Where will the metals for the robot revolution come from?

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10 billion humanoid robots will need a lot of critical metals

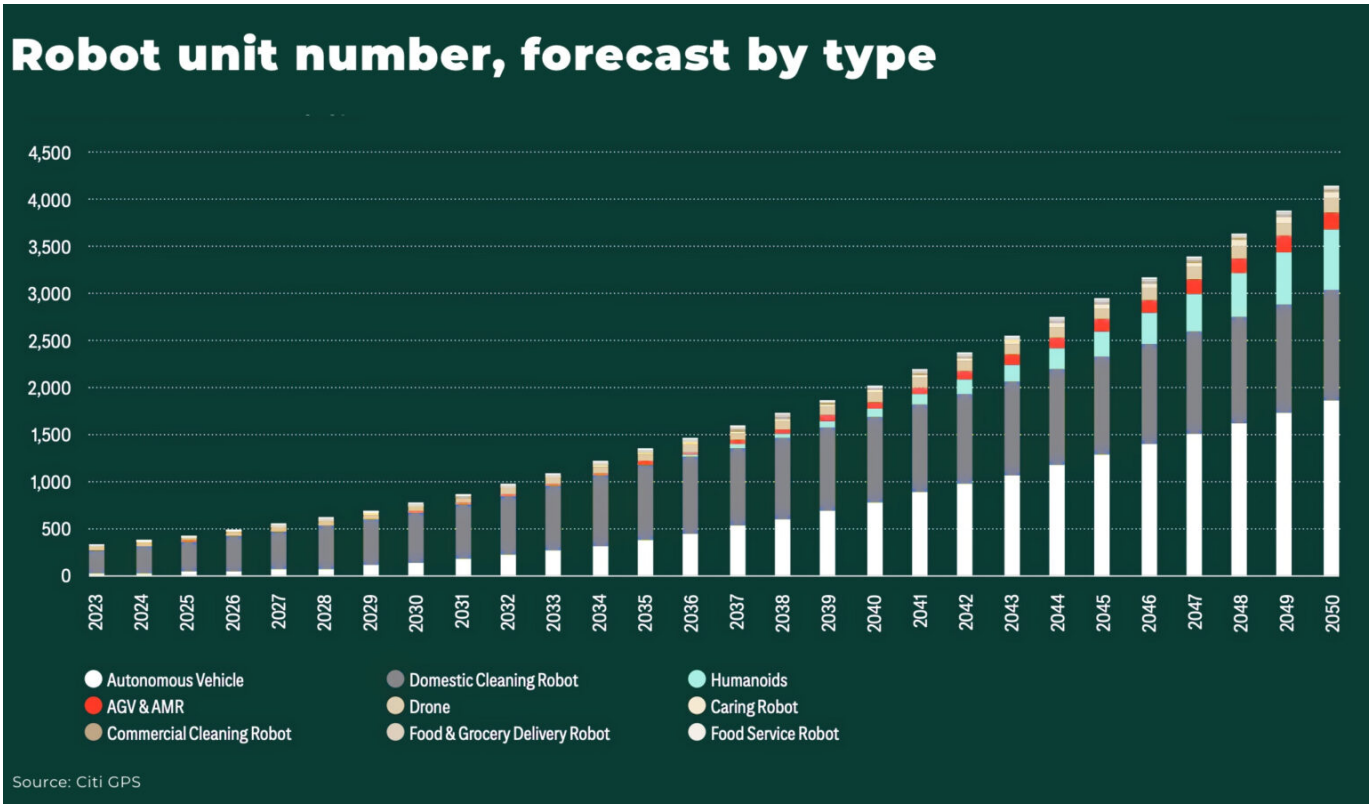
Elon Musk has projected there will be 10 billion humanoid robots by 2040, and he's not alone in predicting such extraordinarily high numbers:

- in China, Shenzhen's city government has released an action plan to offer funding and policy support for intelligent robots, including humanoids. By 2027, it aims to host more than 10 companies valued at over 10 billion yuan (US$1.3 billion) and over 20 companies with annual revenues exceeding 1 billion yuan.
- **a Citi report** estimates there will likely be 1.3 billion AI-robots by 2035 and 4 billion by 2050
- **Morgan Stanley** estimates humanoid robots could reach 63 million units by 2050 in the US
- **David Holz**, founder of MidJourney AI, predicts there will be 1 billion humanoids by 2040. Elon Musk replied on X that he agreed.
- **Peter H. Diamandis**, founder of Singularity University, and Emad Mostaque, founder of Stability AI, stated in a recent podcast that there will be 10 billion humanoids by 2040.
- **Brett Adcock**, founder of Figure AI, also predicted in another podcast episode that there will be "up to 10 billion humanoids on Earth in the coming decades."
- **Goldman Sachs,** one of the more conservative forecasts, still projects a surge in robot production, with 1.4

million units shipped in a US$38 billion market by 2035

Now, we suspect that 10 billion humanoid robots is an optimistic number by 2040 – but we also believe the robot revolution *is* underway – in fact, mass production plans are already underway, with one company planning to make 100,000 humanoid robots in the next four years and Elon Musk announcing his company also intends to make several thousand units of its Optimus humanoid robot this year for deployment in its own factory.

In 2024, the global market for humanoid robots was valued at US$3 billion. Goldman Sachs projects a US$38 billion market by 2035; Morgan Stanley estimates US$357 billion by 2040.

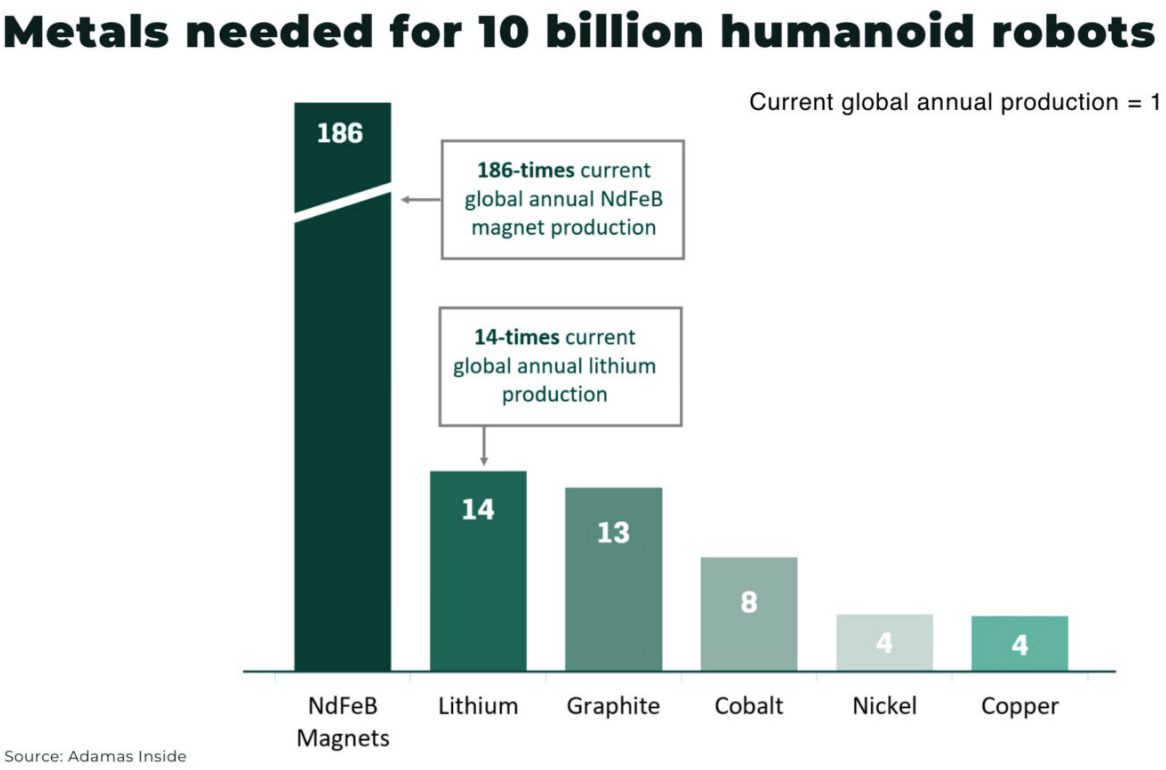


All of the forecasts suggest a significant surge in metal demand, set to place significant new stress on critical mineral supply chains.

A single humanoid robot weighs approximately 60 kilograms,

according to research from Adamas Intelligence. So, 10 billion robots would be 600 million tons of mostly metal; even Morgan Stanley's more conservative estimate of 1.4 million robots would require nearly 4 million tonnes of metal.

To put in context: the total global production of key metals needed for robots was less than 30 million tonnes in 2023.



"To reach 10 billion robots by 2040, annual production would need to increase at a compound annual growth rate (CAGR) of 99%10. By 2040, nearly half of the 600 million tonnes of materials will be needed for the robots manufactured in that single year… This is not a gradual increase; it's an exponential surge demanding a complete overhaul of the metals and mining industry"
— Adamas Intelligence, The mountains of metals needed for 10 billion humanoid robots

This is **significant new demand**, just as supply across a range of critical minerals is already struggling in the face of demand for new data centers, net zero, military and geopolitical stress.

Just a few examples of latest humanoid robots:

Metal robots

So, what are the metals essential for robots:

Rare Earths

Rare earth elements (REEs) are critical for advanced magnets, especially neodymium-iron-boron (NdFeB) magnets to provide the magnetic strength necessary to enable precision movements of robotic arms, hands, and actuators.

Manufacturing 10 billion robots by 2040 would require x186 the current annual global production of NdFeB magnets; to build 63 million robots would require x1.2 current production.

From 2024 through 2040, Adamas forecasts that global demand for NdFeB magnets will nearly quadruple to more than 880,000 tonnes.

Battery metals

Lithium, cobalt and nickel are critical for the lithium-ion batteries are currently the standard energy source for independently-powered robots.

To build 63 million robots by 2050 – as per Morgan Stanley's forecast – would need, for example, approx:

- 83,000 tonnes of **nickel**, or enough to supply 3.3 million batteries for electric vehicles (EVs)
- 12,000 metric tons of **cobalt**, or enough for 2 million EVs

- 130,000 metric tons of **graphite**, or enough for more than 2.6 million EVs

Copper

Essential for electrical wiring, motors, and structural components.

10 billion humanoid robots by 2040 would consume the equivalent of x4 the current global annual copper production, according to Adamas. So, with global copper production at 22 million metric tons in 2023, 554,400 metric tons of copper would be needed for 63 million robots.

Other critical minerals needed would also include tungsten, fluorspar, and many others.

Of course, in the estimated timeframe, new technological advances and battery chemistries may mean less metals are needed for each robot. But, as we've just seen with the furore over DeepSeek, Jevons Paradox suggests that, as technological improvements make a resource cheaper or more efficient to use, overall consumption often increases rather than decreases.

Supply risks

The challenge to supply even the more modest estimates of such new demand are numerous, including:

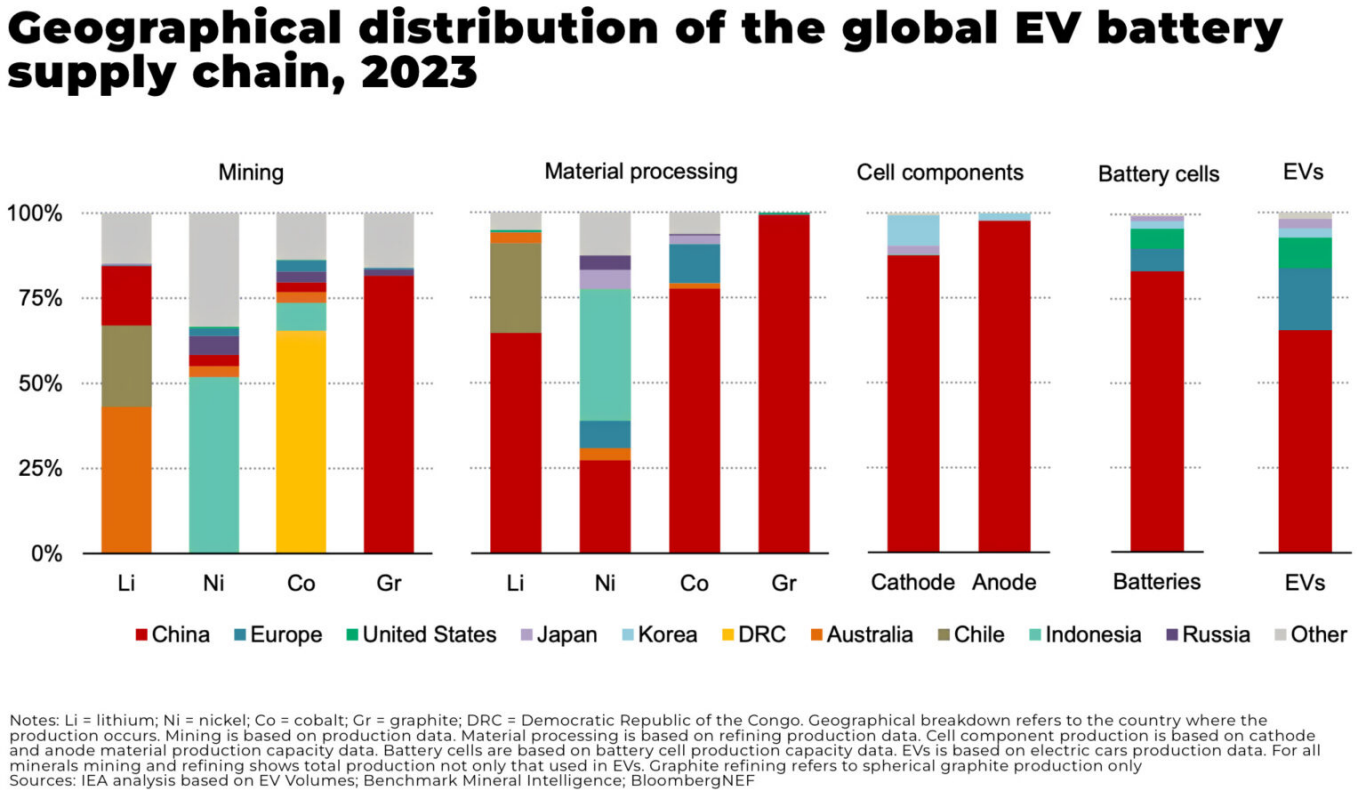
- rising demand for data centers and artificial intelligence, as well as net zero demands
- the average time to develop a new mine globally is 18 years, declining ore grades and environmental restrictions, geopolitical risks
- concentration of mining and processing facilities in China, with nearly 50% of the market value from refining

expected to be concentrated in China by 2030

And the risk is not just over critical minerals. Turning these raw materials into finished robot components requires a robust manufacturing ecosystem.

Marc Andreesen recently issued a warning over China's manufacturing dominance, for example, China's DJI Technology Company, holds a 90% share of the US commercial drone market.

> *"We have the lead in R&D, we have the smartest robotics AI people… but we don't have anything resembling the manufacturing capability at all. It's not just if you have a company that can make a company but whether you have the thousands of companies that can make the components that go in robots"*
> *— Marc Andreesen, interview with Hoover Institution*



Conclusion

From electric vehicles to drones to industrial robots – and, now, humanoid robots – the robotics revolution has arrived.

We may be cautious about some of the wilder claims of 10 billion robots in just 15 years time, but we also expect the demand to be large enough to start placing significant disruption on the metals and mining industry, especially at a time when there are already so many other risks and priorities for metals.

As companies get ready to start taking the first robots off the production line, the race for the metals that build them is only just beginning.