Humanoid robots could drive new demand for critical minerals

Published 9 March 2026

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Key Takeaways

- Humanoids are built around two mineral-heavy systems: actuators drive rare earth magnet and copper demand, while batteries drive lithium demand.
- Recent AI progress makes large-scale deployment more plausible. If humanoids move from pilots to fleets, mineral demand could rise quickly.
- Supply may struggle to respond. New mines and processing projects take many years to come online, so even moderate demand surprises can tighten markets.
- Another risk is supply-chain concentration. Processing and magnet-making are often more concentrated than mining, which increases geopolitical and pricing risk if deployment scales.

Critical minerals are becoming more important. Demand is supported by grid upgrades, rapid EV1 adoption, and rising geopolitical tension around supply chains. But one potential driver is still underappreciated. The rise of humanoid robots could add a new layer of demand and increase the risk of deficits in some minerals.

When Jensen Huang unveiled new physical AI2 models for robots, he said the “ChatGPT moment for physical AI is here.” That statement is not only relevant for AI, it also raises a practical question for investors: what does large-scale humanoid deployment mean for critical minerals?

Building a humanoid: the critical minerals required

Actuators: NdPr and copper

A humanoid needs a lot of motors to move its joints. For example, Tesla’s Optimus Gen 23 uses 28 motors for major joints such as shoulders, elbows, waist, and legs. It also uses extra small motors in the hands to move fingers and improve control.

Many of these motors use strong permanent magnets to make the motor small but powerful. These magnets are usually made from a material called NdFeB4 and contain rare earths, mainly neodymium and praseodymium (NdPr). Copper is the other key input, and it is used heavily in motor windings.

As humanoids develop, more degrees of freedom will be needed to improve dexterity, especially in hands. In turn, this means more actuators and motors will be required and, therefore, more minerals needed (provided permanent magnet motors remain standard).

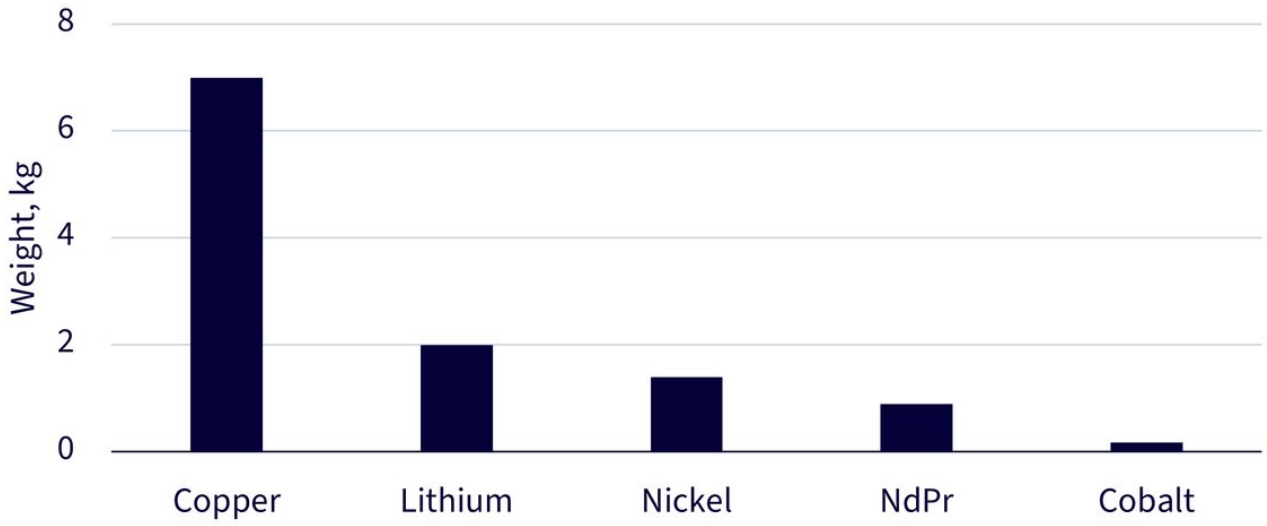
Battery packs: Lithium, nickel, cobalt, copper

Unlike EVs, humanoids need a smaller battery pack to drive the body. Therefore, the batteries with higher energy density like Lithium Nickel Cobalt Aluminium Oxide (NCA) and Nickel Manganese Cobalt (NMC) batteries are more suitable for humanoid applications. Copper is also key for batteries and is used for the internal metal layers and connections.

Wiring, chips, and charging

Copper shows up again in the robot's wiring, which carries power and data through the body and joints. Charging infrastructure can add more copper as fleets scale. Chips may use some materials like gallium, but the quantities are usually tiny compared with copper.

Figure 1: Estimated weights of critical minerals required per humanoid



Source: Morgan Stanley: "The robots are coming…for critical minerals", 21 May 2025. The estimates are for the base case. **Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.**

Why recent tech progress matters for minerals demand

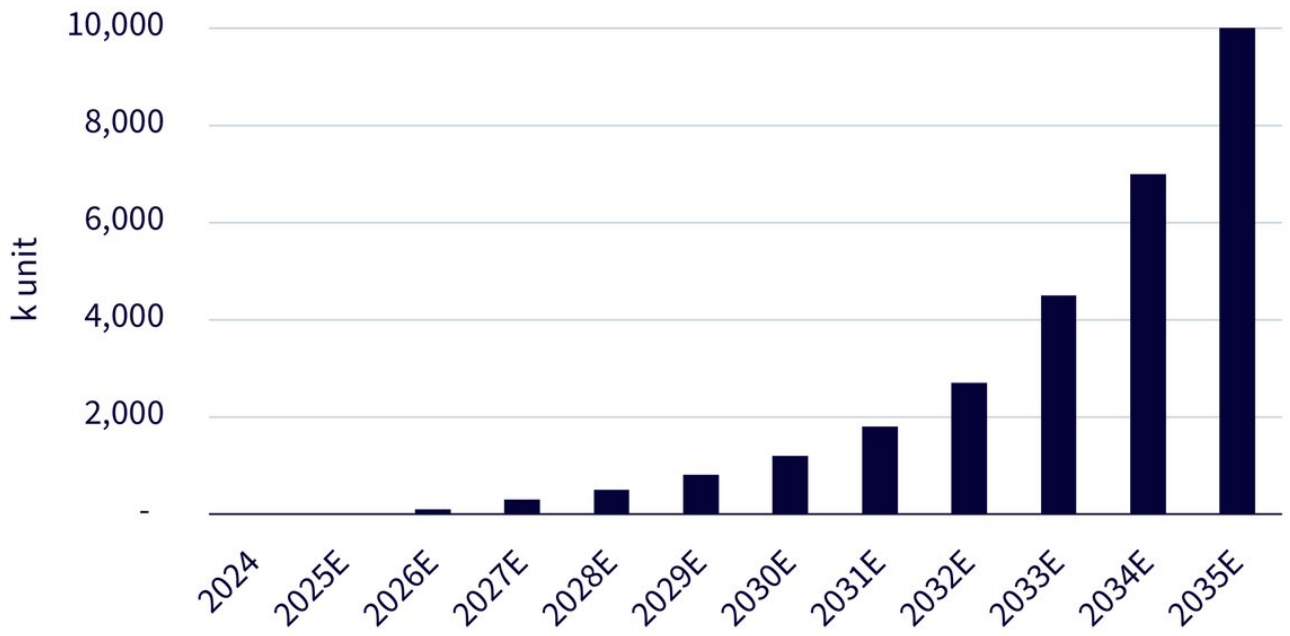
The demand for critical minerals from humanoids depends on the scale of deployment. Recent developments are making the case even more plausible and, if humanoids move from pilots to fleets, minerals demand will scale with unit volumes.

From a software perspective, training robots to operate in the physical world has, historically, been expensive and time consuming compared to training a model in the digital world, as data needs to be collected from physical experiments. However, as vision language models develop and more simulation and synthetic data is applied in training, developers can generate more diverse situations and iterate faster than physical testing alone. Together, they could shorten development cycles and lower integration costs for manufacturers.

Regarding the hardware, as designs standardise and production scales, key component costs, like actuators, should fall. Together with the developments in software, humanoids will likely become more intelligent and more affordable going forward.

Wall Street gives relatively positive forecasts on humanoid deployment. Morgan Stanley projects that the cumulative stock of humanoids may reach 1bn units and annual sales reach 200mn units by 20505. The Bank of America estimates that 10mn units of humanoids will be deployed by 20356. Such figures also reflect the sentiments from the markets.

Figure 2: Annual humanoid robot shipments projection



Source: Bank of America: “AI left the chat! Physical AI Primer”. 05 February 2026. **Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.**

Challenge on supply chains

The potential large-scale deployment of humanoids could affect trade balances through demand for critical minerals. Take lithium as an example. Global lithium production in 2024 was around 240,000 tonnes. If we assume a humanoid requires 2 kg of lithium, then 10 million humanoids would need 20,000 tonnes of

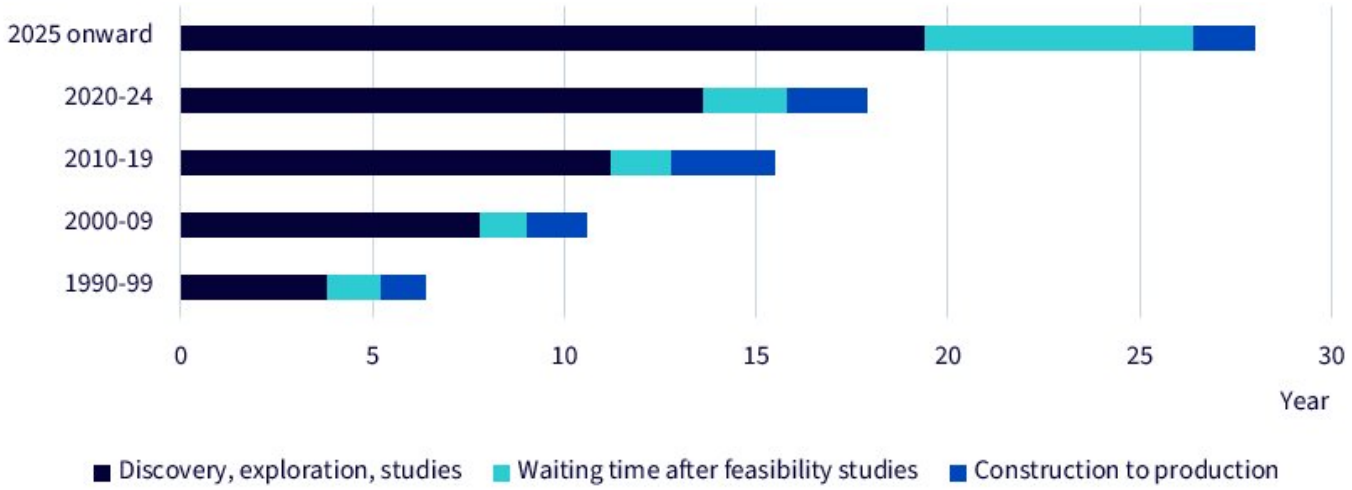
lithium, which is roughly 8% of 2024 global production. Although large-scale humanoid deployment has not yet happened, there are two supply-chain features of relevant critical minerals that need to be considered:

1. Project lead times and the risk of deficits

Humanoid demand, if it arrives, could grow fast and supply is unlikely to keep up. New mines take a long time to reach production, and lead times have lengthened since the 1990s. Across many projects, moving from discovery to production often takes well over 10 years, and recent cohorts are closer to 18 years on average. Most of that time is not construction. It is spent on exploration, feasibility work, permits, and financing.

This creates a clear risk of deficits. If humanoid deployments accelerate while EV and grid demand stay strong, demand for key minerals could rise faster than new supply.

Figure 3: Average lead time for mines since 1990

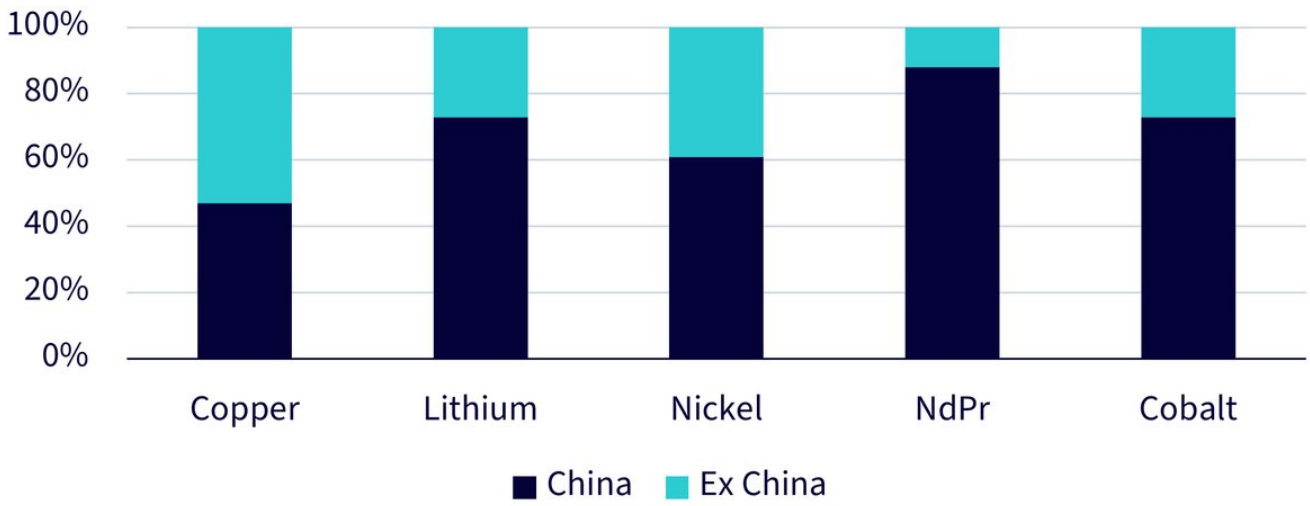


Source: S&P Global: From 6 years to 18 years: The increasing trend of mine lead times. 11 April 2025.
Historical performance is not an indication of future performance and any investments may go down in value.

2. China concentration and geopolitical risk

For several minerals linked to humanoids, dependence is often higher in processing than in mining. Rare earths are the clearest case. Mining is spread across countries, but separation, metal making, and permanent magnet production are far more concentrated, with China being dominant. Battery materials show a similar pattern, with China and Chinese-owned firms deeply involved across refining and manufacturing. This creates a concentration risk in supply chains.

Figure 4: Refined supply of major critical minerals related to humanoids



Source: Morgan Stanley, Wood Mackenzie. China shares include both Chinese and Chinese-owned enterprises. Nickel refined supply doesn't appear to be concentrated in China, until Indonesia supply (which is estimated to be at least 75% China ownership) is factored. **Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.**

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1 Electric vehicle.
2 Artificial intelligence.
3 Optimus Gen 2 is an advanced, lightweight humanoid robot designed by Tesla for industrial and household tasks.
4 NdFeB = an alloy of neodymium, iron and boron.
5 Source: Morgan Stanley: "A $5 Trillion Global Market", 29 April 2025.
6 Source: Bank of America: “AI left the chat! Physical AI Primer”. 05 February 2026.

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