of coercivity in technical terms). The market clearly prefers NdFeB magnets, as evidenced by the 66% global market share they command (see Figure 3).

Figure 3. NdFeB Is the Dominant Permanent Magnet Compound, 2019



Note: The composition of ferrite magnets are mainly iron oxide with small amounts of metallic elements including strontium, barium, manganese, nickel, and zinc; SmCo magnets are composed of samarium and cobalt; Alnico magnets are made from aluminum, nickel, and cobalt. Source: GrandView Research.

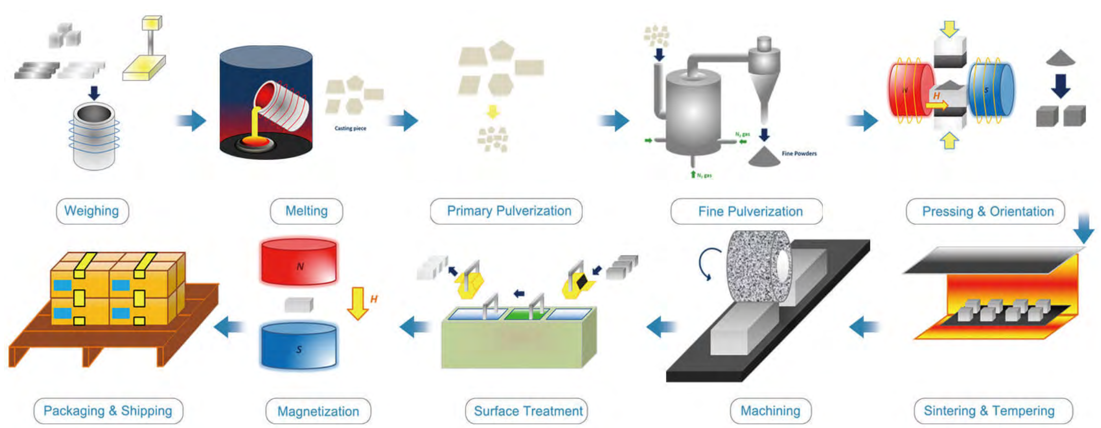
NdFeB magnets are typically composed of roughly one part neodymium (~30%) and two parts iron (66%), with boron and other REEs making up the rest. However, the neodymium portion isn't pure but is usually an oxide composed of about 75% neodymium and 25% praseodymium. NdFeB magnets come in all shapes, sizes, and strengths and are graded according to their intrinsic coercivity and maximum energy (typically from N28-N55). The higher the number following the "N", the stronger the magnet. High-performance NdFeB magnets, for example, start around N46.

At high temperatures NdFeB magnets are more susceptible to demagnetization. So manufacturers mix in small amounts of additional REEs, such as terbium, dysprosium, and praseodymium, to raise the maximum operating temperature of an NdFeB magnet. A magnet with no temperature rating—which is rated according to M, H, SH, UH, EH, and TH—can only operate at a maximum temperature of 80 celsius, while a TH-rated magnet can operate at up to 220 celsius.

What set GM and Sumitomo apart was the respective manufacturing process each company had developed. The US company stuck to bonded NdFeB magnets that required rapidly cooling magnetic powder and molding it into a magnet, while Sumitomo's sintered process pressed the NdFeB powder onto a magnetic field to be sintered in a furnace (see Figure 4).

There are tradeoffs to each process—bonded magnets are versatile, cheap, and relatively easy to make, while sintered magnets generate unmatched power. The industry eventually coalesced around Sumitomo's sintered magnets, opting for more power rather than the cheaper bonded magnets from GM. Unrealized at the time was that this industry standard would have implications for China's eventual rise in magnets production.

Figure 4. Manufacturing Process of Sintered Neodymium Magnet



Note: Manufacturing sintered NdFeB magnets is capital-intensive, with manufacturing comprising up to 30% of the total production cost. The process requires precision technologies, from jet mill systems that break down raw inputs into 5-micron metal flakes to the sintering ovens that set the internal structure of the magnet. Source: SDM Magnetics.

How China Came to Dominate Global NdFeB Production

Although the industry was going the way of Sumitomo's sintered NdFeB magnets, the United States was still a player in magnets production up until the 1990s. But that all changed in 1995 when GM decided to sell its magnets subsidiary Magnequench to a consortium of Chinese companies and US investment firm Sextant Group.

Perhaps surmising that bonded magnets may become obsolete, GM may have used the opportunity to offload an asset that was not as valuable. For its part, China started to focus on capitalizing on its abundant REE resources in the 1990s, but it didn't have the technology to make magnets back then.

Consequently, the deal went through on the condition that the Chinese companies would keep Magnequench's production in the United States for at least ten years. A few years later, China had built Magnequench's production line domestically, and in September 2001, ownership announced all US production lines would be shut down in a few years.

China subsequently scaled up its production to unprecedented levels. The shift was swift and resounding—by the mid-2000s China alone made up nearly 80% of global NdFeB magnet production, about the same market share that was split between Japan, the United States, and Europe more than a decade earlier.

This effectively led to a US exit from the magnets market in the mid-2000s, though that should be put in context. The United States was never a major player and was outcompeted by Japan's magnets production throughout the 80s and 90s.

What was more dramatic was China's displacement of Japan's market share by the end of the 2000s. But herein lies a significant wrinkle: what China produced in volume could not be matched in quality.

That's because taking over GM's operations only allowed China to make bonded magnets and corner the lower end magnets segment. But the value-added was in sintered magnets, particularly high-performance ones for which Sumitomo Special Metals, and then later Hitachi Metals, had an array of patents (they merged under Hitachi in 2004).

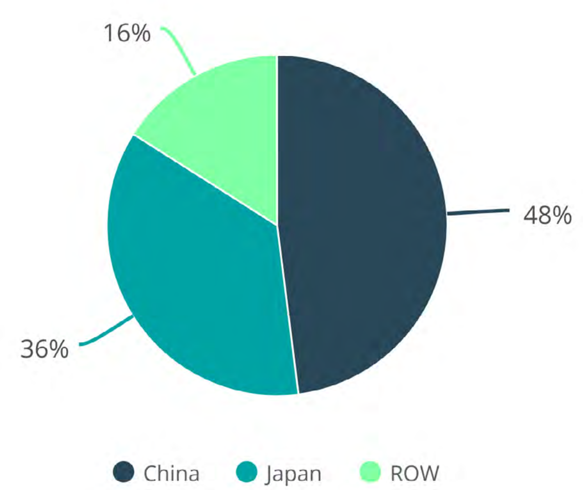
That meant manufacturers, including Chinese ones, had to license the sintered technology from Hitachi. China had little choice but to do so as demand for sintered magnets was rising fast in the 2000s. By 2019, sintered magnets comprised 94% of all NdFeB magnets, and Japan still controlled the vast majority of those patents.

Meanwhile, Hitachi was reticent to license its advanced sintered magnets technology, limiting it to just eight large Chinese manufacturers. This means that of the 200 or so NdFeB magnet producers in China, only 4% are able to make high-performance sintered magnets.

To be sure, China hasn't been sitting still on the patents front. It has filed many magnet patent applications since the 2010s. Still, Japan holds over half of NdFeB patents as of 2020, and this barrier likely explains in part why China still punches below its weight on high-performance magnets.

As of 2018, China produced 87% of the world's NdFeB magnets, but only 48% of the high-performance type, with Japan and Germany making up the rest (see Figure 5).

Figure 5. High-Performance Magnet Production Dominated by Three Countries

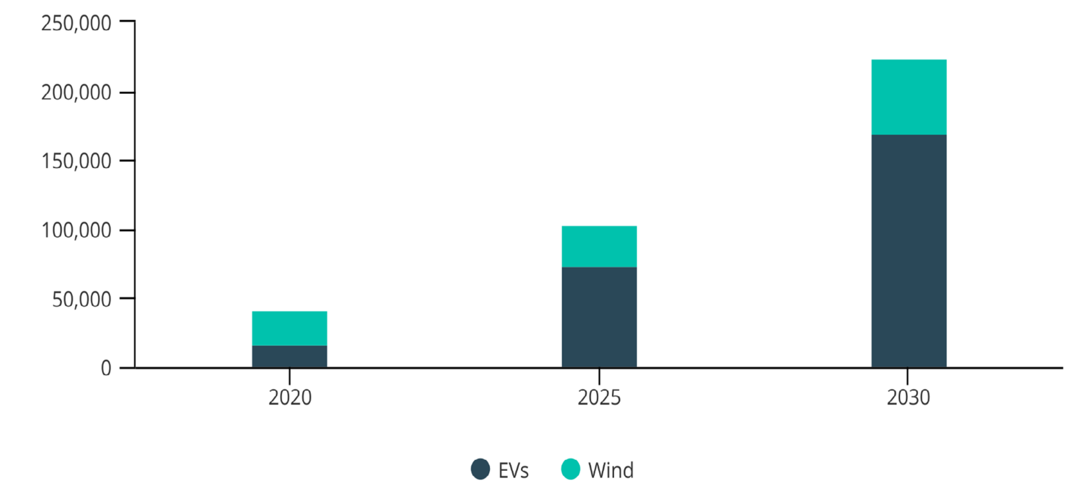


Note: Japan and Germany likely exclusively make high-performance NdFeB magnets; "ROW" essentially means Germany. Source: Hwabao Securities; Ping An Securities.

The Demand Picture

Permanent magnets have many different end uses, but for EVs and wind turbines, high-performance NdFeB magnets are key. Demand for high-performance magnets from those two sectors alone is expected to grow more than 400% from 2020 to 2030, averaging about 18% per annum (see Figure 6). Now, we examine these two sectors.

Figure 6. High-Performance NdFeB Magnet Demand from EVs and Wind, 2020-2030

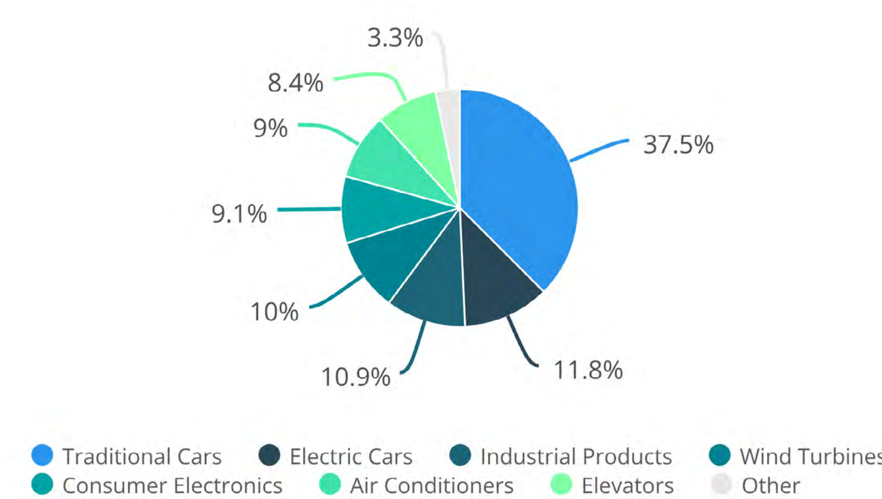


Note: Demand based on averages of projected high- and low-end demand scenarios (see more below).
Source: Authors; Deloitte; Ping An Securities; International Energy Agency; Global Wind Energy Council; and Rethink Technology Research.

Electric Vehicles

Currently, the traditional auto sector makes up about 38% of NdFeB demand, making it the largest demand driver (see Figure 7).

Figure 7. Auto Sector Largest Demand Driver for NdFeB Magnets, 2019



Source: Hwabao Securities.

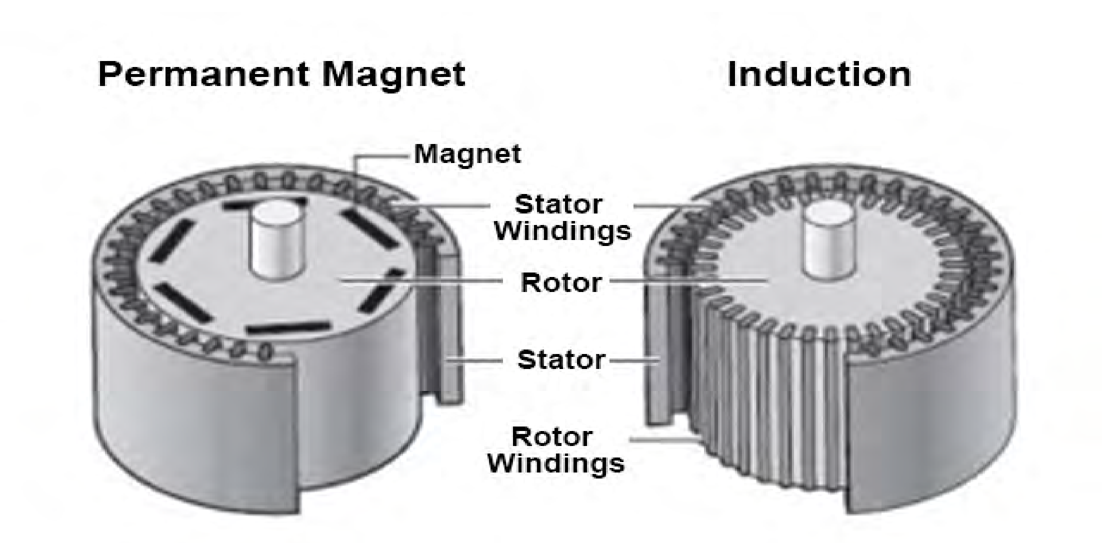
For gasoline-powered cars, NdFeB magnets are primarily used in the electric power steering system (EPS), which typically comes as a standard feature in all contemporary car models. Power steering is estimated to use about 0.25 kg of NdFeB magnets per system. Assuming the continued penetration of EPS, traditional gasoline cars' NdFeB magnet demand is projected to hit nearly 20,000 tons by 2025, up 1.3 times from 2019.

By 2025, the auto sector will likely be an even larger driver of demand, a result of EVs switching places with gasoline cars. With more countries pledging to phase out gasoline cars by 2030, the continued penetration of EVs is all but guaranteed. For instance, EV sales globally are expected to balloon from 2.5 million to 11.2 million by 2025, at a CAGR of 35%.

This dramatic shift to EVs should drive significant NdFeB magnet demand because the amount needed for a single EV is much greater than for a gasoline car—more than 10 times as much. A typical EV contains anywhere between 2.5 kg to as much as 10 kg of NdFeB magnets, and almost all EV motors use permanent magnets.

Instead of an engine, EVs use electric motors to power the wheels, and NdFeB magnets are a crucial input for the motors to function (see Figure 8). Therefore, it is unsurprising that EVs will dethrone traditional cars as the main driver of permanent magnets demand.

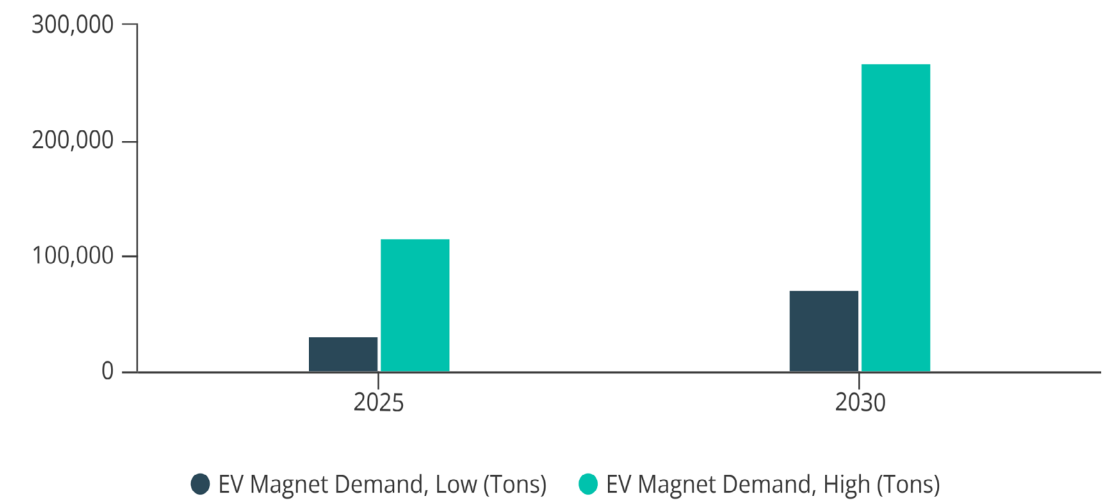
Figure 8. EV Motors Require More Magnets Than Gasoline Cars



Source: New Energy and Fuel.

Based on estimates from China's Hwabao Securities, EV demand for magnets is expected to grow more than 600% from 2019 to 2025, exceeding 35,000 tons and aligning with our low-end projection below. But if an EV uses closer to 7 kg of magnets, the high-end projection puts demand at more than 115,000 tons by 2025 (see Figure 9).

Figure 9. Low- and High-End Projections of EV Demand for NdFeB Magnets



Note: Low-end scenario based on sales of 11.2 million EVs in 2025, 25 million EVs in 2030, and 2.5 kg of NdFeB per EV; high-end scenario based on sales of 15 million EVs in 2025, 34.8 million EVs in 2030, and 7 kg of NdFeB per EV.
Source: Authors; Deloitte; International Energy Agency; and Ping An Securities.

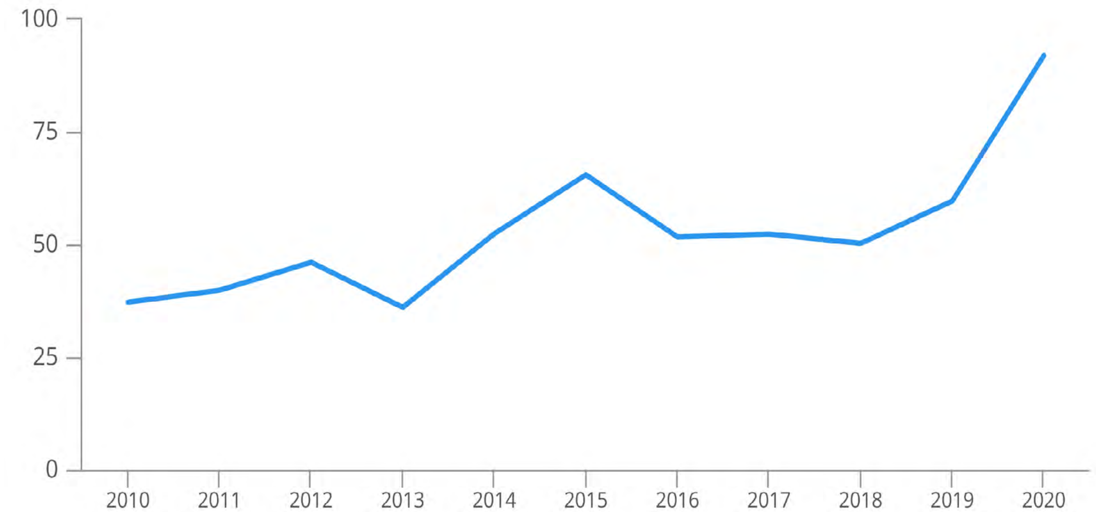
Going by the low-end projection, the EV industry in 2020 would constitute perhaps about one-third of the global demand for NdFeB permanent magnets, with the China market accounting for a significant portion of that demand.

Wind Turbines

The wind industry's demand for NdFeB magnets will not reach the heights of the EV sector, but it will nonetheless see significant growth. The greater adoption of wind power in countries' energy mix, as well as increased installation of offshore wind that requires even more power, will drive magnets demand.

The Global Wind Energy Council estimates that new installed wind capacity should average about 95 GW from 2021 to 2025, with roughly 14% of that capacity being offshore. This marks a moderate acceleration from the average annual installations over the past decade (see Figure 10). This healthy but steady growth reflects the reduction in incentives and the reality that wind power is more difficult and costly to install, since wind farms are essentially infrastructure projects that require large parcels of land.

Figure 10. Annual New Wind Power Installations Globally, 2010-2020

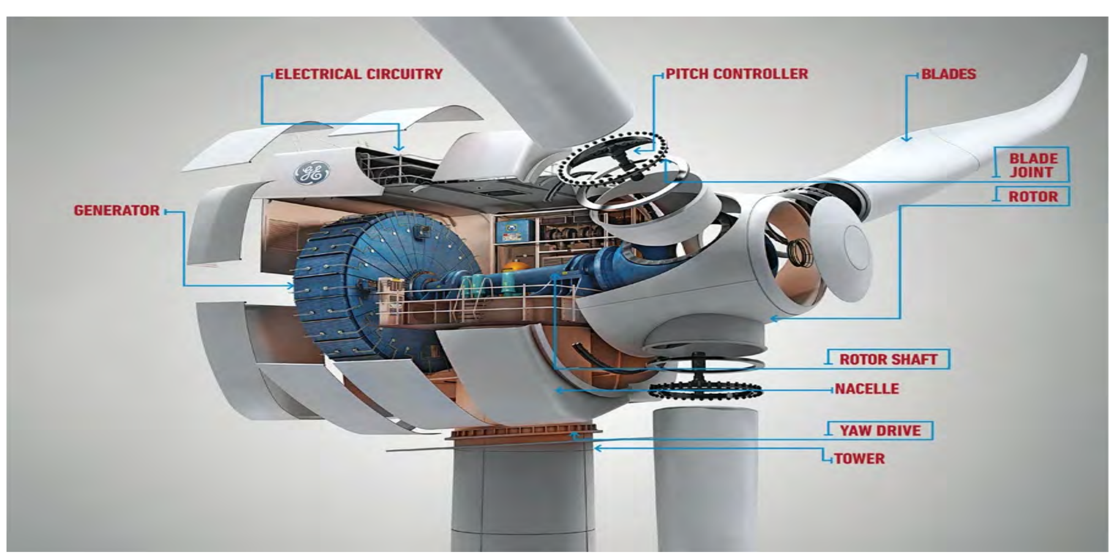


Source: [Statista](#).

However, the per unit demand for NdFeB magnets is far greater for turbines than for EVs. Although there currently lacks an authoritative consensus on the volume needed per turbine, [it is estimated](#) that a wind turbine could use up to 800kg of magnets per MW.

That seems like a huge volume of magnets. But wind turbines are giant structures, with the nacelle—which houses the generator, power converter, and transformers—containing the magnets (see Figure 11). A nacelle for a 5 MW offshore turbine, for example, [can weigh up to](#) 300 tons, with magnets making up just about 1% of the total weight.

Figure 11. Typical Wind Turbine Nacelle Structure

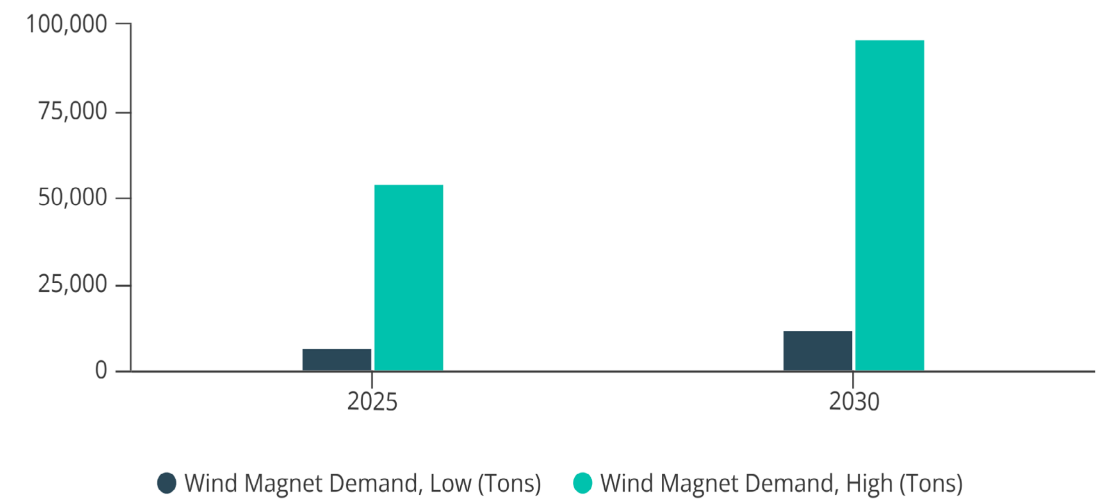


Source: [Popular Science](#).

Another factor complicating demand estimates is that not all turbine manufacturers use NdFeB magnets. Leading manufacturers in China and Europe certainly do, but the smaller, lower quality manufacturers do not. Therefore, it is estimated that perhaps 40% of wind turbines contain NdFeB magnets, a percentage that could rise to two-thirds in coming years.

Given these assumptions, wind turbines are expected to drive 6,500 tons and 11,600 tons of high-performance NdFeB magnets demand by 2025 and 2030 (low-end), respectively, and 54,000 tons and 96,000 tons by 2025 and 2030 (high-end) (see Figure 12). This makes it second only to EVs as a key demand driver for high-performance magnets.

Figure 12. Wind Is Second to EVs in Driving Magnets Demand



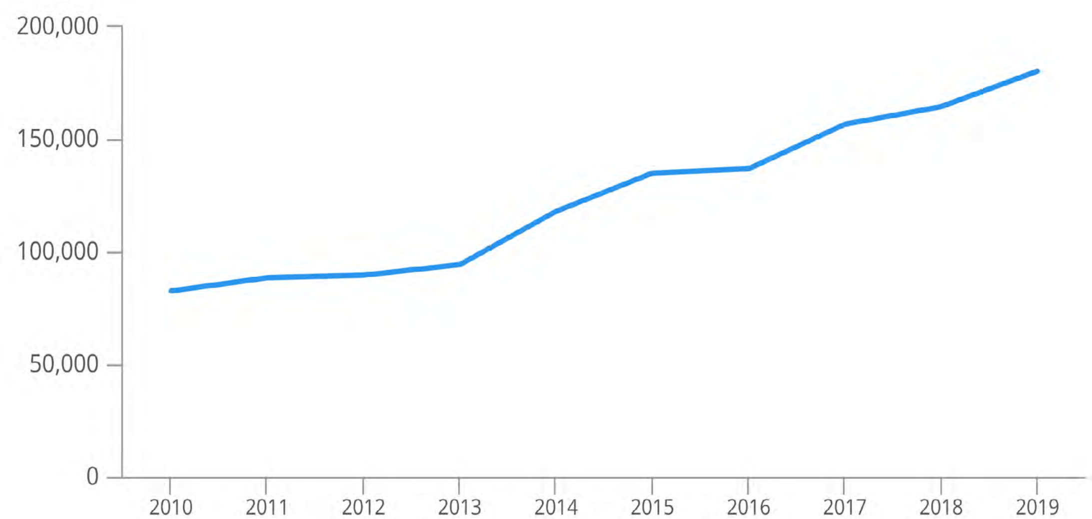
Note: Low-end scenario based on 112 GW of annual newly installed capacity in 2025 and 200 GW in 2030, with 1/3 of that capacity using 150 kg of NdFeB magnets per MW; high-end scenario based on same annual newly installed capacity as low-end, but with 2/3 using 650 kg of NdFeB magnets per MW. Source: Authors; International Energy Agency; Global Wind Energy Council; and Rethink Technology Research.

Of course, permanent magnets will be needed in many smart and green appliances, as well as potential applications in industrial robots and machinery. But by 2025, high-performance NdFeB magnets demand from EVs and wind alone could exceed the total global supply of 48,000 tons back in 2018.

The Supply Picture

On the face of it, China utterly dominates NdFeB magnets production. Between 2010 and 2019, China's output grew by 118% at a CAGR of 9% (see Figure 13). But China is not exporting the vast majority of its domestic production. As of 2020, China exported fewer than 36,000 tons of NdFeB magnets, just about one-fifth of the magnets it produced domestically.

Figure 13. China's NdFeB Magnet Output, 2010-2019



Source: Ping An Securities.

This does not appear to be a deliberate effort to restrict magnet exports, as Beijing did with REEs in 2010, which culminated in a World Trade Organization dispute that China lost. Instead, China is limiting exports because domestic consumption of magnets is likely to skyrocket as EV and wind power adoption picks up steam in the China market.

The rapid expansion of magnets production has also created a fragmented domestic industry with some 200 players, the vast majority of which are small with annual production under 1,500 tons. Moreover, of the nearly 160,000 tons of NdFeB magnets China produced in 2018, only about 15% (23,000 tons) are considered high-performance magnets.

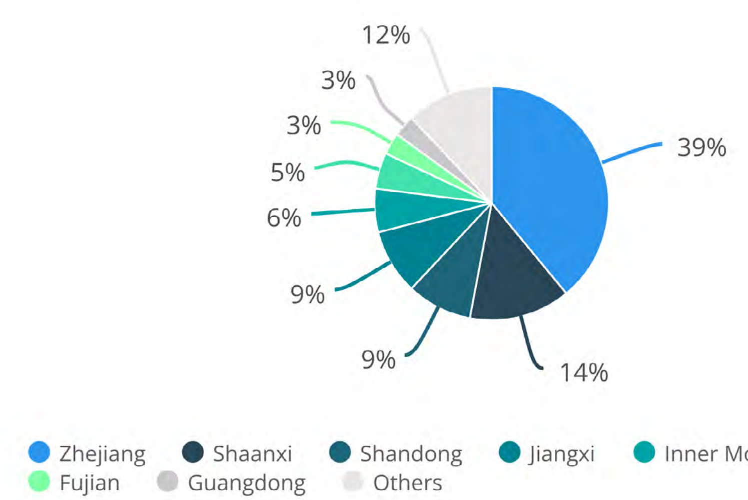
So China appears to face some overcapacity in low-end magnets but is struggling to meet demand in the high-end segment. Climbing the value chain of permanent magnets has proven challenging for a number of reasons, chief among them the high cost of entry and the patents barrier noted above.

Mid-stream manufacturing of magnets requires significant capex, as the factories are complex and require a number of specialized machinery. Smaller players simply do not have the capital to scale production or spend on innovation to develop high-performance magnets.

Another constraint on moving up the value chain appears to be Japan's grip on patents for the most advanced sintered NdFeB magnets. Those Chinese companies that do not have approved license agreements cannot manufacture such magnets and therefore cannot export to end users in Western markets.

As a result, eight Chinese magnet companies—and a total of perhaps just a dozen companies globally—have the capacity and quality to supply to elite end-users like a Tesla or a Siemens. A number of these Chinese companies are in Zhejiang province, incidentally also the first "common prosperity" pilot zone (see Figure 14).

Figure 14. China's Magnet Production Concentrated in Zhejiang



Source: Foresight Industry Research Institute (前瞻产业研究院).

While Zhejiang has become a permanent magnets manufacturing hub, the upstream REE mining is concentrated in Inner Mongolia, Sichuan, Shandong, and seven southern provinces including Jiangxi. Not only does Inner Mongolia account for some 80% of China's REE reserves, it also specializes in light REEs such as neodymium.

Yet another southern province, Jiangxi, may be emerging as one of the more important provinces that you've never heard of. Although its aggregate REE resources are nowhere near Inner Mongolia's, Jiangxi is home to one of the major permanent magnet producers, JL Mag, that is listed in Shenzhen. Its stock may have risen even higher as President Xi Jinping paid the company a visit in 2019 on his tour of Jiangxi (see Box).

JL Mag at a Glance

Company name
English: JL Mag Rare Earth Co. Ltd.
Chinese: 江西金力永磁科技股份有限公司

Current annual output of sintered NdFeB: 15,000 tons (2nd plant under construction in Inner Mongolia to ramp up capacity to 23,000 tons)

Supplier for: BYD, Goldwind, Siemens, Mitsubishi Motors, Midea Electronics, Bosch Rexroth, among others

2018 Revenue: 1.29 billion yuan (~$200 million), 41% y-o-y growth
Revenue distribution: domestic market 86.3%; foreign market: 13.7%

Shenzhen Stock Exchange: Listed September 21, 2018

Even though China still has a handicap on high-end magnets, it has worked to integrate a domestic supply chain. The REE exports on their own didn't necessarily add much value to the Chinese economy, so Beijing decided to allocate supplies to the domestic cleantech supply chain instead. For instance, JL Mag touts one of its selling points as having signed long-term contracts with China's major REE suppliers.

As Chinese EV and wind turbine manufacturers improve in quality, like their foreign counterparts, they too will increasingly demand high-end NdFeB magnets. Yet that could put considerable strain on supplying enough high-performance magnets to meet global demand. As noted above, projected NdFeB demand from EVs and wind alone appears to outstrip expected supply by 2025 or perhaps even earlier, especially if China cannot sufficiently increase its capacity on high-performance magnets in the near term.

With supply chains entangled, which has added to inflationary pressures, another bottleneck on permanent magnets could further raise the cost of the clean energy transition. This is all the more pressing because there does not appear to be a substitute for Chinese production on the horizon, as Japan and the United States are marginal to non-existent players when it comes to NdFeB magnets production.

Implications

There are short-term and longer-term implications that can be drawn from this case study. The tendency may be to fixate on Chinese dominance of current production, but the more important consideration is that the clean energy transition could put upward pressure on the price of high-performance magnets in coming years. This will especially be the case if the demand and supply mismatch is even greater than current estimates.

Putting aside the high-end scenarios, even the low-end scenarios assume EVs and wind turbines will demand over 50% of the high-performance magnet supply in 2025 and nearly 100% of the supply in 2030. That would leave other sectors without magnets and create supply bottlenecks and rising prices as soon as 2025.

While Japan and Germany still account for around half of the high-performance magnets output, their production levels have remained relatively constant. This leaves China as the main supplier to ramp up marginal capacity on high-end magnets. In the absence of substitutes in the near term, China may have little choice but to become the supplier of last resort in the face of a supply crunch.

Over the long term, however, China's dominance in permanent magnets doesn't have to be permanent. It is clear that China is not yet at the leading edge of magnets, so there appears to remain a window of opportunity to ramp up manufacturing capacity elsewhere.
Challenging though it may be, the United States could consider getting back into the game through foreign investment from the likes of Hitachi, the current patent holder, or perhaps even companies like JL Mag or Innuovo.

As the American EV industry continues to grow, companies may prefer to have local magnet suppliers for ease of transport, while suppliers tend to prefer proximity to their end users. Using recycled magnets may also be another partial solution to mitigate potential shortages. This could lead to more investment and partnerships in rebuilding magnet manufacturing capacity in the United States.

However, the current reality is such that there isn't a single large-scale NdFeB manufacturing operation in the United States today. As such, any policies in this arena will have to consider multiple factors centered on how to balance the cost of the clean energy transition with the potential cost of recreating a permanent magnets supply chain essentially from scratch.