Net Zero

Zero Carbon Analytics

Briefing · September 2024

Note: This is an updated version of a briefing originally published by Zero Carbon Analytics in November 2023.

Do we need deep sea mining for the energy transition?

Key points:

- Deep sea mining companies and some states propose boosting supplies of minerals used to produce clean energy technologies such as batteries, solar panels and wind turbines.
- The International Seabed Authority aims to adopt rules on deep sea mining by 2025.
- On-land mining for these minerals has been taking place for years and there is no physical scarcity. However, as demand rises this decade, supply crunches are likely due to the sector's lack of investment and recycling.
- Given that the steepest growth in mineral demand will likely occur before 2035, deep sea mining is unlikely to ease short-term supply crunches as the sector does not yet have the technology to extract or process minerals commercially.
- Copper, cobalt, and manganese are the minerals most available in the deep sea. However, some studies find these are not the minerals most threatened by supply crunches.
- Solutions to short and medium-term bottlenecks for the on-land mining sector include investment, policy incentives and regulations for recycling, supply diversification, and research and development in sustainable mining.

What is deep sea mining and how would it work?

Deep sea mining refers to a process of collecting minerals from a depth of over 200 metres underwater. Three types of deep sea mining are currently being tested:

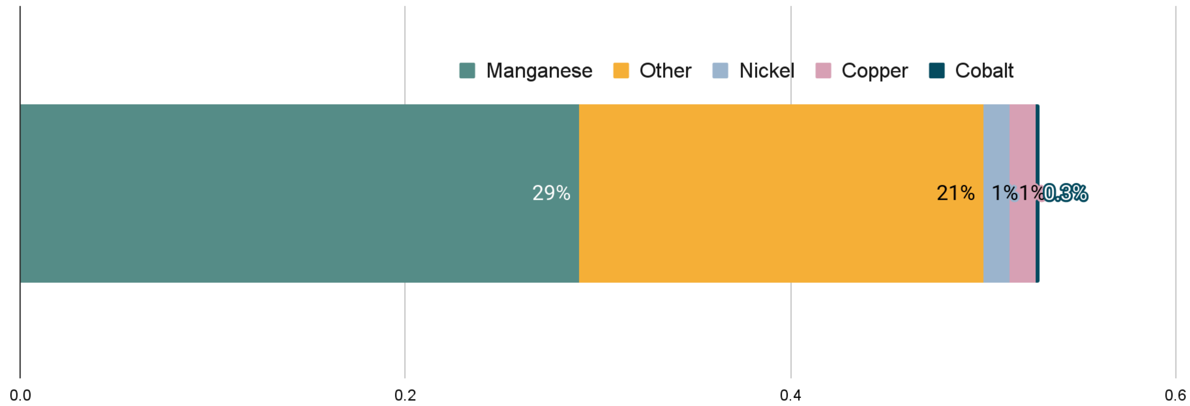
- Mining the ferro-manganese crusts of seamounts, or undersea mountains, by tearing up the superficial layer to obtain cobalt
- Mining hydrothermal vents, or inactive underwater chimneys, for their copper, zinc and lead
- Mining polymetallic nodules, which are potato-sized lumps resting on the seabed and containing mainly manganese and smaller amounts of nickel, copper and cobalt.

The third option is the most popular one for mining companies as they contain high levels of minerals.[1] Commercialisation would require overcoming technical challenges. It involves collecting the nodules from the sea floor with a type of underwater bulldozer and ploughing the top layers of sediment, with less invasive options still in development. The

[1] Therefore, the present analysis will focus on those metals of the polymetallic nodules: manganese, nickel, copper and cobalt.

nodules are pumped up to a vessel at the surface and attached sediments and organic materials are then removed and pumped back into the water. Further processing is needed to use the metals from the nodules.

Fig 1: Composition of metals in polymetallic nodules with economic interest



Source: Polymetallic Nodules, International Seabed Authority.

Where are the deep sea minerals?

Most of the most attractive mineral deposits are on the ocean floor in international waters. The Clarion-Clipperton Zone, in the middle of the Pacific Ocean, is an area of particular interest to mining companies. The zone is divided into 16 exploration areas controlled by different countries and the International Seabed Authority (ISA). According to an ecologist at the Scripps Institution of Oceanography, "the largest coal mine in Germany is less than half the size of the area that would be mined for polymetallic nodules in the Clarion-Clipperton Zone in one year by one contractor".

Individual countries can also mine the seabed in their own waters. Japan expects to begin large-scale extraction from its deep seabed in 2025. Norway's parliament voted in favour of allowing mining in its national waters. In 2019, a deep sea mining project failed in Papua New Guinea, with the company behind the project, Nautilus, becoming insolvent and the government losing USD 101 million in investment.

Who regulates deep sea mining?

The International Seabed Authority (ISA), a United Nations-appointed body, regulates international waters. As of today, no official commercial mining operations have taken place in international waters. In 2023, the ISA failed to adopt a mining code that would regulate deep sea mining. It has set an indicative 2025 timeline to decide if and how countries may mine in international waters.

Due to a two-year legal loophole, ISA can consider and provisionally approve mineral exploitation contracts submitted by mining companies, irrespective of whether rules are adopted and implemented. Canada-based The Metals Company announced it would submit a mining application before the end of 2024. However, ISA's new secretary-general Leticia Carvalho stated that rules to regulate deep-sea mining will take time and that mining applications should not be approved until those rules are defined. "ISA has to find ways to compromise and reach consensus. Scientific evidence, broader participation and inclusive knowledge are the key basis of consensual decisions," she said.

Is deep sea mining already happening?

The ISA has issued 31 exploration permits since 2001 to national agencies and private companies covering about one million square kilometres of exploration areas - roughly equivalent to the size of Egypt. However, the permits do not allow companies to undertake for-profit activities. An international law expert said that even if the ISA finalises the rules, it "does not have submersibles or ocean-going vessels at its disposal" to oversee activities properly and would need more financial resources to enforce regulations. In 2024, 32 countries oppose fast-tracking deep sea mining licences. This number has increased sharply over the past three years. Countries including China, Nauru, Norway, Russia and India remain in favour of a regulation that allows deep sea mining soon.

Environmental risks

Environmental organisations and scientists have warned that the deep sea is largely unknown, and comprehensive studies are needed to understand what role deep sea ecosystems play in carbon sequestration, global temperature cycles, biodiversity and food provision for animals and humans. Little evidence is available on the damages that such mining operations would have through wastewater release or noise pollution compared to on-land mining. One study found that after 77 years, the seabed had not recovered from a shipwreck sliding over the sea floor. It is also unclear who would be liable for environmental damages, and NGOs argue that monitoring companies' activities would be highly challenging due to the remoteness of the offshore mining areas.

A study published in 2024 found that polymetallic nodules produce oxygen without photosynthesis. The study raised questions about how oxygen is produced and what role it plays in the deep-sea ecosystem, increasing the need for a cautionary approach to deep sea mining.

Why are deep sea minerals such a hot topic?

Technologies such as wind turbines, solar panels, batteries, electric vehicles (EVs) and electricity networks play a crucial role in the global transition to clean energy. The production of these technologies requires different types and quantities of critical minerals. Currently, 40% of cobalt is used for manufacturing clean energy technologies.

Most minerals are used for a wide range of purposes. For instance, only 16% of mined nickel and 10% of neodymium are used for clean energy technologies. Rare earth elements are used in the production of military equipment and weapons, as well as smartphones, computer hard disks, LED lights, flat screen televisions and air transport. Cobalt and nickel are also used to manufacture consumer electronics.

Demand varies significantly depending on the mineral, and innovations such as cobalt-free batteries have reduced demand for some minerals. Table 1 shows the minerals found in polymetallic nodules which could be used to manufacture different clean energy technologies. Many other minerals are important for clean energy technologies but are not found in the deep sea. Mining companies and other business voices advocate that deep sea mining is crucial to meet the demand for clean energy technologies.

Table 1: Minerals required for energy transition technologies present in the polymetallic nodules[2]

Cobalt	Lithium-ion batteries
Copper	Electricity networks, wind turbines, lithium-ion batteries, solar panels
Manganese	Wind turbines, EVs
Nickel	Geothermal, EVs and battery storage, hydrogen

Source: IEA, Deep-ocean polymetallic nodules as a resource for critical materials.

Do we have enough minerals for the energy transition?

No physical scarcity

There is no physical scarcity in the earth's crust for most critical minerals, and reserves of minerals are often geographically widespread. Demand for minerals is set to rise over the next 15 years as the transition to clean energy raises demand for solar PVs, wind turbines and batteries. According to a survey conducted by KPMG, almost 80% of executives in the metals and mining industry are confident or very confident that the industry will be able to meet the rising demand.

What causes supply crunches?

Short to medium-term supply shortages of minerals can occur due to geopolitical risks, such as:

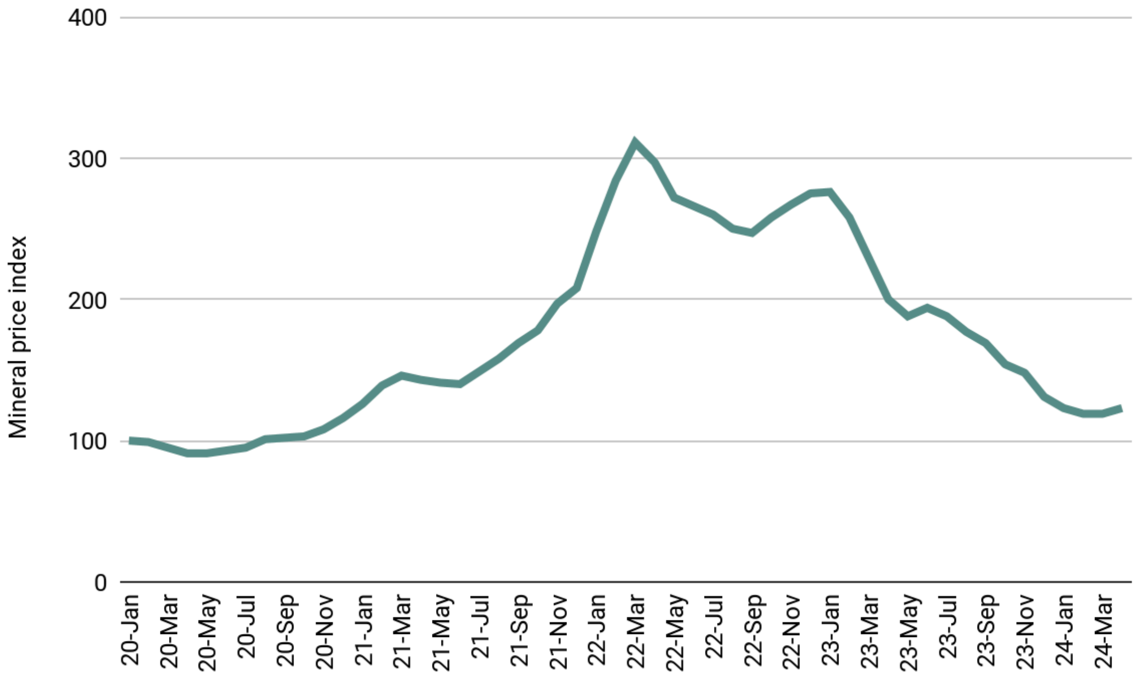
- External shocks (e.g. natural disasters, pandemics, wars)
- Resource nationalism (e.g. tax disputes)
- Export restrictions (e.g. export taxes)
- Political instability and social unrest (e.g. corruption, labour strikes)
- Market manipulation (e.g. market cornering, insider trading)

In the long term, a lack of investment in upstream activities can cause undersupply. Undersupply can also originate in "long lead times in opening new mines and processing of manufacturing plants, uncertainty regarding future demand, price volatility, a lack of downstream transparency, and local opposition", according to the Intergovernmental agency IRENA. Policymakers can also impact supply by providing signals about a country's energy transition. "If companies do not have confidence in countries' energy and climate policies, they are likely to make investment decisions based on much more conservative expectations," according to the IEA.

Many minerals are currently extracted and processed in China. For instance, the country extracts 82% of global graphite, 62% of rare earths and processes more than 50% of the world's processed manganese. According to the IEA, over the past decades, countries have "prioritised short-term profits over the importance of diversified supply chains". Therefore, developing new refining and processing projects is challenging outside of China. Developing clean energy technologies today depends on trade relationships with China, which is considered risky by many countries, particularly by Europe and the US. The US offers production tax credits in the Inflation Reduction Act to diversify mineral processing. Similarly, the EU recently set domestic targets for extraction (10%), processing (40%), and recycling (15%).

[2] Nodules in the Clarion Clipperton Zone

Fig 2: IEA energy transition mineral price index, January 2020-April 2024



Source: IEA, IEA energy transition mineral price index, January 2020-April 2024, Licence: CC BY 4.0. Includes a basket price for copper, major battery metals and rare earth elements.

How dangerous are supply crunches?

Mineral supply crunches are expected to have less severe consequences than shortages of fossil fuels, and events similar to the 1970s oil crisis are improbable in a net-zero world. A lack of fossil fuels in a fossil fuel economy affects all consumers using fuels such as gas, gasoline and fossil-powered electricity. A shortage of minerals in a net zero scenario only affects the short-term production of technology such as solar panels, batteries and wind turbines or the construction of new energy assets.

Negative consequences include higher prices for minerals, as was the case in 2022 and 2023 (see Fig. 2). Subsequently, the price for clean energy technology, which depends on the scarce mineral, can increase equally. If fossil fuels are used to compensate for such bottlenecks, the pace of the energy transition could slow down.

Recycling, investments that accelerate innovation, or high prices can reduce demand for minerals. For instance, the IEA had to reduce its projections for cobalt demand due to the development of lithium iron phosphate and high-nickel chemistries, which do not require cobalt. Strong demand can also drive production. For instance, global lithium production increased by 21% in 2022 compared to 2021 amid strong demand for lithium-ion batteries and increased prices of lithium.[3]

[3] Excludes US production.

Which minerals could suffer from bottlenecks?

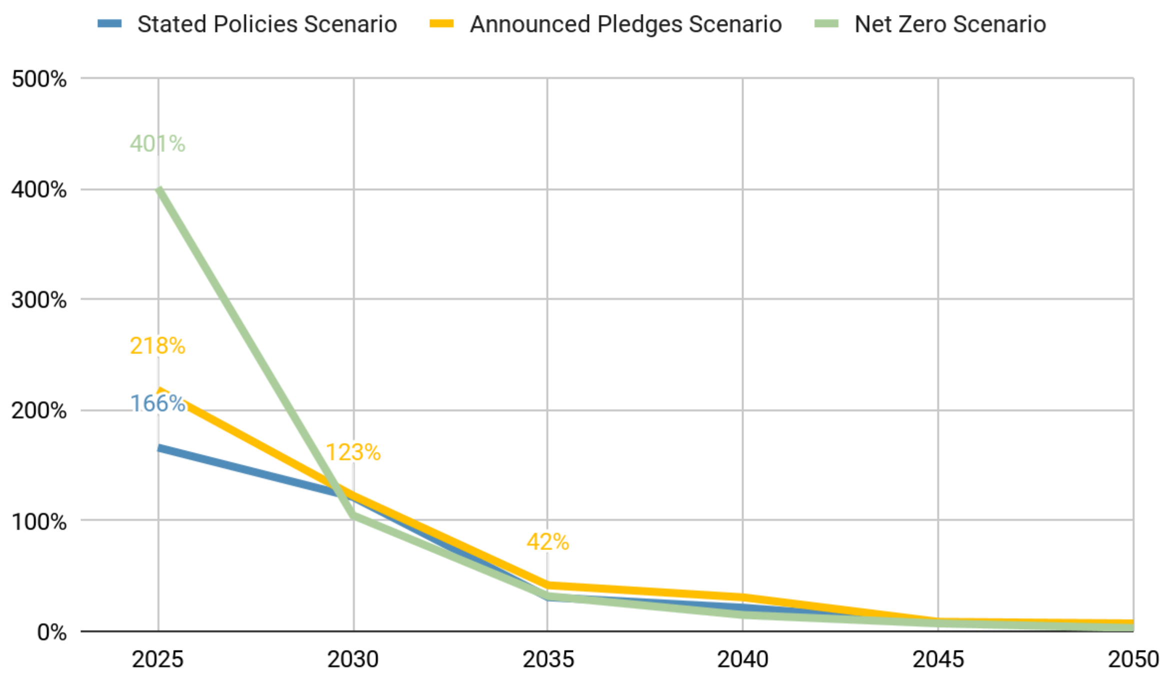
Organisations and countries have different assessments of the potential criticality or urgency of supplying certain minerals. Those differences are due to trade relationships, clean energy needs and targets, and domestic supply. Which minerals will suffer from bottlenecks also depends on the scenarios and underlying assumptions.

Rare earths, graphite and lithium are likely to experience short-term supply crunches. However, polymetallic nodules only contain traces of those minerals. Of the deep sea minerals, most countries and regions name cobalt and nickel as the most important minerals needed for clean energy technology. According to the IEA, copper is the deep sea mineral with the greatest gap between current production and output in 2035. Anticipated mine supply from announced projects will meet 70% of copper demand by 2035. Nickel and cobalt supply could be balanced if prospective projects are considered along with confirmed projects. The European Academies' Science Advisory Council, an association of science academies, highlights that "three of the main metals targeted in deep-sea mining (manganese, copper, and nickel) are considered to be of low supply risk while cobalt is moderate."

When are those minerals most needed?

The IEA predicts an increased need for minerals in all its climate scenarios. When considering the deep sea minerals needed for clean energy technology, the projected demand increases by most in the present decade (see Figure 3). The five-year increase ranges from 191% to 442% between 2020 and 2025. After 2030, the rise in demand is much smaller.

Fig 3: Projected average demand increase for deep sea minerals used in clean energy technology



Source: IEA Critical Minerals Demand Datasets of 2021, 2023 and 2024.[4]

[4] Assumptions underpinning scenarios are often based on current conditions and then extrapolated to future demand.

This drop in demand is due to the fact that compared to fossil fuels, **clean energy requires significantly less minerals.** As explained in the IEA's World Energy Outlook, in a net-zero world in 2050, every unit of energy would require two-thirds less materials, fossil fuels and minerals combined compared to 2023.

Understanding IEA Scenarios

Stated Policies Scenario (STEPS):
"A scenario which reflects **current policy settings** based on a sector-by-sector and country by country assessment of the specific policies that are in place, as well as those that have been announced by governments around the world." STEPS does not include Nationally Determined Contributions (NDCs) - country action plans to cut emissions and adapt to climate impacts.

Announced Policies Scenario (APS):
"A scenario which assumes that all **climate commitments** made by governments around the world, including NDCs and longer-term net zero targets, as well as targets for access to electricity and clean cooking, **will be met** in full and on time."

Net Zero Scenario (NZE):
"A scenario which sets out a pathway for the global energy sector to **achieve net zero CO2 emissions by 2050**. It doesn't rely on emissions reductions from outside the energy sector to achieve its goals. Universal access to electricity and clean cooking are achieved by 2030."

Source: IEA: Global Energy and Climate Model, 2023.

Does deep sea mining make sense for the green transition?

The steepest growth in demand for minerals will take place in the present decade, according to the IEA's predictions. After 2030, growth in demand for key minerals will continue at a lower rate in both ambitious and less ambitious scenarios. If bottlenecks arise, they will more likely occur during this decade and at latest until 2035 due to the steep growth in demand.

Since private or public companies have not yet extracted minerals from the deep sea on a large scale, and the technology to do so is not readily available on a large scale, it seems unlikely that this solution will ease potential bottlenecks which are already happening. Until now, deep sea mining is mainly being explored by start-up companies, some of which have lost important investments due to reputational risks. Most deep-sea mining companies say they won't be able to start commercial operations until towards the end of the decade, provided they receive clear regulatory signals. The Metals Company plans to start small-scale commercial mining in 2026. This is unlikely to happen until at least 2025, when the ISA is supposed to set rules on mining in international waters. Given the new ISA's secretary-general stance on the importance of regulation, the deadline is likely to be postponed further. Companies will likely only be ready to mine after the demand for critical minerals has peaked. Moreover, technology to process deep sea minerals is still being developed and would have to mature before 2030 to ease the bottlenecks.

It is also unclear if deep sea mining is cost-competitive compared to on-land mining. A report by think tank Planet Tracker shows that seafloor restoration would cost USD 5.3 million-5.7 million per square kilometre - which is more than the revenue a typical company would make from deep sea mining.

What are the alternatives to deep sea mining?

More sustainable land mining practices, battery recycling, substitution and demand reduction measures could reduce the likelihood of mineral supply crunches. This is especially important since minerals are used for a wide range of purposes outside of producing net zero technology. One study found that "without sufficient and adequate resource saving measures it will be difficult or impossible for a substantial part of the future world population to attain the service level of mineral resources prevailing in developed countries at this moment."

Sustainable land mining

Land mining faces challenges around declining ore grades, long permit times and waste. A just energy transition should include more investment in research and development and commitments to sustainable mining practices.[5] Mining in line with a just energy transition is also highly dependent on meaningful stakeholder dialogue, increased local ownership and sanctioning reporting gaps by mining companies.

Diversifying supply

There is a need to diversify the supply of minerals. Despite Western countries highlighting the threats of putting all their eggs in one basket, the concentration of processing plants has increased in the last years for nickel and cobalt. Currently, around 70% of critical mineral reserves are located in Africa, where they are extracted and shipped in their crude form to China, where the refining, processing and manufacturing take place. From there, they are shipped to the US and EU.

Global South countries could be vital in reshaping the mining and processing landscape. Indonesia imposed an export ban on raw materials and has successfully pushed for investments in its manufacturing sector.

Recycling

Minerals and metals can be reused and recycled continuously if the right infrastructure and technologies are available – a significant advantage compared to fossil fuels. The US has allocated a budget of about USD 6.33 billion for battery development, including recycling. The EU has set domestic targets for battery recycling in the EU Raw Materials Act of 15%. Similar and more ambitious measures such as extended producer responsibility, are necessary to ease medium to long-term bottlenecks.[6]

Substitution

Sustained high prices for materials, pressures to reduce costs, geopolitical issues or environmental and social concerns can accelerate the search for alternative materials. "Perceptions that many metals are critical and scarce for renewable energy transitions appear exaggerated" if ongoing and past technological development and change is taken into account. Current lithium-ion batteries require cobalt or nickel. New alternatives such as Svolt's cobalt-free lithium-ion car battery or Tesla's lithium-ion phosphate batteries can reduce demand for those minerals. An IEA report showed that between 2005 and 2018, patenting for batteries and similar

[5] Initiatives include Towards Sustainable Mining (TSM) and the Initiative for Responsible Mining Assurance (IRMA).
[6] Extended Producer Responsibility is a concept by which the producer has to take care of the product even after it isn't used anymore. For instance, car producers would have to take back and recycle batteries of cars after their end of life.

storage technologies grew at an average rate of 14% worldwide every year, four times faster than the average for all technology areas across the economy.

Demand reduction

In a world of environmental fragility, reducing demand is necessary and increasingly plays a role in projections. Restricted lithium availability raises questions about the sustainable use of battery EVs. Globally, 40% of battery EVs are SUVs, and only roughly 20% are small-sized cars. In the US, SUVs account for 60%, and less than 10% are small cars. Similarly, 37% of households in the US possessed two vehicles in 2022. Increased demand for electric SUVs pushes up the size of the battery, the requirement of minerals and the prices, excluding many households from participating in sustainable practices. Nevertheless, if all announced manufacturing plans for EV batteries are implemented globally, there would be enough capacity to fulfil expected demand requirements in 2030 in the IEA's NZE Scenario for EVs.