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To engage in deep-sea mining or not to engage: what do full net cost analyses tell us?

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If the full net cost of deep-seabed mining (DSM) is determined for different entities with a stake in DSM (e.g., countries, private companies, the public), would such analysis support DSM or not? We surveyed existing literature to lay the foundation for addressing this question. Although further work is needed before a conclusive determination can be made, preliminary findings suggest that DSM is unlikely to be appealing to most of the entities covered by this study if the full net cost of DSM is comprehensively considered.

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INTRODUCTION

Deep-sea mining (DSM)—the extraction of minerals from the deep seafloor, currently focused intensively on the abyssal plains of the Pacific Ocean—has attracted the attention of mining companies, investors, non-governmental organizations (NGOs), governments, scientists, and the public at large, for good reason[1]. The International Seabed Authority (ISA), an intergovernmental organization established under Article 156 of the United Nations Convention on the Law of the Sea (UNCLOS), is the primary body regulating the exploration and exploitation of minerals found on the international seafloor, termed the Area. These minerals are the common heritage of humankind under UNCLOS, and ISA is entrusted to ensure that mining activities are to be carried out for the benefit of humankind as a whole[2]. As a global platform for states to organize and control activities in the international seabed, ISA's role in resolving DSM-related issues is very important.

Advocates of DSM argue that the latter is necessary to provide the metals needed for electric vehicle batteries and other electronic infrastructure for a carbon-neutral economy [https://www.savethehighseas.org/wp-content/uploads/2021/07/DSCC_FactSheet9_DSM_Alternatives_4pp_14July_web.pdf]. Conversely, opponents of DSM point to evidence that it will impose irreparable damage to the delicate habitats that constitute the deep seafloor[3]. For instance, a single mining operation could release into the ocean up to 80 km^3 of sediment plume every day, spreading to an area of up to 24,000 km^2 in the Clarion-Clipperton Zone [https://www.bbc.com/future/article/20230310-what-does-the-high-seas-treaty-]. This plume is capable of reducing light penetration and water oxygenation while at the same time dispersing toxins and radioactivity[4].

At the same time, several authors have advanced arguments against the use of decarbonization as an excuse for pushing for DSM[5]. Emerging technologies and resource efficiency processes (such as battery storage innovation), circular economy processes (that extend the useful life of products), responsible mining via impact assessments and screening of companies, projects, and products (through certification schemes), and the substitution of critical materials with uncritical ones (through the European Innovation Partnership on Raw Materials), can help reduce the need for cobalt, nickel, and copper—and thus decrease or even eliminate the need for DSM. In fact, it is estimated that the demand for critical minerals may be reduced by 58% through new technology and circular economy models [https://wwf.panda.org/wwf_news/?3059466%2FWWF-statement-on-move-to-fast-track-deep-seabed-mining].

Here, we explore and set the stage for a full net cost analysis of DSM in the Area for key interested entities, as doing so allows us to explore the economics of DSM more comprehensively. We pose a key question: If the full net cost of DSM is determined for different entities who have a stake in DSM, would such analysis support DSM or not? We surveyed existing literature to lay the foundation for addressing this question and discuss findings for a number of key entities. The latter include private mining companies (e.g., The Metals Company—TMC [https://metals.co/]), investors in such companies, lower-income countries that are expected to benefit from DSM, countries currently sponsoring DSM (e.g., Nauru), countries engaged in terrestrial mining for similar metals (e.g., South Africa) and therefore potentially competing with DSM-sourced minerals, and nature and humanity in general.

PRIVATE MINING COMPANIES

Companies such as TMC, with sponsorship from states like Nauru, plan to engage in DSM to maximize profits for their shareholders. Through such sponsorship, TMC, for example, has gained access to 'reserved area' sites (i.e., sites that have already previously been prospected and known to have substantial commercial value) designated for low-income countries. This is a significant advantage as operators in reserved area sites are spared a lot of time and expenses in search of lucrative mining sites. Still, one can ask the question, how profitable are these private mining companies likely to be? A few studies have attempted to address

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this question. The cost-benefit analysis model of Cardno et al.[6] suggests that DSM might be profitable in the case of mining Seafloor Massive Sulfides (SMS) deposits at hydrothermal vents and polymetallic nodules on abyssal plains. The total estimated capital and operational cost the mining company would spend is between US$4–6 billion. In turn, the estimated revenues are between US $9–11 billion over 30 years from the commencement of the exploitation contract[7]. According to a study by the Massachusetts Institute of Technology (MIT), annual operational costs for mining and refining polymetallic nodules are approximately US$1.1 billion, while annual revenue is approximately US$2.3 billion (which would result in a profit of about US$1.2 billion) [https://www.isa.org.jm/document/algeria-obo-african-group]. However, while the current high demand for metals would, in the first few years, likely make them reap huge revenues, after some time market constraints due to surplus availability of the metals and the expected decrease in prices will generate only modest short-term profits. Furthermore, these mining operations are also expected to face technological failures, unexpected expenditures, environmental hiccups, and litigation. Efforts to understand the profitability of DSM continue, suggesting we will eventually learn more. For instance, in June 2023, the U.S. House of Representatives Armed Services Committee directed the Pentagon to investigate approaches to mining and process seabed nodules to compete with China for vital minerals [https://www.mining.com/pentagon-ordered-to-probe-undersea-mining-to-counter-china/].

INVESTORS IN DSM COMPANIES

Working on the ocean floor is challenging but investors may believe that the payoff from mining the deep sea would be substantial due to the large mineral resources believed to be found in the deep sea. However, an important issue for investors to be aware of is the high level of risk exposure that private equity investors in DSM companies represent for their executives, boards, and shareholders [https://www.blueclimateinitiative.org/sites/default/files/2023-10/whitepaper.pdf], as they are likely to face both litigation and business model risks. As the experience with the surge in climate change and biodiversity cases indicates, DSM litigation is foreseeable. Aggrieved countries, communities, and other stakeholders impacted by DSM—for instance, whose natural resources or ways of life are disrupted—can take the ISA, mining companies, and other parties they deem liable to international, regional, and national courts (depending on the jurisdiction they establish under applicable laws) [https://www.isa.org.jm/wp-content/uploads/2022/06/impactstudy.pdf]. Business model risks arise from changes to technologies and social systems[8]. For instance, new battery technologies not requiring metals targeted by DSM, such as cobalt and nickel, are quickly coming to market and replacing today's conventional lithium nickel cobalt-based batteries [https://ejfoundation.org/news-media/environmentalists-warn-investors-of-deep-sea-mining-risk]. An important example is the lithium ferro-phosphate (LFP) batteries[9] used by Tesla and BYD, the two largest electric vehicle manufacturers. Approximately 90% of BYD's domestic market cars use LFP batteries, which do not have any dependency on metals found in the deep sea. The same applies to Tesla, as in 2022, 50% of its new cars did not use metals targeted by DSM[9].

LOW-INCOME COUNTRIES

A coalition of African countries (the African Group)[8] participating in the current deliberations of ISA regulations for future exploitation activities have developed immense interest in DSM for the potential profits that can be captured from the DSM mining companies in the form of royalties and taxes. These countries are very much focused on the quick operationalization of ISA's mining arm (the Enterprise) and the Economic Planning Commission, in order to receive updates on key decisions taken by ISA and on the supply and demand of DSM-sourced metals. A pertinent question here is, how profitable is DSM likely to be, and how much would be available for distribution to low-income countries? According to studies by the African Group and MIT, potential profits to be distributed to low-income countries are likely to be very little[10]. More specifically, a recent African analysis[11], estimates that each member of ISA—excluding the European Union—is anticipated to receive a total net present value (NPV) of only US$2.93 million over a 30-year period of DSM, which corresponds to an average value of approximately US $97,800 per year. Moreover, the MIT model estimates that, at full production, a single polymetallic mine in operation might generate US$55 million in ISA income under a 2% royalty and US$165 million under a 6% royalty[10]. However, the proportion of this amount that will be available for sharing, and the payment mechanisms through which it is to reach low-income countries are yet to be laid out. A centralized fund designated 'the common heritage fund' has been suggested as an alternative to the direct distribution of monetary benefits among member states. Rather than distributing the funds equally to member states, such fund is intended to promote more executive projects for maintaining sustainability and inherent values for future generations.

COUNTRIES/STATES SPONSORING DSM IN THE AREA

These countries are attracted to DSM mining because of its perceived potential to generate economic benefits, including tax revenues, foreign exchange earnings, and jobs. Currently, there is a total of 21 sponsoring states with exploration contracts, six of which jointly sponsor one Congestion Charge Zone (CCZ) contract [https://www.isa.org.jm/]. Recent studies[12,13] show that these countries are likely to sign contracts with mining companies to conduct mining operations. However, what is the potential that these anticipated benefits will actually materialize? Based on an MIT study, the African Group estimates[10] that the expected profits to these sponsoring member states (which would likely flow in terms of corporate tax payment of 25%) is a maximum of US$3 billion over the same 30-year contracting period, again delivering 'pittance' to the African Group countries. Additionally, country policies to incentivize investment may reduce potential public revenues further. Conversely, a decision to sponsor DSM activities in the Area will expose sponsoring states to significant risks (including reputational). Such risks could result in potential liability under international law[14].

COUNTRIES ENGAGED IN TERRESTRIAL MINING AND THUS POTENTIALLY COMPETING WITH DSM-SOURCED MINERALS

Terrestrial-based mining countries, such as South Africa or Chile, have a broader but somewhat conflicting interest in DSM. Given their long years of terrestrial mining experience[15,16], these countries could directly engage in DSM through state-owned corporations or their private companies (even if DSM faces circumstances different from those of terrestrial mining). Leveraging their experience, they could share in the profits of DSM mining companies through royalties and taxes. However, if DSM companies start operating, terrestrial ones would have to compete to capture market share. The basic demand-supply dynamics[17] imply that market prices for minerals extracted from land would likely decrease due to the expected increase in market supply from DSM. Ultimately, such anticipated price drops would result in reduced profits for land-based mining. In order to counterbalance the adverse effect of DSM on the economy of these countries, a compensation mechanism will have to be developed by ISA as a part of its obligation to the global community [https://isa.org.jm/files/files/documents/1-algeriaoboag_finmodel.pdf]. Laptera et al.[18] identified a number of countries, of which a majority are

African, that would be particularly affected by DSM in the Area. The compensation mechanism required under UNCLOS—yet to be developed—the ISA may have to charge contractors a specific amount based on the expected percentage drop in the metal prices as a result of an increase in supply from DSM.

NET COST TO NATURE AND HUMANITY GENERALLY

Irreversible damage is almost certainly imposed on the delicate habitats and life in the deep sea. Some of the world's most important fisheries will increasingly overlap with deep-sea mining operations as, for example, tuna's range shifts due to warming waters[19]. From the delicate habitats on the seafloor to the sensitive, long-lived, slow-growing organisms in the deep sea[20], potential damages to be caused could be permanent and irreparable. The cost of managing such damages is likely to be astronomical. For instance, it is estimated that US$5.3–5.7 million would have to be spent per km^2 to replace the polymetallic nodules with artificial clay nodules in an attempt to restore the biota lost, with no guarantee of success, and it is estimated that the cost of restoring 30% of DSM concessions in international waters would likely far exceed the entire global defense budget [https://planet-tracker.org/report/the-sky-high-cost-of-deep-sea-mining/]. Therefore, the cost and time required to truly repair deep-sea habitats and marine life may legally and/or economically may justify a ban on DSM, Moreover, if these expenses are included in the operational costs of DSM, the result is likely to be a significant reduction in profitability. Given these potential implications of DSM, public stakeholders are increasingly pushing against it and prioritizing nature over profit[21,22]. The moratorium movement on DSM is already growing with the support of more than 20 states, the International Union for Conservation of Nature, European Union institutions and bodies, NGOs, financial groups, civil society activists, and business leaders [https://seas-at-risk.org/general-news/deep-sea-mining-moratorium-takes-centre-stage-at-international-seabed-authority-meetings/].

CONCLUDING REMARKS

Minerals of the international seafloor are humanity's shared heritage. A crucial aspect of the mining argument is, thus, 'Who stands to benefit?' At the same time, discussions around leaving these minerals —and dependent ecosystems and their services—for future generations are ongoing. Therefore, the pros and cons of DSM will continue to be debated. Our contribution intends to put this debate into perspective. We find that while DSM may generate short-term profits for private mining companies, prospects for long-term benefits are minimal for multiple reasons, including business model and litigation risks, public opposition, and competition from land-based mining. At best, there will be limited profits to private companies most likely in the short-term only, some of which may marginally benefit low-income countries under ISA, if at all, and countries sponsoring DSM in the Area. However, this would come with dire, irreparable loss to humanity and nature, making it difficult to justify.

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U.R.S. contributed to conceptualization, writing, and supervision; R.F. contributed to conceptualization and writing; A.L. and P.K. worked on information curation, editing, and formatting. T.T.O., S.T.K., S.P., and L.A.L. contributed to writing and revising the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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