Planet Tracker

The climate myth of deep sea mining

December 2023

CONTENTS

EXECUTIVE SUMMARY

The transition to a low carbon economy will be mineral- and metal-intensive. At the same time, mining and metals production is currently a source of greenhouse gas emissions, contributing to climate change.

The climate impacts of deep sea and terrestrial mining vary hugely

Deep sea mining companies claim that mining polymetallic nodules could provide a low carbon alternative to terrestrially mined metals. However, this report has found that the results of the three current studies comparing the cradle-to-gate (nodule-to-commodity) climate impact of deep sea and terrestrial mining vary hugely, estimating that **polymetallic nodules could have a higher or lower climate impact than land ores.**

In addition, two out of the three studies were funded and supported by deep sea mining companies: Paulikas et al.'s 2020 research paper[1] was funded by The Metals Company (formerly DeepGreen Metals) and Alvarenga et al.'s 2022 study[2] was funded by Global Sea Mineral Resources. For example, Paulikas et al.'s paper excluded 95% of polymetallic nodules' manganese content from its lifecycle assessment study, along with the associated climate impact. Not only does this significantly reduce the estimated climate impact of polymetallic nodules, it would also not be economically feasible to exclude any metal content from nodule production given the cost of deep sea mining operations.[3]

Such uncertainty in results is not a good enough basis for making decisions about the future of deep sea mining. Additionally, considering the high cost of deep sea mining operations, any metals produced are likely to be premium-priced products that will not displace the bulk of terrestrial production, and the associated climate impact.

Metallurgical processing is a universal emissions hotspot

Over 70% of greenhouse gas emissions for both land ores and polymetallic nodules come from energy and fossil fuel-intensive metallurgical processing. The proposed metallurgical processing of nodules is currently similar to that of land ores. Consequently, the severity of climate impact is less dependent on whether ores come from the deep sea or land and is more dependent on the properties of processing: mainly the sources of fuel and electricity used, process efficiency and processing technique.

Reducing the climate impact of both land and deep sea ores therefore requires investment in technologies such as electrification with renewable power sources and low carbon processing routes such as hydrometallurgy, which remove or reduce the use of fossil fuels.

The unknown impact on ocean carbon stocks and sequestration

Marine sediments are estimated to be the largest pool of sediment/soil carbon stocks in the world and are an important part of the global carbon cycle.[4]

Although less than 1% of gross primary production on Earth makes it to the seafloor,[5, 6] organic carbon buried in ocean sediments can be stored there for thousands to millions of years, if left undisturbed.[7, 8] Deep sea mining vehicles kicking up sediment plumes could result in an estimated 172.5 tonnes of carbon being disturbed every year for every km^2 mined.[9]

Only 13.9 kg of carbon per km^2 is sequestered every year in the Clarion-Clipperton Zone,[10] which is 0.00804%[a] of the quantity of seafloor carbon disturbed by collector vehicles per year. Sediment plumes caused by mining machinery could also impact carbon sequestration services taking place in ocean waters by blocking sunlight and reducing photosynthesis, although this has not been quantified. By removing nodules and the fauna which depend on them, deep sea mining could also impact the carbon sequestration services associated with fauna. The effect of these carbon services has not yet been calculated, but considering nodules take tens of millions of years to form,[11] the loss of these ecosystem services caused by deep sea mining would essentially be permanent.

CALL TO ACTION

Deep sea mining still has a significant climate impact and could expose financial institutions to substantial policy, regulatory and reputational risks.

Financial institutions should therefore support a moratorium on deep sea mining.

Instead of investing in deep sea mining, financial institutions could **support the decarbonisation of terrestrial mining and metals production.**

a 13.9kg vs 172.5 tonnes

INTRODUCTION

The transition to a low carbon economy will be mineral- and metal-intensive. At the same time, mining and metals production is currently a source of greenhouse gas emissions. These sectors must therefore decarbonise to meet future demand without contributing to climate change.

Deep sea mining companies claim that mining polymetallic nodules could provide a low carbon alternative to terrestrially mined metals. However, it has also attracted significant and growing opposition, with companies, investors, national governments, scientists and civil society organizations calling for a moratorium on deep sea mining.[12, 13]

Purpose, methodology and scope of this report

Considering the potential climate impact caused by deep sea mining, this report aims to investigate current research on this issue and how it compares to climate risks and decarbonisation opportunities for terrestrial mining.

This report focuses on the impact of mining polymetallic nodules in the Clarion-Clipperton Zone (equatorial eastern Pacific), as this has received the most commercial interest to date and is presently the most likely area to be mined in international waters. The analysis focuses on academic lifecycle analysis studies in order to maintain comparability between results.

Current research highlights that the vast majority of the climate impact of both land ores and polymetallic nodules comes from the energy and fossil fuel-intensive metallurgical processing. Therefore, reducing the climate impact of both land and deep sea ores requires investment in technologies such as low carbon electrification and the development of low carbon processing routes and technologies.

The information and recommendations in this report were developed using a bottom-up approach, grounded in an extensive literature review and primary analysis.

This paper provides a practical working resource for financial institutions to understand and assess their exposure to the environmental risks associated with deep sea mining. This report is aimed at financial institutions with potential exposure to deep sea mining activities and those seeking to support the transition towards a sustainable economy. The overall aim is to empower investors to better integrate nature, climate and marine ecosystem health into capital allocation decisions.

HOW DOES DEEP SEA MINING IMPACT THE CLIMATE?

The climate impact of deep sea mining is under-researched

Academic research into the climate impact of deep sea mining is currently relatively limited. The metal ores contained in polymetallic nodules are very different to those found on land, which can make comparisons challenging.[14] There are only three academic studies[b] that model the potential cradle-to-gate (nodules-to-commodity) climate impact of ferromanganese, copper, cobalt and nickel produced from deep sea polymetallic nodules, compared to land ores.

Two of the three studies were funded by and conducted in collaboration with deep sea mining companies: Paulikas et al.'s 2020 research paper[15] was funded by The Metals Company (formerly DeepGreen Metals) and Alvarenga et al.'s 2022 study[16] was funded by Global Sea Mineral Resources. Only one study - Fritz et al.'s 2023 research paper[17] - has no support (financial or otherwise) from the deep sea mining industry.

Deep sea mining and land ore climate impact estimates vary hugely

The estimated climate impact of producing the full nickel, copper, cobalt and manganese content from 1 kg of dry polymetallic nodules ranges from 1.371 kg CO_2e - 2.03 kg CO_2e in Alvarenga, et al.'s[18] and Fritz et al.'s[19] studies' respectively – see Figure 1.

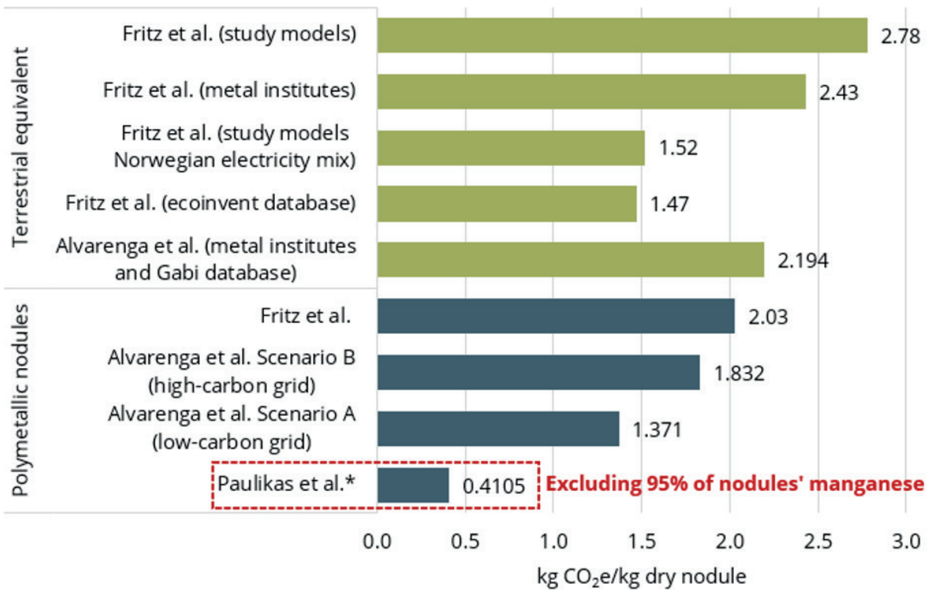


Figure 1: *Comparative climate change impact of the cradle-to-gate processing of copper, cobalt, nickel and ferromanganese from deep sea and terrestrial mining. *Figures from Paulikas et al. were converted from wet nodules to dry nodules equivalent assuming 23.75% water content based on data from the study.*

b Heinrich et al. published a paper in 2020 estimating the climate impact of polymetallic nodule collection and transportation, which will not be analysed in this paper as it does not cover the most significant sources of emissions from deep sea mining.

In comparison, these studies estimate that the equivalent metals produced from land ores would result in a climate impact of 1.47 kg CO_2e – 2.87 kg CO_2e.

When comparing the climate impact of deep sea and terrestrial mining, the results of these studies vary hugely, estimating that polymetallic nodules could have up 28% higher[20] or 76% lower[21] climate impact than land ores. **Such a variation in lifecycle assessment results is not a good enough basis for making decisions about the future of deep sea mining.**

It is also important to note that Paulikas et al.'s study assumed only 5%[22] of polymetallic nodules' manganese content would be processed into a marketable end product, as only metals currently used for electric vehicle batteries (specifically nickel-manganese-cobalt (NMC) 811 batteries) were assessed. This excluded 95%[23] of the production and associated climate impact of manganese and contributed to a significantly lower overall climate impact of approximately 0.4105 kg CO_2e/kg dry nodule. Given the cost of deep sea mining operations, it would not be economically feasible to exclude any metal content from polymetallic nodule production, and a zero-waste value chain is considered essential for making deep sea mining economically viable.[24] This begins to highlight issues with some of the parameters and assumptions used in these studies, which will be explored throughout this paper.

The following sections will analyse the differences in estimated climate impact for polymetallic nodules compared to land ores, and what implications this has for decarbonising mining and metals more broadly.

Metallurgical processing: the universal climate impact hotspot

80 - 85% of the climate impact of deep sea metals is driven by metallurgical processing: the energy- and fossil fuel-intensive process of turning polymetallic nodules into metal products. At the lower end of this range, Paulikas et al.'s[25] models estimated pyrometallurgical processing could make up 80% of the global warming potential of polymetallic nodules, while Alvarenga et al.'s study estimated this figure could be 80 -85% – see Figure 2.

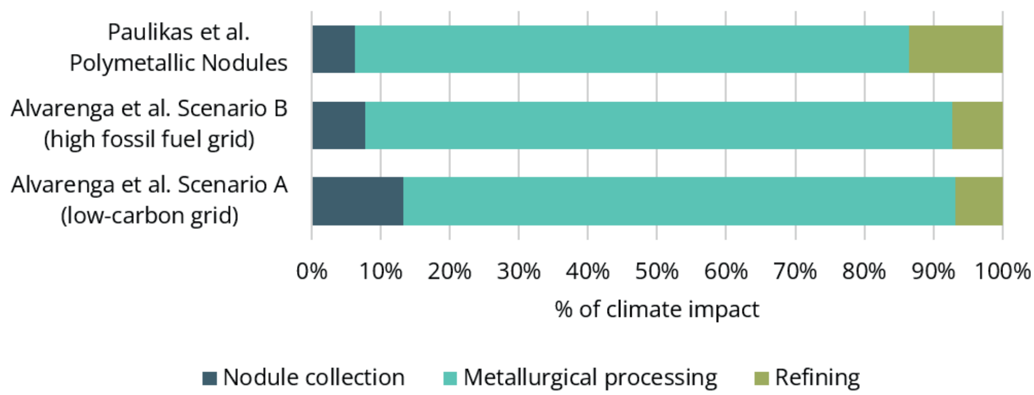


Figure 2: *Climate change impact of deep sea mining by production process. (Source: Paulikas et al. 2020 & Alvarenga et al. 2022)*

Fritz et al.'s study did not disaggregate metallurgical processing and refining but highlighted that these processes combined would constitute 95% of the climate impact of polymetallic nodules.

For land-based production of nickel, copper, cobalt and ferromanganese, metallurgical processing is also the biggest contributor to climate change, making up approximately 70 - 85%[26, 27, 28, 29] of total cradle-to-gate climate impact. The proposed metallurgical processing of polymetallic nodules is currently similar to that of land ores. **This means that climate impact is less dependent on whether metals come from the deep sea or land and is more dependent on the properties of processing: mainly the sources of fuel and electricity used, process efficiency and processing technique.**

Therefore, reducing the climate impact of both land and deep sea ores requires technologies such as electrification with renewable power sources, and the use of low carbon processing routes and technologies, based on for example hydrometallurgy.

DEEP SEA MINING COULD BE WORSE FOR THE CLIMATE THAN LAND ORES

Fritz et al.'s 2023 study[30] found that the climate impact of producing nickel, cobalt, copper and ferromanganese from polymetallic nodules could be around 25% higher or lower than that of equivalent terrestrially mined metals. This is the only study that demonstrated that land ores could have a lower climate impact than deep sea metals and is also the only research that was not funded or conducted in collaboration with a deep sea mining company.

This research estimated that polymetallic nodules could produce 2.03 kg CO_2e/kg dry nodule, 28% higher climate impact than the equivalent metals produced from land ores (1.47 kg CO_2e/kg dry nodule equivalent) as estimated via the lifecycle assessment software ecoinvent 3.7.1 – see Figure 3.

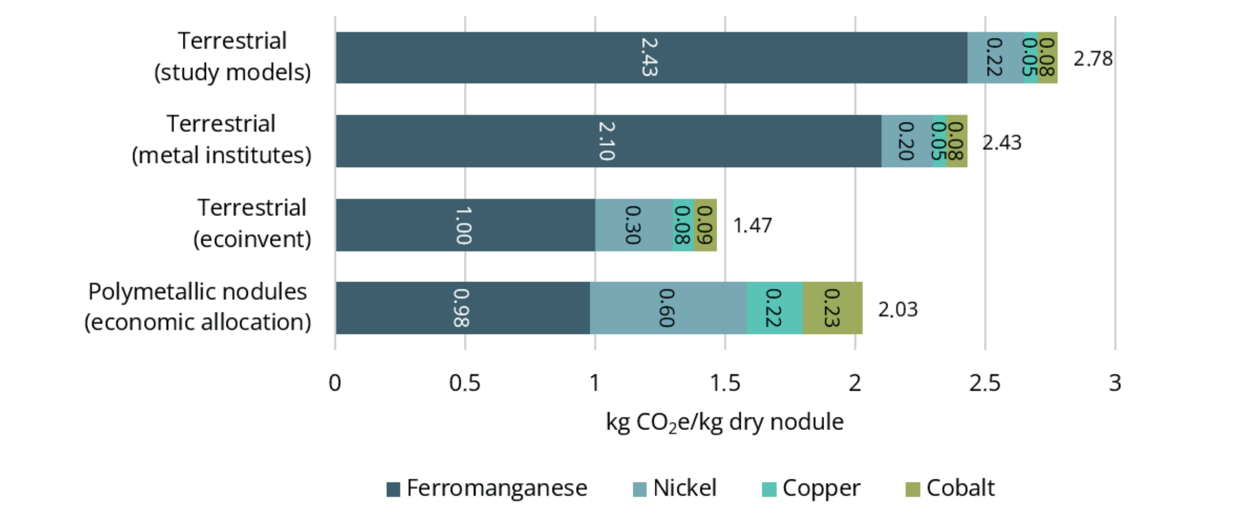


Figure 3: *Climate impact by metal in kg CO_2e/kg dry nodule. (Source: Fritz et al. 2023)*

In contrast, deep sea metals had 16% lower climate impact than equivalent terrestrial production based on data published by metal institutes (2.43 kg CO_2e/kg dry nodule equivalent), and 27% lower when compared to the studies' own modelled terrestrial production emissions (2.78 kg CO_2e/kg dry nodule equivalent).

Comparing three different sources of data to calculate land ore emissions highlights a key issue: estimated greenhouse gas emissions from terrestrial metal production vary hugely, as explored in the next section. Fritz et al. developed novel climate impact models using data from real mines: the Kevitsa sulfide nickel project in Finland (producing nickel, copper and cobalt), the Murrin Murrin nickel-cobalt project in Australia and the Woodie Woodie ferromanganese project in Australia.

This was compared with generic data for each metal from the ecoinvent database (a key lifecycle assessment inventory database) and with data from metal commodity associations (the Nickel Institute[31], the Cobalt Development Institute[32], the International Copper Association[33] and the International Manganese Institute[34]).

The climate impact of terrestrial metal production can be affected by the type of deposit, extraction technologies and techniques and data availability by geography and energy carriers, to name a few variables.[35,36] The carbon intensity of the electricity grid has a substantial impact on the carbon footprint of deep sea and terrestrial metal production. Fritz et al. recalculated terrestrial and polymetallic nodule production using the Norwegian electricity mix (which has the lowest carbon intensity in the ecoinvent database at 0.016 kg CO_2e/kWh). This reduced the climate impact of polymetallic nodules by 24% and the terrestrial equivalent by 45% – see Figure 4.

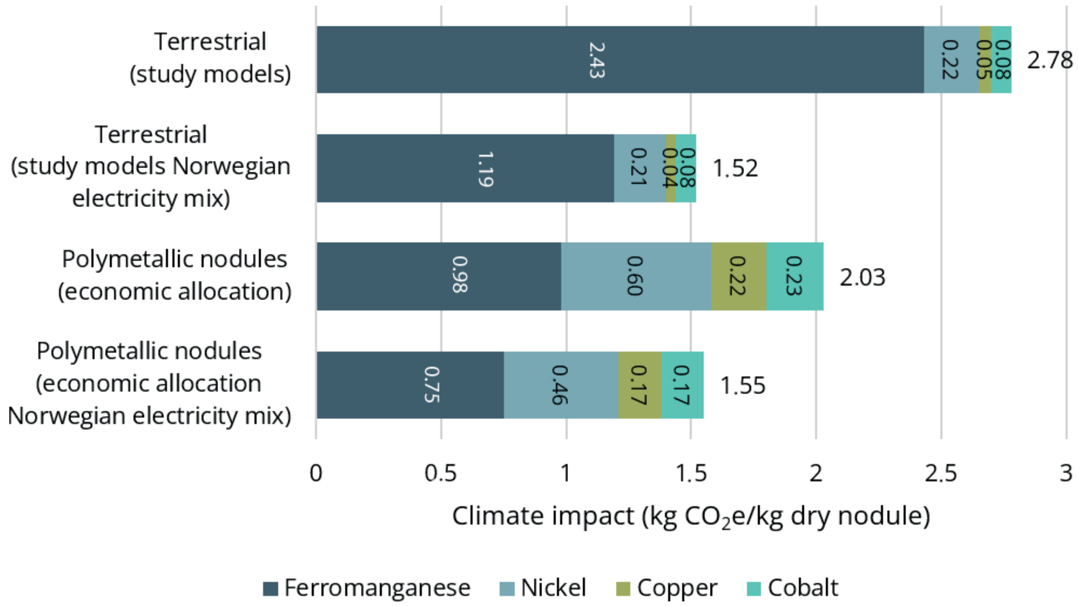


Figure 4: *Influence of low emissions energy scenario on the climate change impact of terrestrial and deep sea metals. (Source: Fritz et al. 2023)*

Importantly, in this alternative low carbon grid scenario polymetallic nodules have a higher climate impact (1.55 kg CO_2e/kg dry nodules) than land ores (1.52 kg CO_2e/kg dry nodules).

How much do emissions estimates for land ores vary?

To highlight the variation in emissions estimates for land ores, Planet Tracker conducted research into the climate impact of nickel, copper, cobalt and manganese from commodity associations and academic studies as well as mining companies.

11 relevant academic or metal commodity association lifecycle assessments were identified for nickel[37, 38] copper[39, 40, 41, 42] cobalt[43, 44] and manganese[45,46,47] the results of which are summarised in Figure 5.

Many studies provided multiple results for different production pathways, ore grades, product types and electricity sources, and all studies were published from 2016 – 2023.

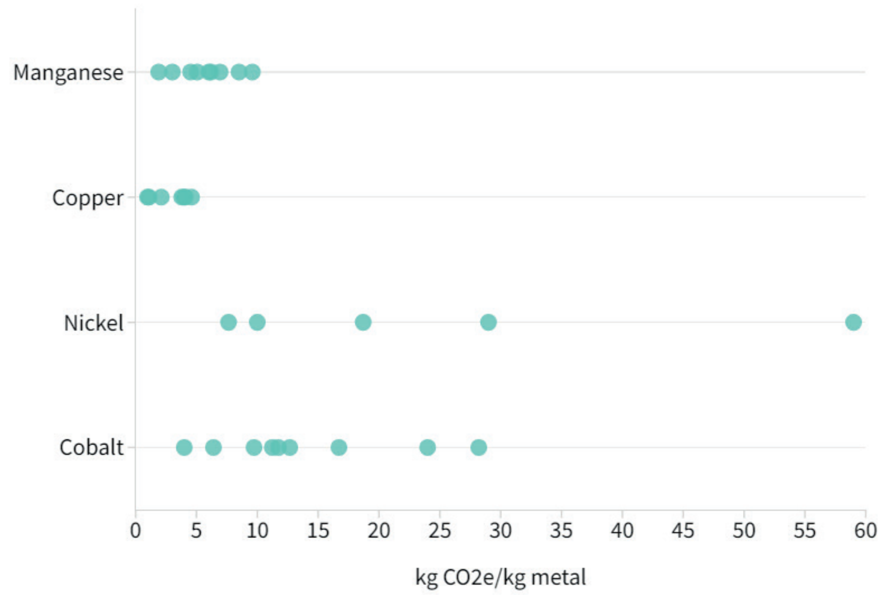


Figure 5: *A comparison of lifecycle assessments from academic literature and metal commodity associations.*

Figure 5 highlights that climate impact results for manganese and copper were lower than nickel and cobalt, with an average of 3.7 kg CO_2e/kg copper and 5.7 kg CO_2e/kg manganese, compared to 13.9 kg CO_2e/kg cobalt and 24.9 kg CO_2e/kg nickel. This reflects the higher energy intensity of cobalt and nickel production processes.

The results for manganese and copper were relatively closely distributed, ranging from 0.98 – 7.33 kg CO_2e/kg copper and 1.90 – 9.59 kg CO_2e/kg manganese. The lower climate impact results for copper reflect the production of less refined copper products, requiring less energy and producing lower emissions. The lower climate impact manganese results reflect the use of higher ore grades which require less energy to refine as well as more extensive use of renewable energy in metallurgical processing. This highlights the importance of decarbonising metallurgical processing in reducing the overall climate impact of terrestrial mining.

The climate impact of nickel and cobalt are much more varied, ranging from 7.64 – 59 kg CO_2e/kg nickel and 4 – 28.2 kg CO_2e/kg cobalt. The particularly high emissions for nickel are based on producing nickel matte from nickel pig iron, which requires significantly more electricity (usually met using coal-fired power plants) than most of today's typical nickel production.[48] Again, decarbonization through increasing renewable energy use could significantly reduce the climate impact of this production route.

Publicly reported greenhouse gas emissions data were collected from eight large mining companies[c] for nickel, copper and manganese, from 2016 – 2022, as summarised in Figure 6. No data was readily available for cobalt, most likely because 98%[49] of the mineral is produced as a by-product from large-scale copper and nickel mines.

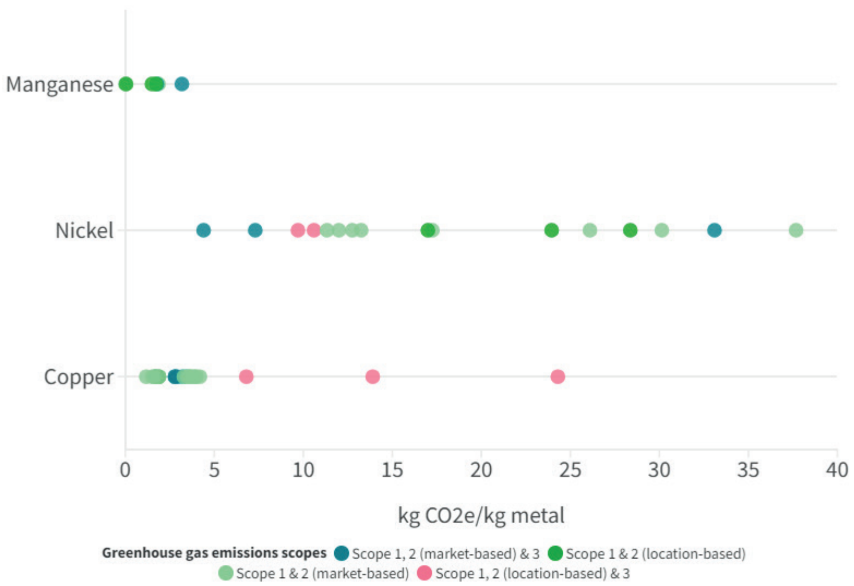


Figure 6: *A comparison of lifecycle assessments from mining companies.*

Company greenhouse gas emissions data shows similar trends to the results of the academic and commodity association studies. Again, nickel has the broadest range of emissions, from 4.4 – 37.7 kg CO_2e/kg nickel, with average emissions across the sample at 18.5 kg CO_2e/kg nickel. Vale's Long Harbour nickel refinery[50] in Newfoundland, Canada, provided the lowest carbon nickel of the sample, produced using hydrometallurgical processing which does not require energy- and coal-intensive smelting and smokestacks. Once more, this highlights the need to develop low carbon production technologies, with Vale investing USD 200 million to transform the facility.[51]

Company greenhouse gas emissions for copper were also widely distributed, ranging from 1.2 – 24.3 kg CO_2e/kg copper, with average emissions of 4.3 kg CO_2e/kg copper. The lowest carbon copper production is reported by BHP[52] which has invested heavily in renewable energy power purchasing agreements to reduce the carbon-intensity of its electricity supply.[53]

Company climate impact data for manganese was relatively closely distributed, ranging from 0.045 – 3.2 kg CO_2e/kg manganese. The lowest climate impact was for manganese ore, which did not include downstream processing emissions.

c Copper data was collected from: Codelco, Glencore, Nornickel, Vale and BHP. Nickel data was collected from: Glencore, Nornickel, Vale, BHP and Eramet. Manganese data was collected from: Vale, South32, Assmang and Eramet.

All lifecycle assessment studies have their limitations

While Fritz et al.'s study concluded that polymetallic nodules could have a higher or lower climate impact than terrestrial metals, the authors also state that the c. 25% difference in results is not significant, considering the overall variability and uncertainty associated with lifecycle assessment studies. Lifecycle assessment results vary widely due to the range of methodologies that can be applied as well as choice of background data, software and study design.[54] For example, a 2022 study[55] comparing lifecycle assessments for copper found a 26% difference in climate change impact driven by different combinations of software and databases.

As commercial-scale deep sea mining does not yet exist, the assumptions and estimations included in lifecycle assessment studies can add further uncertainty and variability to results, as discussed in the next section.

DEEP SEA MINING-FUNDED STUDIES HAVE SIGNIFICANT LIMITATIONS

Paulikas et al.[56] published a life cycle assessment study on the climate impact of deep sea mining in 2020, funded by deep sea mining company The Metals Company (formerly DeepGreen Metals) which also provided data and expertise for the research. The study estimated that to produce 1 billion electric vehicle batteries by 2047, deep sea mining would emit 445 metric megatons (Mt) of CO_2e, 76% less than the equivalent land ores – see Figure 7. However, the research has several key limitations, which reduced the estimated CO_2 emissions for polymetallic nodule production or increased the estimated emissions for terrestrially mined metals.

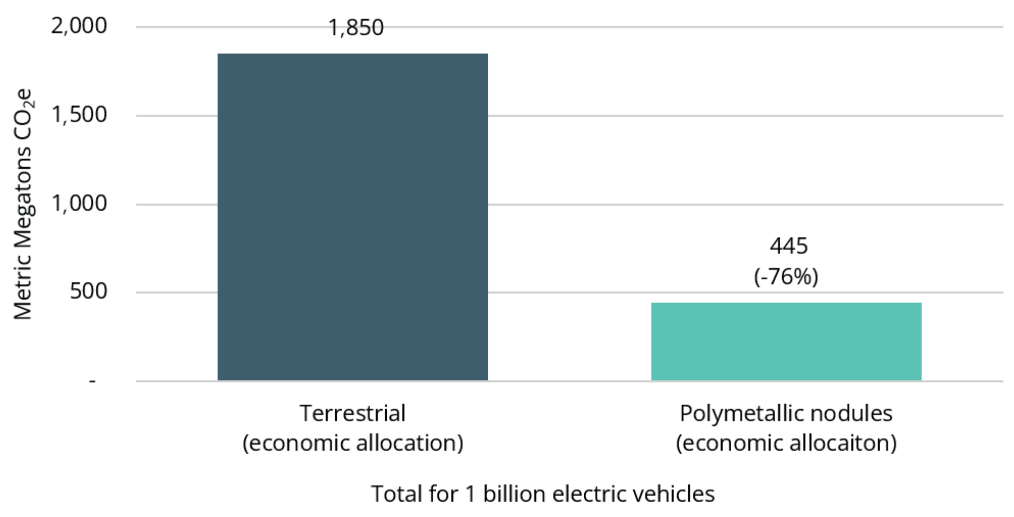


Figure 7: *Total estimated global warming potential for 1 billion electric vehicles by 2047. (Source: Paulikas et al. 2020).*

Not assessing the whole polymetallic nodule

As highlighted earlier in this report, Paulikas et al.'s study only considered the metals used for nickel-manganese-cobalt (NMC) 811 batteries, excluding 95% of polymetallic nodule's manganese content, and the associated climate impact. This is particularly important as manganese (or ferromanganese) smelting is particularly carbon-intensive, estimated to contribute 55%[57] of the overall climate impact of polymetallic nodule production, due to the use of coal as a reducing agent. It would not be economically feasible to exclude any metal content from polymetallic nodule production given the cost of deep sea mining.[58]

Different electricity scenarios for polymetallic nodule and land ore production

Paulikas et al.'s study also assumed that onshore polymetallic nodule processing electricity demand would be fully provided by hydropower. As discussed earlier in this report, this is the most energy-and carbon-intensive phase of the polymetallic nodule production process, and a zero-carbon energy source therefore significantly reduces the climate footprint of the metals produced.

This assumption is countered by The Metals Company's own pre-feasibility study of a commercial scale plant in India,[59] a country in which hydropower is projected to remain below 20% of the total electricity mix until 2030.[60] Ensuring low carbon electricity sources for processing polymetallic nodules is feasible, but this is equally true for terrestrial metals production. Increasing the use of low or zero carbon energy has been identified as key measure for reducing the carbon footprint of terrestrial metals, but Paulikas et al.'s study did not consider an equivalent 100% renewable energy-based scenario for land ores.

Alvarenga et al.[61] published a comparative life cycle assessment in 2022 funded by Global Sea Mineral Resources, a company exclusively involved in deep sea mining. This research addressed some of the limitations of Paulikas et al.'s study by assessing two undisclosed real country's electricity grid mixes to estimate emissions from polymetallic nodule production. Scenario A modelled production in a country located 4,010 km from the deep sea mining area (the Clarion-Clipperton Zone), but with a low carbon electricity grid (85% hydropower, 6% natural gas, 4% coal and lignite, 2% wind, 3% other). Scenario B modelled a country closer to the mine site (2,000 km away), but with a more carbon intensive electricity grid (55% natural gas, 15% hydropower, 13% coal and lignite, 10% oil, 4% nuclear and 3% other).

The study found that the low carbon intensity electricity grid scenario resulted in a lower overall climate impact (1.371 kg CO_2e/kg dry nodule) compared to the higher carbon intensive electricity grid scenario (1.832 kg CO_2e/kg dry nodule) – see Figure 8. The research highlights the importance of renewable energy in reducing the climate impact of deep sea mining, but as already stated, the same is true for terrestrial mining.

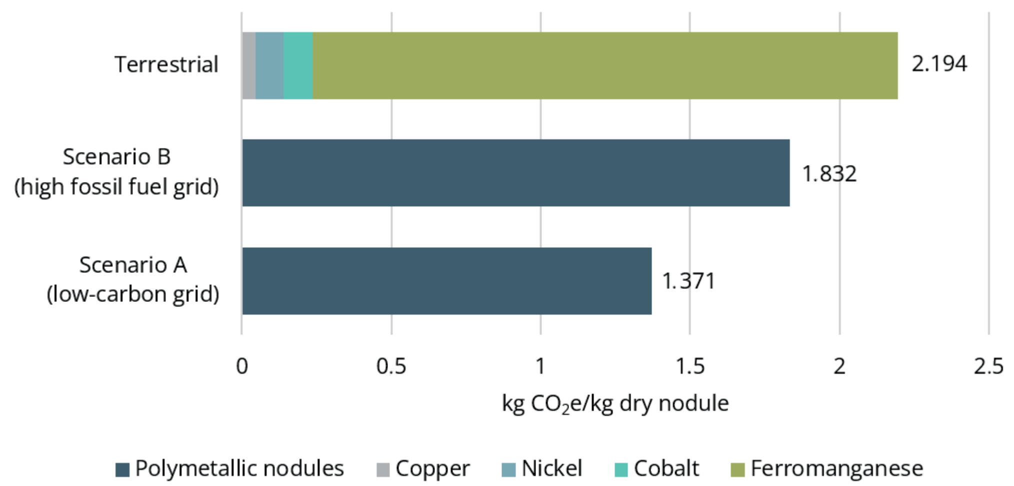


Figure 8: *Comparative climate change performance of copper, cobalt, nickel and ferromanganese from the deep sea and land-based mining systems (all values are in function of one tonne of dry nodules). (Source: Alvarenga et al., 2022)*

Novel processing techniques for polymetallic nodules

Beyond decarbonising electricity supply, another decarbonisation route for metals processing is the development of processing routes and techniques that reduce or remove the need for coal as a reducing agent. Alvarenga et al.'s study found that the climate impact of metals sourced from polymetallic nodules could be 16 - 38% lower than their land-based counterparts, based on the use of a novel lower-carbon hydrometallurgical refining process - see Figure 8 above. However, as highlighted earlier in this report, hydrometallurgical processing is being developed as a major decarbonisation lever in terrestrial metal production, for example at Vale's Long Harbour nickel refinery[62] in Newfoundland, Canada. However, this study does not consider an equivalent hydrometallurgical processing route for land ores.

Estimating the impact of terrestrial mining on carbon sequestration

Terrestrial mining can impact carbon stocks and sequestration services in two key ways:

1) carbon is released when soil and vegetation is removed to develop mines and supporting infrastructure and;

2) pollution from mining can damage surrounding habitats, releasing carbon and impacting their future ability to sequester carbon.

No published estimates have been found of terrestrial mining's impact on carbon stocks and sequestration, so Paulikas et al.'s study represents a novel attempt to estimate this.

Paulikas et al. estimated that 2.53 metric gigatonnes (Gt) of stored carbon could be at risk of being released from terrestrial mining of copper, cobalt, nickel and manganese required to produce 1 billion electric vehicle batteries by 2047.

This is the equivalent to 9.3 metric Gt CO_2 when exposure to air, oxidation and microbial metabolism are taken into account. The study also estimates that 0.56 metric Gt of carbon, or 2.1 metric Gt of CO_2 could have been sequestered over 100 years had terrestrial mining not occurred.

It is not possible to fully evaluate Paulikas et al.'s estimates for carbon stocks and sequestration services at risk, as there is not a detailed enough breakdown of assumptions and calculations. However, calculating the unweighted climate impact of terrestrial metals that Paulika's et al. used to calculate a comparable climate impact to polymetallic nodules (based on the price of metals) gives an indication of how this has impacted the study results. The estimated climate impact of carbon stocks and sequestration at risk from terrestrial mining contribute a significantly higher unweighted climate impact than the two other comparable studies – see Figure 9.

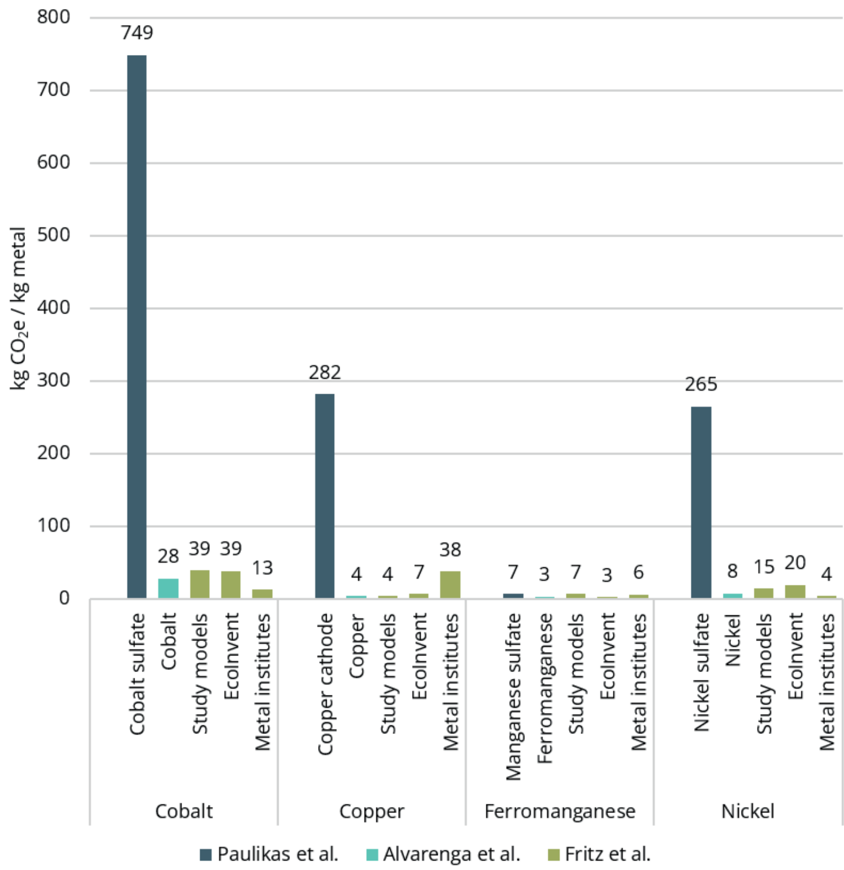


Figure 9: *Comparison of the unweighted climate impact of terrestrial metals from studies on the climate impact of deep sea mining. (Source: Paulikas et al., 2020; Alvarenga et al., 2022 and; Fritz et al., 2023)*

The unknown impact on ocean carbon sequestration

Marine sediments are estimated to be the largest pool of sediment/soil carbon stocks in the world and are an important part of the global carbon cycle.[63] Marine sediments currently store an estimated 2,322 Gt of carbon in the top 1m of sediments[64], 1.75 times greater than the top 1 metre of terrestrial soils.[65] 79% of ocean sediment carbon is estimated to be stored in abyssal plains or basin zones, such as the Clarion-Clipperton Zone.[66] Although less than 1% of gross primary production[d] on Earth makes it to the seafloor[67, 68] organic carbon buried in ocean sediments can be stored there for thousands to millions of years, if left undisturbed.[69, 70] However, deep sea mining could make these once semi-permanent carbon stocks vulnerable to remineralization, the process via which they could re-enter the atmosphere and exacerbate future climate change.

d The amount of chemical energy, typically expressed as carbon biomass, that primary producers like plants, algae and bacteria create in a given amount of time.

Mining polymetallic nodules could impact carbon sequestration in several key ways:

1) stored carbon could be released from seabed sediment disturbed during nodule collection;

2) carbon sequestration services (on the seabed and in the water column) could be disrupted during nodule collection and;

3) dissolved carbon could be released from riser water brought up from the deep sea

As with land ores, no published estimates of deep sea mining's impact on carbon sequestration were found, so Paulikas et al.'s study represents a novel attempt to estimate the current and future impact of mining on carbon stocks and sequestration.

Disturbing deep sea carbon stocks and sequestration services

Deep sea mining machinery is expected to compact, remove and redeposit sea floor sediment, creating sediment plumes which could spread hundreds to thousands of kilometers in the water column.[71] This could result in an estimated 172.5 tonnes of carbon being disturbed every year for every km^2 mined.[72]

Only 13.9 kg of carbon per km^2 is sequestered every year in the Clarion-Clipperton Zone,[73] which is 0.00804%[e] of the quantity of seafloor carbon disturbed by collector vehicles per year – see Table 1.

Table 1: *Comparing the carbon sequestered in the seabed versus the sediment plume.*

Item	Value	Source / Comments
Quantity of seafloor carbon disturbed by collector vehicles (tonnes of carbon per km2 per year)	172.5	Based on Orcutt et al., 2020.[74]
Average carbon sequestered in the seabed in the CCZ (tonnes per km^2 per year)	0.0139	Based on Yu et al., 2023.[75]
Average carbon sequestered as a % of carbon disturbed	0.008%	Based on the two numbers above.
Proportion of carbon in benthic plume estimated to settle back onto the seafloor	92-99%	Based on Paulikas et al., 2020[76] and Muñoz-Royo et al., 2022.[77]

However, it is not known how much of this carbon could be remineralised by microbes and make its way into the atmosphere. Due to the geological time scale of deep sea ocean currents it could take decades to hundreds of years for sediment plumes from deep sea mining to make it to the surface.[78] The organic matter in which carbon in stored in marine sediments is also highly processed, making it unlikely to be released via microbial remineralization.[79]

Based on a 2021 field study, researchers at MIT estimated that 92 – 98% of the sediment plume would either settle back down or remain within two meters of the seafloor after several hours, with no indication of the proportion that could settle back down over a longer time period.[80] Paulikas et al.'s study claimed that "99% of the suspended material would resettle back to the bottom within one-two months and 1 - 100km", referencing a 2017 study by Jones et al.,[80] but this assertion or any such similar statement is not present in Jones et al.'s study, which was confirmed in writing by its lead author.[82]

e 13.9kg vs 172.5 tonnes

Deep sea mining sediment plumes could affect carbon sequestration in ocean waters

A deep sea mining vessel could release up to 120,000 tonnes of sediment into the ocean's water column per year,[83] which could increase water turbidity (cloudiness). If released in the sunlit zone where phytoplankton live, this could reduce light penetration, lowering photosynthesis rate which ultimately impacts carbon sequestration in the waters above the Clarion-Clipperton Zone – see Figure 10.

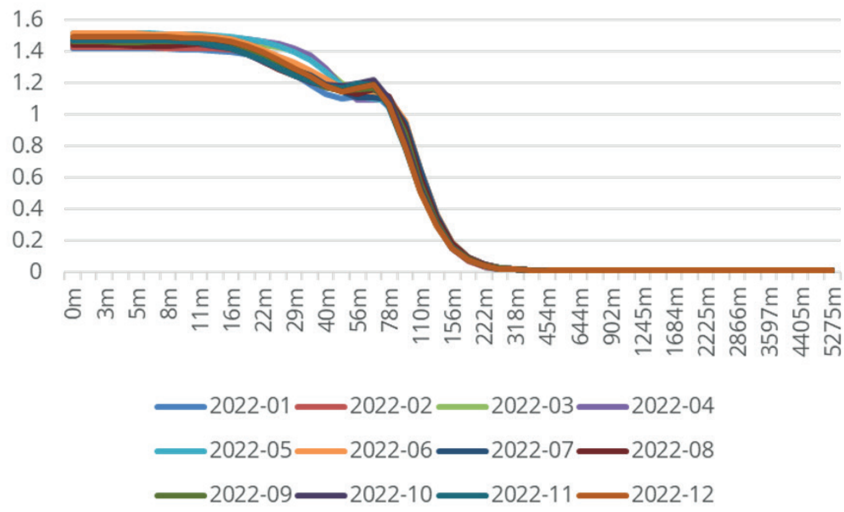


Figure 10: *Mole concentration of phytoplankton by column depth and by month in the area of the Clarion-Clipperton Zone where deep-sea mining may occur, expressed as carbon in sea water across the water, in mmol/m³ (Source: Planet Tracker, based on Copernicus and ISA Data).*

Even if the sediment plume is released deeper than the sunlit zone (which seems to be the planned approach of e.g. The Metals Company, bar any accident), it could still impact carbon sequestration as sediment particles could interfere with the slow vertical flux of carbon-rich material.[84] Polymetallic nodule mining in particular produces sediment plumes which can spread especially far[85] due to the fine natural sediment on the abyssal sea floor, with particles typically less than 10µm in diameter.[86] It is expected to take around 1 year for a 10µm particle to settle 3,000m in depth and travel thousands of kilometres laterally.[87] While the severity of this impact is not yet known, it is of concern for many scientists.[88]

Disrupting polymetallic nodules' carbon sequestration services

Current research indicates that the fauna in polymetallic nodule regions play an important role in carbon cycling, storage and fixation, although the mechanics of this are not well understood.[89,90,91,92] Over half of the species living in the Pacific abyssal plains depend on nodules to exist,[93] so deep sea mining is likely to impact these carbon services by removing nodules. The effect of these carbon services has not yet been quantified, but considering nodules take tens of millions of years to form,[94] the loss of these ecosystem and carbon cycle services caused by deep sea mining would essentially be permanent.

CONCLUSIONS

This report has found that the results of current studies comparing the climate impact of deep sea and terrestrial mining vary hugely, estimating that polymetallic nodules could have a higher or lower climate impact than land ores. Such a variation in results is not an acceptable basis for making decisions about the future of deep sea mining.

Over 70% of greenhouse gas emissions for both land ores and polymetallic nodules come from energy and fossil fuel-intensive metallurgical processing. The proposed metallurgical processing of nodules is currently similar to that of land ores. Consequently, the severity of climate impact is less dependent on whether ores come from the deep sea or land and is more dependent on the properties of processing: mainly the sources of fuel and electricity used, process efficiency and technique.

Therefore, reducing the climate impact of both land and deep sea ores requires investment in technologies such as electrification with renewable power sources, lower-carbon processing routes, such as hydrometallurgy, which remove or reduce the use of fossil fuels.

There is also a risk that deep sea mining could transform the Clarion-Clipperton Zone from a carbon sink to a carbon source by disturbing carbon contained in sediments. Sediment plumes caused by mining machinery could impact carbon sequestration services taking place in ocean waters by blocking sunlight and reducing photosynthesis. By removing nodules and the fauna which depend on them, deep sea mining could also effectively permanently remove the carbon sequestration services associated with fauna.

CALL TO ACTION

Deep sea mining would have a significant climate impact and could expose financial institutions to significant policy, regulatory and reputational risks.

Financial institutions should therefore support a moratorium on deep sea mining.

Instead of investing in deep sea mining, financial institutions could support the decarbonisation of terrestrial mining and metals production. **Opportunities to support a blue economy include: seafood traceability,[f] greater efficiency of marine protected areas,[g] a blue recovery bond to reverse overfishing,[h] greater monitoring of fishing fleets,[i] sustainable feeds for aquaculture,[j] regenerative aquaculture,[k] or greater recycling of shipping and fishing vessels.[l]**

f See Planet Tracker's report: How to Trace USD 600 Billion.

g See Planet Tracker's report: Rewarding Conservation Efficiency in Marine Protected Areas.

h See Planet Tracker's report: Can Blue Bonds Finance a Fish Recovery?

i See Planet Tracker's report: Bonding with Observers.

j See Planet Tracker's report: Bonds for Ponds.

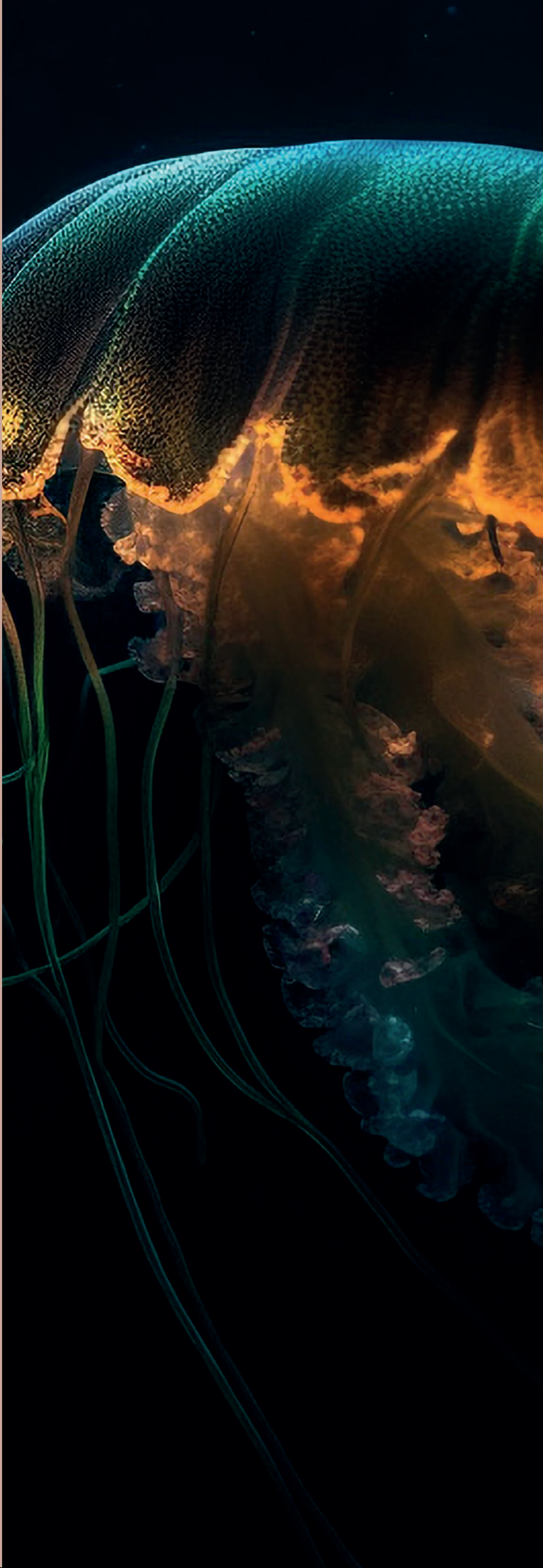
k See Planet Tracker's report: Avoiding Aquafailure.

l See Planet Tracker's blog: Beached, not Stranded.

DISCLAIMER

As an initiative of Tracker Group Limited, Planet Tracker's reports and datasets are impersonal and do not provide individualised advice or recommendations for any specific reader or portfolio. Tracker Group Limited is not an investment adviser and makes no recommendations regarding the advisability of investing in any particular company, investment fund or other vehicle. The information contained in this research report or dataset does not constitute an offer to sell securities or the solicitation of an offer to buy, or recommendation for investment in, any securities within any jurisdiction. The information is not intended as financial advice.

The information used to compile this report or dataset has been collected from a number of sources in the public domain and from Tracker Group Limited licensors. While Tracker Group Limited and its partners have obtained information believed to be reliable, none of them shall be liable for any claims or losses of any nature in connection with information contained in this document, including but not limited to, lost profits or punitive or consequential damages. This research report or dataset provides general information only. The information and opinions constitute a judgment as at the date indicated and are subject to change without notice. The information may therefore not be accurate or current. The information and opinions contained in this report or dataset have been compiled or arrived at from sources believed to be reliable and in good faith, but no representation or warranty, express or implied, is made by Tracker Group Limited as to their accuracy, completeness or correctness and Tracker Group Limited does also not warrant that the information is up-to-date.



REFERENCES

1 Paulikas, Daina, Steven Katona, Erika Ilves, and Saleem H. Ali. "Life cycle climate change impacts of producing battery metals from land ores versus deep-sea polymetallic nodules." Journal of Cleaner Production 275 (2020): 123822.

2 Alvarenga, R. A. F., Nils Préat, C. Duhayon, and Jo Dewulf. "Prospective life cycle assessment of metal commodities obtained from deep-sea polymetallic nodules." Journal of Cleaner Production 330 (2022): 129884.

3 Volkmann, Sebastian Ernst, Felix Lehnen, and Peter A. Kukla. "Estimating the economics of a mining project on seafloor manganese nodules." Mineral Economics 32 (2019): 287-306.

4 Atwood, Trisha B., Andrew Witt, Juan Mayorga, Edd Hammill, and Enric Sala. "Global patterns in marine sediment carbon stocks." Frontiers in Marine Science 7 (2020): 165.

5 Hedges, John I., and Richard G. Keil. "Sedimentary organic matter preservation: an assessment and speculative synthesis." Marine chemistry 49, no. 2-3 (1995): 81-115.

6 Burdige, David J. "Preservation of organic matter in marine sediments: controls, mechanisms, and an imbalance in sediment organic carbon budgets?." Chemical reviews 107, no. 2 (2007): 467-485.

7 Mcleod, Elizabeth, Gail L. Chmura, Steven Bouillon, Rodney Salm, Mats Björk, Carlos M. Duarte, Catherine E. Lovelock, William H. Schlesinger, and Brian R. Silliman. "A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2." Frontiers in Ecology and the Environment 9, no. 10 (2011): 552-560.

8 Estes, Emily R., Robert Pockalny, Steven D'Hondt, Fumio Inagaki, Yuki Morono, Richard W. Murray, Dennis Nordlund et al. "Persistent organic matter in oxic subseafloor sediment." Nature Geoscience 12, no. 2 (2019): 126-131.

9 Orcutt, Beth N., James A. Bradley, William J. Brazelton, Emily R. Estes, Jacqueline M. Goordial, Julie A. Huber, Rose M. Jones et al. "Impacts of deep sea mining on microbial ecosystem services." Limnology and Oceanography 65, no. 7 (2020): 1489-1510.

10 Yu, W., F. Lin, and L. Lin. "Bioturbation in sediment cores from the Clarion-Clipperton Zone in the northeast Pacific: Evidence from excess 210Pb." Marine Pollution Bulletin 188 (2023): 114635.

11 Chin, A., and Hari, K. Predicting the impacts of mining deep sea polymetallic nodules in the Pacific Ocean: A review of Scientific literature. Deep Sea Mining Campaign and MiningWatch Canada, 2020. Accessed Aug 23, 2023.

12 Deep sea conservation coalition. (2023). Moment for a moratorium.

13 IUCN. (2023). IUCN Director General's open letter to ISA Members on deep-sea mining.

14 Sharma, Rahul, ed. Deep-sea mining: Resource potential, technical and environmental considerations. Springer, 2017.

15 Paulikas, Daina, Steven Katona, Erika Ilves, and Saleem H. Ali. "Life cycle climate change impacts of producing battery metals from land ores versus deep-sea polymetallic nodules." Journal of Cleaner Production 275 (2020): 123822.

16 Alvarenga, R. A. F., Nils Préat, C. Duhayon, and Jo Dewulf. "Prospective life cycle assessment of metal commodities obtained from deep-sea polymetallic nodules." Journal of Cleaner Production 330 (2022): 129884.

17 Fritz, Benjamin, Pia Heidak, Jürgen Vasters, Thomas Kuhn, Gudrun Franken, and Mario Schmidt. "Life cycle impact on climate change caused by metal production from deep sea manganese nodules versus land-based deposits." Resources, Conservation and Recycling 193 (2023): 106976.

18 Alvarenga, R. A. F., Nils Préat, C. Duhayon, and Jo Dewulf. "Prospective life cycle assessment of metal commodities obtained from deep-sea polymetallic nodules." Journal of Cleaner Production 330 (2022): 129884.

19 Fritz, Benjamin, Pia Heidak, Jürgen Vasters, Thomas Kuhn, Gudrun Franken, and Mario Schmidt. "Life cycle impact on climate change caused by metal production from deep sea manganese nodules versus land-based deposits." Resources, Conservation and Recycling 193 (2023): 106976.

20 Fritz, Benjamin, Pia Heidak, Jürgen Vasters, Thomas Kuhn, Gudrun Franken, and Mario Schmidt. "Life cycle impact on climate change caused by metal production from deep sea manganese nodules versus land-based deposits." Resources, Conservation and Recycling 193 (2023): 106976.

21 Fritz, Benjamin, Pia Heidak, Jürgen Vasters, Thomas Kuhn, Gudrun Franken, and Mario Schmidt. "Life cycle impact on climate change caused by metal production from deep sea manganese nodules versus land-based deposits." Resources, Conservation and Recycling 193 (2023): 106976.

22 Fritz, Benjamin, Pia Heidak, Jürgen Vasters, Thomas Kuhn, Gudrun Franken, and Mario Schmidt. "Life cycle impact on climate change caused by metal production from deep sea manganese nodules versus land-based deposits." Resources, Conservation and Recycling 193 (2023): 106976.

23 Alvarenga, R. A. F., Nils Préat, C. Duhayon, and Jo Dewulf. "Prospective life cycle assessment of metal commodities obtained from deep-sea polymetallic nodules." Journal of Cleaner Production 330 (2022): 129884.

24 Volkmann, Sebastian Ernst, Felix Lehnen, and Peter A. Kukla. "Estimating the economics of a mining project on seafloor manganese nodules." Mineral Economics 32 (2019): 287-306.

25 Paulikas, Daina, Steven Katona, Erika Ilves, and Saleem H. Ali. "Life cycle climate change impacts of producing battery metals from land ores versus deep-sea polymetallic nodules." Journal of Cleaner Production 275 (2020): 123822.

26 Volkmann, Sebastian Ernst, Felix Lehnen, and Peter A. Kukla. "Estimating the economics of a mining project on seafloor manganese nodules." Mineral Economics 32 (2019): 287-306.

27 Cobalt Institute. Life Cycle Assessment of Cobalt and Refined Cobalt Compounds. (2019). Accessed Aug 21, 2023. link

28 International Copper Association. Copper Cathode Life Cycle Assessment. (New York, USA, 2017).

29 Westfall, Luke Aiden, Julia Davourie, Mohammed Ali, and Doreen McGough. "Cradle-to-gate life cycle assessment of global manganese alloy production." The International Journal of Life Cycle Assessment 21 (2016): 1573-1579.

30 Fritz, Benjamin, Pia Heidak, Jürgen Vasters, Thomas Kuhn, Gudrun Franken, and Mario Schmidt. "Life cycle impact on climate change caused by metal production from deep sea manganese nodules versus land-based deposits." Resources, Conservation and Recycling 193 (2023): 106976.

31 Mistry, Mark, Johannes Gediga, and Shannon Boonzaier. "Life cycle assessment of nickel products." The International Journal of Life Cycle Assess ment 21 (2016): 1559-1572.

32 Cobalt Development Institute. The Environmental Performance of Refined Cobalt - Life Cycle Inventory and Life Cycle Assessment of Refined Cobalt. (Surrey, UK, 2016).

33 International Copper Association. Copper Cathode Life Cycle Assessment. (New York, USA, 2017).

34 Westfall, Luke Aiden, Julia Davourie, Mohammed Ali, and Doreen McGough. "Cradle-to-gate life cycle assessment of global manganese alloy production." The International Journal of Life Cycle Assessment 21 (2016): 1573-1579.

35 Skarn Associates Limited, GHG & Energy curves for copper, 2020, Accessed Aug 21, 2023, link

36 Vale, Vale receives third-party assurance for additional carbon nickel products, 2022, Accessed Aug 21, 2023, link

37 Mistry, Mark, Johannes Gediga, and Shannon Boonzaier. "Life cycle assessment of nickel products." The International Journal of Life Cycle Assess ment 21 (2016): 1559-1572.

38 IEA, The role of critical minerals in the clean energy transition, 2021, Accessed Aug 21, 2023, link

39 IEA, The role of critical minerals in the clean energy transition, 2021, Accessed Aug 21, 2023, link

40 Hong, Jinglan, Yilu Chen, Juan Liu, Xiaotian Ma, Congcong Qi, and Liping Ye. "Life cycle assessment of copper production: a case study in China." The International Journal of Life Cycle Assessment 23 (2018): 1814-1824.

41 International Copper Association, Copper Environmental Profile: Global 2023, 2023, Accessed Aug 21, 2023, link

42 Kuipers, Koen JJ, Lauran FCM van Oers, Miranda Verboon, and Ester van der Voet. "Assessing environmental implications associated with global copper demand and supply scenarios from 2010 to 2050." Global Environmental Change 49 (2018): 106-115.

43 IEA, The role of critical minerals in the clean energy transition, 2021, Accessed Aug 21, 2023, linkt

44 The Cobalt Institute, Life Cycle Assessment, 2019, Accessed 21 Aug, 2023, link

45 Farjana, Shahjadi Hisan, Nazmul Huda, MA Parvez Mahmud, and Candace Lang. "A global life cycle assessment of manganese mining processes based on EcoInvent database." Science of the total environment 688 (2019): 1102-1111.

46 Westfall, Luke Aiden, Julia Davourie, Mohammed Ali, and Doreen McGough. "Cradle-to-gate life cycle assessment of global manganese alloy production." The International Journal of Life Cycle Assessment 21 (2016): 1573-1579.

47 Zhang, Ruirui, Xiaotian Ma, Xiaoxu Shen, Yijie Zhai, Tianzuo Zhang, Changxing Ji, and Jinglan Hong. "Life cycle assessment of electrolytic manga nese metal production." Journal of Cleaner Production 253 (2020): 119951.

48 IEA, The role of critical minerals in the clean energy transition, 2021, Accessed Aug 21, 2023, link

49 The Cobalt Institute, Cobalt Mining, 2021, Accessed 21 Aug, 2023, link

50 The Nicke Institute, Powering electric vehicles with low-carbon nickel, 2022, Accessed Aug 21, 2023, link

51 The Nicke Institute, Powering electric vehicles with low-carbon nickel, 2022, Accessed Aug 21, 2023, link

52 BHP, BHP ESG Standards and Databook 2022, 2022, Accessed Aug 21, 2023, link

53 BHP, BHP operations in Chile start to operate with renewable energies, 2021, Accessed Aug 21, 2023, link

54 Sanjuan-Delmás, David, R. A. F. Alvarenga, M. Lindblom, Tobias Christoph Kampmann, Lauran van Oers, Jeroen B. Guinée, and Jo Dewulf. "Environmental assessment of copper production in Europe: an LCA case study from Sweden conducted using two conventional software-data base setups." The International Journal of Life Cycle Assessment 27, no. 2 (2022): 255-266.

55 Sanjuan-Delmás, David, R. A. F. Alvarenga, M. Lindblom, Tobias Christoph Kampmann, Lauran van Oers, Jeroen B. Guinée, and Jo Dewulf. "Environmental assessment of copper production in Europe: an LCA case study from Sweden conducted using two conventional software-data base setups." The International Journal of Life Cycle Assessment 27, no. 2 (2022): 255-266.

56 Paulikas, Daina, Steven Katona, Erika Ilves, and Saleem H. Ali. "Life cycle climate change impacts of producing battery metals from land ores versus deep-sea polymetallic nodules." Journal of Cleaner Production 275 (2020): 123822.

57 Fritz, Benjamin, Pia Heidak, Jürgen Vasters, Thomas Kuhn, Gudrun Franken, and Mario Schmidt. "Life cycle impact on climate change caused by metal production from deep sea manganese nodules versus land-based deposits." Resources, Conservation and Recycling 193 (2023): 106976.

58 Volkmann, Sebastian Ernst, Felix Lehnen, and Peter A. Kukla. "Estimating the economics of a mining project on seafloor manganese nodules." Mineral Economics 32 (2019): 287-306.

59 The Metals Company, TMC enters into business collaboration MoU with epsilon carbon to Complete A Pre-Feasibility Study For the World's First Commercial Polymetallic Nodule Processing Plant in India, 2022, Accessed Sep 11, 2023, link

60 IEA, India Energy Outlook 2021, 2021, Accessed Sep 11, 2023, link

61 Alvarenga, R. A. F., Nils Préat, C. Duhayon, and Jo Dewulf. "Prospective life cycle assessment of metal commodities obtained from deep-sea polymetallic nodules." Journal of Cleaner Production 330 (2022): 129884.

62 The Nicke Institute, Powering electric vehicles with low-carbon nickel, 2022, Accessed Aug 21, 2023, link

63 Atwood, Trisha B., Andrew Witt, Juan Mayorga, Edd Hammill, and Enric Sala. "Global patterns in marine sediment carbon stocks." Frontiers in Marine Science 7 (2020): 165.

64 Atwood, Trisha B., Andrew Witt, Juan Mayorga, Edd Hammill, and Enric Sala. "Global patterns in marine sediment carbon stocks." Frontiers in Marine Science 7 (2020): 165.

65 Köchy, Martin, Roland Hiederer, and Annette Freibauer. "Global distribution of soil organic carbon–Part 1: Masses and frequency distributions of SOC stocks for the tropics, permafrost regions, wetlands, and the world." Soil 1, no. 1 (2015): 351-365.

66 Atwood, Trisha B., Andrew Witt, Juan Mayorga, Edd Hammill, and Enric Sala. "Global patterns in marine sediment carbon stocks." Frontiers in Marine Science 7 (2020): 165.

67 Hedges, John I., and Richard G. Keil. "Sedimentary organic matter preservation: an assessment and speculative synthesis." Marine chemistry 49, no. 2-3 (1995): 81-115.

68 Burdige, David J. "Preservation of organic matter in marine sediments: controls, mechanisms, and an imbalance in sediment organic carbon budgets?." Chemical reviews 107, no. 2 (2007): 467-485.

69 Mcleod, Elizabeth, Gail L. Chmura, Steven Bouillon, Rodney Salm, Mats Björk, Carlos M. Duarte, Catherine E. Lovelock, William H. Schlesinger, and Brian R. Silliman. "A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2." Frontiers in Ecology and the Environment 9, no. 10 (2011): 552-560.

70 Estes, Emily R., Robert Pockalny, Steven D'Hondt, Fumio Inagaki, Yuki Morono, Richard W. Murray, Dennis Nordlund et al. "Persistent organic matter in oxic subseafloor sediment." Nature Geoscience 12, no. 2 (2019): 126-131.

71 Muñoz-Royo, Carlos, Thomas Peacock, Matthew H. Alford, Jerome A. Smith, Arnaud Le Boyer, Chinmay S. Kulkarni, Pierre FJ Lermusiaux et al. "Extent of impact of deep-sea nodule mining midwater plumes is influenced by sediment loading, turbulence and thresholds." Communications Earth & Environment 2, no. 1 (2021): 148.

72 Orcutt, Beth N., James A. Bradley, William J. Brazelton, Emily R. Estes, Jacqueline M. Goordial, Julie A. Huber, Rose M. Jones et al. "Impacts of deep sea mining on microbial ecosystem services." Limnology and Oceanography 65, no. 7 (2020): 1489-1510.

73 Yu, W., F. Lin, and L. Lin. "Bioturbation in sediment cores from the Clarion-Clipperton Zone in the northeast Pacific: Evidence from excess 210Pb." Marine Pollution Bulletin 188 (2023): 114635.

74 Orcutt, Beth N., James A. Bradley, William J. Brazelton, Emily R. Estes, Jacqueline M. Goordial, Julie A. Huber, Rose M. Jones et al. "Impacts of deep sea mining on microbial ecosystem services." Limnology and Oceanography 65, no. 7 (2020): 1489-1510.

75 Yu, W., F. Lin, and L. Lin. "Bioturbation in sediment cores from the Clarion-Clipperton Zone in the northeast Pacific: Evidence from excess 210Pb." Marine Pollution Bulletin 188 (2023): 114635.

76 Paulikas, Daina, Steven Katona, Erika Ilves, and Saleem H. Ali. "Life cycle climate change impacts of producing battery metals from land ores versus deep-sea polymetallic nodules." Journal of Cleaner Production 275 (2020): 123822.

77 Muñoz-Royo, Carlos, Raphael Ouillon, Souha El Mousadik, Matthew H. Alford, and Thomas Peacock. "An in situ study of abyssal turbidity-current sediment plumes generated by a deep seabed polymetallic nodule mining preprototype collector vehicle." Science Advances 8, no. 38 (2022): eabn1219.

78 Atwood, Trisha B., Andrew Witt, Juan Mayorga, Edd Hammill, and Enric Sala. "Global patterns in marine sediment carbon stocks." Frontiers in Marine Science 7 (2020): 165.

79 Orcutt, Beth N., James A. Bradley, William J. Brazelton, Emily R. Estes, Jacqueline M. Goordial, Julie A. Huber, Rose M. Jones et al. "Impacts of deep sea mining on microbial ecosystem services." Limnology and Oceanography 65, no. 7 (2020): 1489-1510.

80 Muñoz-Royo, Carlos, Raphael Ouillon, Souha El Mousadik, Matthew H. Alford, and Thomas Peacock. "An in situ study of abyssal turbidity-current sediment plumes generated by a deep seabed polymetallic nodule mining preprototype collector vehicle." Science Advances 8, no. 38 (2022): eabn1219.

81 Jones, Daniel OB, Stefanie Kaiser, Andrew K. Sweetman, Craig R. Smith, Lenaick Menot, Annemiek Vink, Dwight Trueblood et al. "Biological responses to disturbance from simulated deep-sea polymetallic nodule mining." PLoS One 12, no. 2 (2017): e0171750.

82 Daniel O.B. Jones (2023). Personal correspondence.

83 Muñoz-Royo, Carlos, Raphael Ouillon, Souha El Mousadik, Matthew H. Alford, and Thomas Peacock. "An in situ study of abyssal turbidity-current sediment plumes generated by a deep seabed polymetallic nodule mining preprototype collector vehicle." Science Advances 8, no. 38 (2022): eabn1219.

84 Gillard, Benjamin, Rob P. Harbour, Nicolas Nowald, Laurenz Thomsen, and Morten H. Iversen. "Vertical distribution of particulate matter in the Clarion Clipperton Zone (German sector)—potential impacts from deep-sea mining discharge in the water column." Frontiers in Marine Science 9 (2022): 820947.

85 Aleynik, Dmitry, Mark E. Inall, Andrew Dale, and Annemiek Vink. "Impact of remotely generated eddies on plume dispersion at abyssal mining sites in the Pacific." Scientific Reports 7, no. 1 (2017): 16959.

86 Simon-Lledó, Erik, Brian J. Bett, Veerle AI Huvenne, Kevin Köser, Timm Schoening, Jens Greinert, and Daniel OB Jones. "Biological effects 26 years after simulated deep-sea mining." Scientific reports 9, no. 1 (2019): 8040.

87 Muñoz-Royo, Carlos, Raphael Ouillon, Souha El Mousadik, Matthew H. Alford, and Thomas Peacock. "An in situ study of abyssal turbidity-current sediment plumes generated by a deep seabed polymetallic nodule mining preprototype collector vehicle." Science Advances 8, no. 38 (2022): eabn1219.

88 DOSI. Stakeholder feedback form for NORI-D Social Impact Assessment Scoping.

89 Orcutt, Beth N., James A. Bradley, William J. Brazelton, Emily R. Estes, Jacqueline M. Goordial, Julie A. Huber, Rose M. Jones et al. "Impacts of deep sea mining on microbial ecosystem services." Limnology and Oceanography 65, no. 7 (2020): 1489-1510.

90 Atwood, Trisha B., Andrew Witt, Juan Mayorga, Edd Hammill, and Enric Sala. "Global patterns in marine sediment carbon stocks." Frontiers in Marine Science 7 (2020): 165.

91 Molari, Massimiliano, Felix Janssen, Tobias R. Vonnahme, Frank Wenzhöfer, and Antje Boetius. "The contribution of microbial communities in polymetallic nodules to the diversity of the deep-sea microbiome of the Peru Basin (4130–4198 m depth)." Biogeosciences 17, no. 12 (2020): 3203-3222.

92 Sweetman, Andrew K., Craig R. Smith, Christine N. Shulse, Brianne Maillot, Markus Lindh, Matthew J. Church, Kirstin S. Meyer, Dick van Oevelen, Tanja Stratmann, and Andrew J. Gooday. "Key role of bacteria in the short-term cycling of carbon at the abyssal seafloor in a low particulate organic carbon flux region of the eastern Pacific Ocean." Limnology and Oceanography 64, no. 2 (2019): 694-713.

93 Stratmann, Tanja, Karline Soetaert, Daniel Kersken, and Dick van Oevelen. "Polymetallic nodules are essential for food-web integrity of a prospec tive deep-seabed mining area in Pacific abyssal plains." Scientific Reports 11, no. 1 (2021): 12238.

94 Chin, A., and Hari, K. Predicting the impacts of mining deep sea polymetallic nodules in the Pacific Ocean: A review of Scientific literature. Deep Sea Mining Campaign and MiningWatch Canada, 2020. Accessed Aug 23, 2023.

ABOUT PLANET TRACKER

Planet Tracker is an award-winning non-profit think tank focused on sustainable finance with the purpose of ensuring that capital markets' investment and lending decisions are aligned with planetary boundaries and support a just transition. Its mission is to create transformation of global financial activities by 2030 that create real world change in our means of production that align with a resilient, just, net-zero and nature-positive economy.

ABOUT THE DEEP SIX PROJECT

This report is the second in a series of six (the 'Deep Six Project'), focused on deep sea mining. The first report, 'The Sky High cost of Deep Sea Mining' can be found here. The goals of the Deep Six project are to 1) assess the potential environmental impact of deep-sea mining, including in relation to equivalent land-based mining and 2) for investors to apply six different learnings from the risks and opportunities of deep sea mining to other industries that impact marine ecosystems, focusing on: climate change vs. nature considerations, resource-based valuations vs. natural capital value, restoration potential, circularity, sovereign risk and stranded assets risk.

ACKNOWLEDGEMENTS

Authors: Emma Amadi, François Mosnier

Researchers: Emma Amadi, François Mosnier, Chris Baldock, Filippo Grassi

Editor: Dominic Lyle

WITH THANKS TO OUR FUNDER

Flotilla FOUNDATION

Suggested citation: Emma Amadi, François Mosnier. The Climate Myth of Deep Sea Mining. Planet Tracker (2023).

For further information please contact:
Nicole Kozlowski, Head of Engagement, Planet Tracker
nicole@planet-tracker.org

Planet Tracker

www.planet-tracker.org #planet_tracker