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Enhancing QUAD Cooperation for Sustainable and Equitable Utilisation of Marine Mineral Resources

November 2022

About this Publication

This publication has been developed by a group of researchers and experts from Keio University's India-Japan Laboratory, National Maritime Foundation (NMF), the Resilience Innovation Knowledge Academy (RIKA), and RIKA Institute. The views and opinions expressed in this book are those of the authors and do not necessarily represent the official policy of the organisations or their governments.

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Preface

The Quadrilateral Security Dialogue (QUAD), comprising Australia, India, Japan, and the United States, is becoming increasingly important in the current geopolitical context. While the economic, defence and political dimensions are well researched within the QUAD cooperation framework, collaboration on resource utilisation is not found to be a popular research subject. This study is, possibly, one of the first attempts to understand the potential and identify the challenges of utilisation of marine mineral resources. The Indo-Pacific oceans have abundant living and non-living resources. While the marine biodiversity of the region is quite rich in terms of different flora and fauna, mineral resources, too, are plentiful in the region.

The Paris Agreement on Climate Change, and the post-Paris commitments made by several countries have, in aggregate, posted ambitious targets to reduce their greenhouse gases. However, the ubiquitous 'green growth' strategy, and the growing preference for renewable energy, have generated a pressing need for rare earths and specific metals such as cobalt, cadmium, and lithium. The rapid surge in demand for critical minerals has posed a new global challenge driven by the global quest for energy-security. Recently, the QUAD member-States agreed to cooperate in funding new production technologies and establishing a global supply chain in respect of critical minerals.

Keeping this urgent need of rare metal in mind, this report analyses non-living marine resources in the Indo-Pacific and explores the manner in which the QUAD framework could be operationalised beyond the limiting-scope of hard security alone, and encompassing a number of areas mutually identified by the four countries.

We hope that the report provides an insightful analysis of marine mineral resources and the importance of the QUAD partnership, and that it will be useful for further research into this important topic.

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INTRODUCTION

1. Introduction

1.1 History and Evolution of the Indo-Pacific Concept and the QUAD Framework

The geo-strategic centrality of the ‘Indo-Pacific’ is crucial for attaining a country’s economic goals, not merely for Asia, but internationally. The earliest mention of the Indo-Pacific was made by the erstwhile Japanese Prime Minister Shinzo Abe in his address to the Indian parliament in August 2007, referring to it as the “*Confluence of the Two States*”, with the Indian Ocean and the Pacific Ocean converging “as seas of freedom and prosperity*”* (Abe 2007). It also includes the “contiguous seas off East Asia and Southeast Asia” to form the Indo-Pacific regional construct (Khurana, 2017). He emphasised manifesting a broader ‘Indo-Pacific’ by strengthening multipolarity and making the global shift from the Asia-Pacific to the Indo-Pacific, thereby accommodating the global economy and international trade. The many rounds of bilateral and multilateral meetings among the partner states laid the ground for establishing the Quadrilateral Security Dialogue (QUAD), which aims to work cooperatively on development-related activities and to secure the concept of the common good and security.

Japan was one of the early countries to adopt the idea of the Indo-Pacific in its official foreign policy document and shared the vision for a “Free and Open Indo-Pacific” to ensure stability and prosperity in this region, along with open and secure trade sea lines of communication (Ministry of Foreign Affairs of Japan, 2017). The United States (US) then subsequently included the concept in its National Security Strategy 2017, National Defense Strategy 2018, Indo-Pacific Strategy Report 2019, and Indo-Pacific Strategy of the United States 2022 (Trump, 2017; Mattis, 2018; The Department of Defense, 2019; The White House 2022). The shifting focus of the US from the ‘Asia-Pacific’ towards the Indo-Pacific paved the way for a robust foreign and security policy in the Indo-Pacific aimed at tackling the assertiveness of a growing China. Furthermore, the US glance at the Indo-Pacific scaled from “Africa, Europe, and the Middle East, along with its Maritime Silk Road (MSR) connectivity initiative” (Pejsova, 2018).

The incumbent Prime Minister of India, Narendra Modi, outlined the Indo-Pacific Policy of India in the Shangri-La Dialogue in 2018, in which he delineated India’s vision for the region (Modi, 2018). He reiterated the importance of maintaining an inclusive, free, and open Indo-Pacific. He stressed the centrality of the Association of Southeast Asian Nations (ASEAN) states towards strengthening connectivity in the region. India has become a key pillar in the proposed security architecture of the Indo-Pacific. It envisages the role of a net provider of security and preferred security partner for its immediate maritime neighbourhood (Agnihotri, 2022). In its 2017 Foreign Policy White Paper, Australia went on to outline its Indo-Pacific partnerships and visions, which indicated the emergence of the Indo-Pacific as the new theatre for strategic competition (Australian Government, 2017).

1.2 Objectives and Scope of the QUAD Framework

The QUAD—comprising Australia, India, Japan, and the United States—is another manifestation of the Indo-Pacific partnership of like-minded democratic countries that emerged first as the ‘Tsunami Core

Group' in response to the 2004 Indian Ocean Tsunami, and set a precedent for countries to work together in a quadrilateral format towards addressing issues in the Indo-Pacific region (Buchan and Rimland, 2020). After multiple rounds of discussion among the member countries, the first meeting of the QUAD was held in May 2007 in Manila, the Philippines. The countries worked closely on security, economy, climate change, and public health (Smith, 2021). The first joint statement by the leaders of the four partner countries emphasised cooperating firstly with "COVID-19 vaccine production, facilitating cooperation over emerging technologies, and mitigating climate change" (Kutty and Basrur, 2021). The second working group was dedicated to concentrating on critical and emerging technologies. For China, the varied sphere of interests of the QUAD grouping has been seen as an affirmation of them being a primarily anti-China bloc. The attempts by the QUAD countries to address China's territorial and economic pursuits in "South Asia, the South China Sea, and the East China Sea" have further been read by China as attacks on her territorial claims (ibid).

The identified areas, nonetheless, can be handled by establishing focused working groups. For example, the third area of cooperation concentrating on climate change was the QUAD climate working group, which intended to work cooperatively with China as a significant player for the global good. This cooperative role of the QUAD intends to shed its image as merely a global strategy for containing China and instead project it as an inclusive forum for addressing the regional traditional and non-traditional security concerns.

The leaders of the QUAD countries participated in the first QUAD Leaders' Virtual Summit on 12 March 2021, where they deliberated on common regional and international issues pertaining to "maintaining a free, open and inclusive Indo-Pacific region" and meeting the "contemporary challenges such as resilient supply chains, emerging and critical technologies, maritime security, and climate change" (Ministry of External Affairs, 2021). The joint statement also mentioned their re-commitment "to promoting the free, open, rules-based order, rooted in international law and undaunted by coercion, to bolster security and prosperity in the Indo-Pacific and beyond" (ibid). Concerning the traditional security domain, the summit's efforts led to collaborative defence exercises such as the *MALABAR* naval exercises and further consolidated the strategic partnerships among the four countries. Subsequently, the respective Trade Ministers of Australia, India, and Japan came together virtually to launch the Supply Chain Resilience Initiative (SCRI) on 27 April 2021. This initiative intended to secure the global supply-chain system by addressing the vulnerabilities that plague them, utilising digital technology, and diversifying investment and trade practices. It aimed to steer the investments away from the over-dependence on Chinese natural resources, including rare earth materials, and to ensure inclusive and balanced growth for the region (Krishnan, 2021).

The leaders of the QUAD states met for the first in-person summit on 24 September 2021 in Washington, United States, to chart out the future course of the grouping. They had agreed to iron out the goal-posts for the mutually identified joint initiatives in the Indo-Pacific that included, among others, the COVID-19 vaccine partnership, "climate change, decarbonisation efforts in shipping and port operations, deployment of clean hydrogen technology, the need for responsible and resilient clean energy supply chains" (Ministry of External Affairs, 2021). This vision was encapsulated in the QUAD Leaders' Joint Statement, which mentioned the QUAD Infrastructure Coordination Group that was formed to discuss regional infrastructure needs assessments and to coordinate approaches, technical support, and capacity-building efforts. The leaders also established a working group on space cooperation that sought to facilitate the (Ministry of External Affairs, 2021) sharing of satellite data for climate change monitoring and adaptation, disaster planning, and responding to issues in mutually identified areas.

The second in-person QUAD Leaders' Summit on 24 May 2022 in Tokyo, Japan, saw the formation of the Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA), the QUAD Satellite Data Portal, the QUAD Debt Management Resource Portal, the QUAD Climate Change Adaptation and Mitigation Package (Q-CHAMP), and other such mechanisms to further the workings of critical areas of cooperation (Ministry of External Affairs, 2022). Efforts like the IPMDA cover within their scope the means to counter IUU (Illegal, Unreported, and Unregulated) fishing. Particular stress was laid on augmenting the vaccination efforts of the grouping. In the context of emerging technologies, the four countries agreed to collaborate on the development and diversification of 5G telecommunications, as well as the establishment of supply chains for vital minerals and semiconductor manufacturing technology—another area in which China is a leader.

1.3 Brief Description of the Sections of the Paper

In the Indo-Pacific region, around two-thirds of the ocean lies in Areas Beyond National Jurisdiction (ABNJs), home to unique species and habitats critical to marine biodiversity. The biodiversity in ABNJ is in peril due to a patchwork of legislative frameworks. The loss of biodiversity in ABNJ impacts the ocean's ability to withstand climate change and offer resources vital for human life. It is hence essential to negotiate a secure mechanism to protect and further ABNJ governance and safeguard the marine environment and species while analysing the impacts of human activities, creating capacity, transferring technology, and sharing the benefits of marine genetic resources equitably (IUCN, 2022).

The current paper comprises five sections. The first section analyses the non-living marine resources in the Indo-Pacific region and how the QUAD framework could be operationalised beyond the realm of security. The second section studies the region's global reserve of resources and supply chains. The third section looks into the challenges in the sustainable and equitable utilisation of marine resources through seabed mining in ABNJ. The fourth section explores the opportunities for the institutionalisation and operationalisation of the QUAD framework in the areas mutually identified by the four countries. The final section encompasses the conclusion of the paper.

Marine Non-living Resources in the Indo-Pacific

2. Marine Non-living Resources in the Indo-Pacific

2.1 How can the QUAD Framework be Operationalised Beyond Traditional Security?

The deep seabed is one of the most unexplored regions on this planet. A common saying is that we know far less about the oceans and seabed than the moon. The deep ocean hosts a large number of species and is the largest habitat on Earth (FAO Fisheries & Aquaculture, 2021). The seafloor comprises plateaus, canyons, volcanic peaks, abyssal plains, and mountain ranges, just like the territorial floor. Some portions of the seabed, just like the terrestrial environment, are rich in different types of mineral resources such as polymetallic nodules, cobalt, and ferromanganese-rich crusts, rare earth elements, calcareous and siliceous oozes, and various liquid and gaseous substances such as carbon dioxide, nitrogen, helium, and other petroleum products (Lodge, 2017).

The availability of these minerals on the seabed allows humankind to explore and exploit these large reserves. The vast potential that these mineral resources hold can be significant to the industrial economies of many countries worldwide. Many of the world's valuable assets are found in the deep seas, at a depth of 5000-6000 metres. The oceans will soon be the "New Frontiers" of the mining industry due to the enormous potential of mineral deposits.

For the financial and commercial advantages of deep seabed minerals, international organisations—particularly the UN—stepped forward and established deep-sea mining, extraction, and exploitation regulations. Developing nations have begun to doubt that the technical prowess of rich nations would give the latter an advantage in extracting the majority of ocean resources, eventually manifesting as a potential 'Ocean Struggle'. Resolution 2340 (XXII)—which acknowledged "the common interest of mankind in the seabed and the ocean floor, which form the majority of the area of this planet" —was unanimously adopted by the General Assembly on 18 December 1967. The UNGA (United Nations General Assembly) said the following in the resolution:

> "The exploration and use of the seabed and the ocean floor, and the subsoil thereof should be conducted as per the purposes and principles of the Charter of the United Nations, in the interest of maintaining international peace and security and for the benefit of all mankind" (Shen, 2017).

The draft of the rules for ocean mining was established after many rounds of discussions, consultations, and agreements between the various governments. The UNCLOS (United Nations Convention on the Law of the Sea) draft was eventually approved after many rounds. As a result, the International Seabed Authority (ISA), which serves as the primary governing authority for deep seabed mining operations, was established in accordance with UNCLOS Article 153. The ISA's responsibility is to oversee deep seafloor mining operations. All nations that have signed the UNCLOS convention are also ISA members.

The mineral wealth in the ocean can potentially boost the economy of various countries. Therefore, a lot of countries are looking forward to the development of techniques that would help in the mapping and exploitation of these unexplored reserves. The mineral resources in the seabed like manganese, copper, nickel, cobalt, and rare earth elements have a huge potential that can boost a country's technical and manufacturing industry. The mineral resources exploration and exploitation with the technical exchange in the deep seabed mining industry are where the countries can collaborate towards developing a resilient mineral resource supply chain in the region.

Cobalt, nickel, manganese, and rare earth elements (REEs) are the seabed's most essential and strategic mineral resources. Cobalt is used extensively in manufacturing fast-charging rechargeable batteries, alloys, super alloys, catalysts, etc., used in turbines, aircraft engines, e-vehicles, etc. Nickel is widely used in stainless steel, rechargeable batteries, AlNiCo magnets, and alloys. Manganese is primarily used with other metals to make various alloys and in dry-cell batteries.

The most important of these mineral resources are the rare earth elements (REEs) which are considered the secret ingredients for powering our future world. Starting from devices as common as a smartphone or headphones to strategic weapons like guided missiles, REEs are the backbone of today's hi-tech world. However, REEs are 'rare' because of their staggering global distribution. These elements are not present in the deposits in big mines like the other precious elements. Instead, they are spread across the planet, but the problem is associated with these elements' extraction, isolation, and refining. Therefore, despite their abundance across the globe, REEs are 'rare' due to the limited capacities of countries in refining these minerals.

2.2 Importance of non-living seabed resources

A. *Applications in the renewable energy sector*

The mineral resources are intensively used in the production of renewable energy equipment such as wind turbines, solar panels, fuel cells, and batteries used in electric vehicles. In addition, new-generation vehicles such as hybrids, fuel-cell vehicles, plug-in hybrids, and battery-electric vehicles require these critical minerals in their manufacturing. With the increasing shift towards low-carbon energy from fossil fuel-based energy, the demand for specific mineral resources which are used in the supply chain is set to increase in the future. There is a possibility that the terrestrial resources will not be enough to fulfil the growing needs, and there would be a possible shift toward marine resources.

Lithium-ion batteries are considered the backbone of green energy-based equipment and require the production of cobalt, nickel, manganese, and aluminium. With the increasing demand for lithium-ion batteries, the demand for other related minerals such as cobalt, nickel, and aluminium has also risen. Specific unique properties of cobalt make it essential for renewable energy equipment such as the production of wind turbines, rechargeable batteries, cathodes of lithium-ion batteries, nickel-metal hydride batteries, etc. Around 50% of globally produced cobalt is used to make rechargeable batteries in many devices and electric vehicles. Nickel is used in producing nickel-based batteries and is also intensively used in manufacturing lithium-ion batteries. Manganese, one of the most abundant seabed minerals, is also used in manufacturing lithium-ion batteries.

REEs are critical hardware used in the production of renewable energy. The magnets of REEs—such as dysprosium and neodymium—are used in offshore and onshore wind turbines (Rollet, 2019). The magnets produced by these mineral resources are also used in the equipment of other renewable energy sectors like wave energy and tidal energy (Stegen, 2014). Wind turbines that drive permanent magnets are highly efficient at low wind speeds and are comparatively cheaper and lighter to maintain. The production of solar panels also requires terbium, praseodymium, neodymium, and dysprosium. In the production of fuel-cells, yttrium is used along with other metals such as platinum and palladium (Chakarvarty, 2018).

B. Applications in electronic equipment

Mineral resources form a crucial raw material for electronic and allied industries and act as the backbone of modern society. They are used in producing LEDs, televisions, batteries, home appliances, communication devices, computers, etc. For example, cobalt is widely used in lithium-ion and cobalt-lithium-manganese-nickel oxide batteries which are the most crucial part of modern-day electronics. Apart from this, cobalt is used in power tools, flashlights, and parts of wireless mobile phones. Furthermore, nickel is used in wires in electronics, electrodes, capacitors, and batteries due to its very high conductivity in its pure form.

Rare earth elements and their associated compounds are a crucial constituent of modern-day technology, including wireless phones, cutting-edge systems, LEDs, televisions, etc. They are also used in the production of phosphors which are used to produce luminescence in various flat-panel displays used in televisions, smartphones, etc. They also have applications in RGB LED lights. Furthermore, due to their impressive magnetic properties, REEs are used in headphones, speakers, hard disk drives, DVD drives, and automotive assemblies like power steering, power windows, etc. They have other uses in carbon-arc lighting, lasers, sonar systems, microwave equipment, nuclear reactors, lenses, glass, superconductors, etc. (Sharp N., 2019).

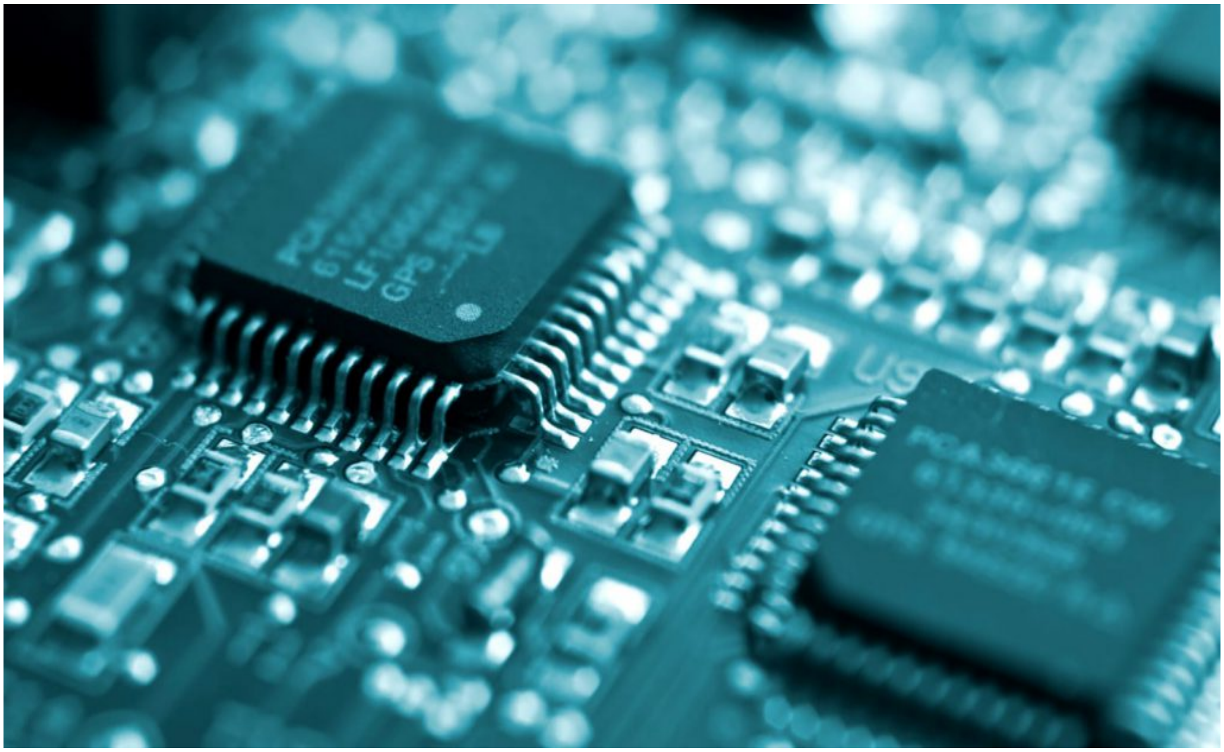
C. Applications in defence equipment

The seabed mineral resources are almost indispensable for electronic, optical, and magnetic applications. The metals are presently irreplaceable from modern devices such as smartphones, electric vehicles, radars, wind turbines, magnets, speakers, aircraft, rechargeable batteries, and so forth. As the world is presently in a transitional phase from traditional sources of energy to renewable ones, the demand for these metals is expected to rise in the coming years.

The mineral resources are also of great significance for the defence industry. Neodymium and samarium magnets are used in guided missile systems, unmanned aerial vehicles, munitions, propulsion systems, and other defence equipment. The magnetic strength of these metals is apt for military technologies such as smart bombs and other weapon systems (Grasso, 2013). REEs produce permanent magnet materials—i.e., samarium cobalt (SmCo) and neodymium iron boron (NdFeB)—which are considered the world's strongest permanent magnets. The magnetic properties of these minerals provide the strength for using lighter and smaller magnets used in defence weapon systems. These magnets retain their power even at higher temperatures and are ideal for military technologies. These minerals are used in the manufacturing and development of much of the defence-related equipment such as lasers for detecting mines, sonar on submarines, satellite communications, missile guidance systems, motors in tanks, aircraft, missile systems, and optical equipment (ibid). The importance of the metals can be assessed by the fact that each F-35 fighter aircraft uses 417 kilograms of REEs in its various equipment, which include electric motors, electronic warfare systems, and radars (Grier, 2017).

Other than rare earth elements, many metals are used in the production of defence-related equipment. For instance, due to its anti-resistant properties, copper is used in the production of military vehicles like naval ships, submarines, and aircraft. Copper and nickel are often mixed and used to make protective body armour. Cobalt is used to create superalloys that are anti-corrosive and heat-resistant in nature. These superalloys are widely used in producing gas turbine aircraft engines, sensors, radars, marine propulsion systems, and other machine tools. Similarly, titanium is used to produce new-age, fuel-efficient, lighter aircraft with increased durability (Magnuson, 2018).

Analysis of Global Reserves and Supply Chains



3. Analysis of Global Reserves and Supply Chains

3.1 Global Reserves of Critical Mineral Resources

Presently, the Democratic Republic of Congo (DRC) holds the largest reserves, is the largest supplier of cobalt—with around 50% of the total global supplies—and dominates the supply chain (Garside, 2022). Australia holds the second-largest cobalt reserves with a share of approximately 20%. Cuba has the third-largest cobalt reserves with a moderate share of around 7%. Finally, the Philippines and Russia hold a relatively small percentage of about 4% of the total global reserves ("Profiling the six largest," 2021).

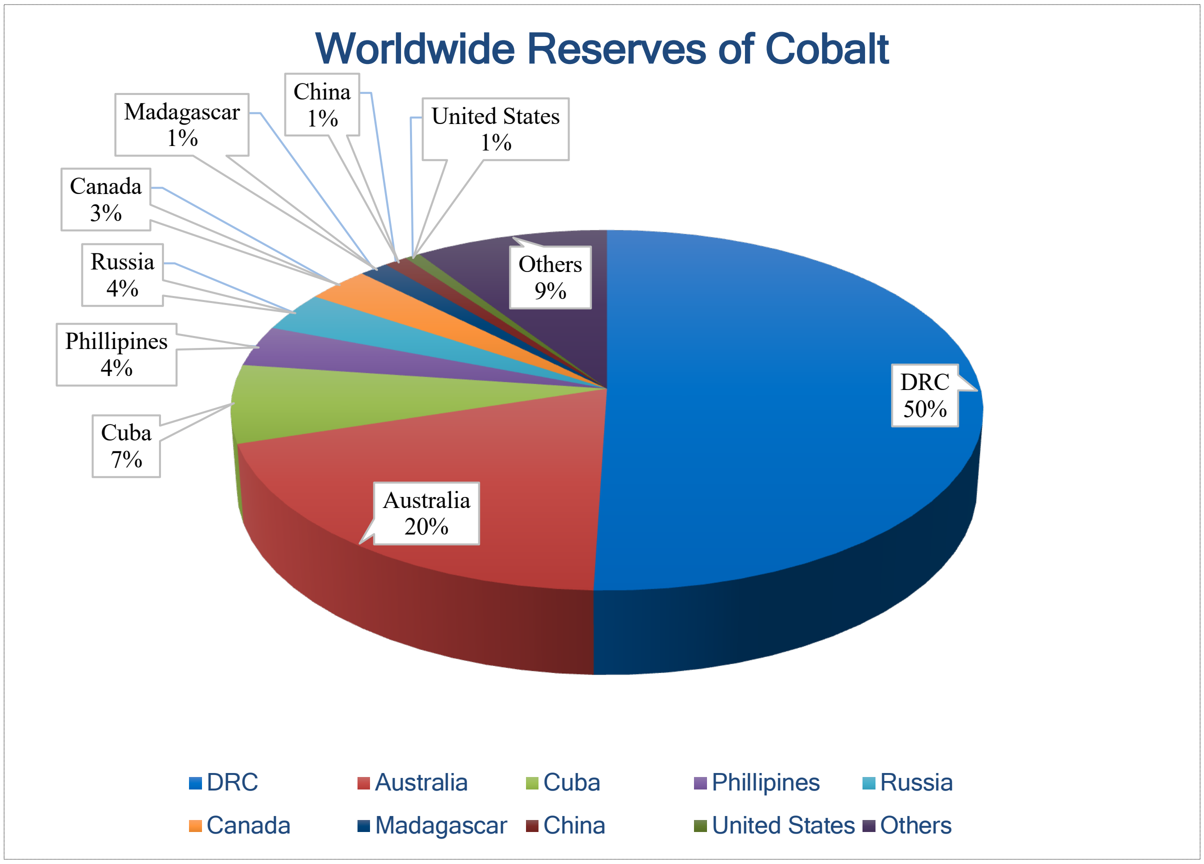


Figure 1: Share of Countries in the Global Cobalt Reserves
Source: https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-cobalt.pdf

As estimated by the US Geological Survey, nickel's estimated global reserves are close to around 94,000,000 metric tons (ibid). Almost half of the nickel reserves are found in Indonesia and Australia, with 23% and 21% worldwide. Other countries with nickel reserves are Canada, Russia, Cuba, and the Philippines, which also hold significant reserves.

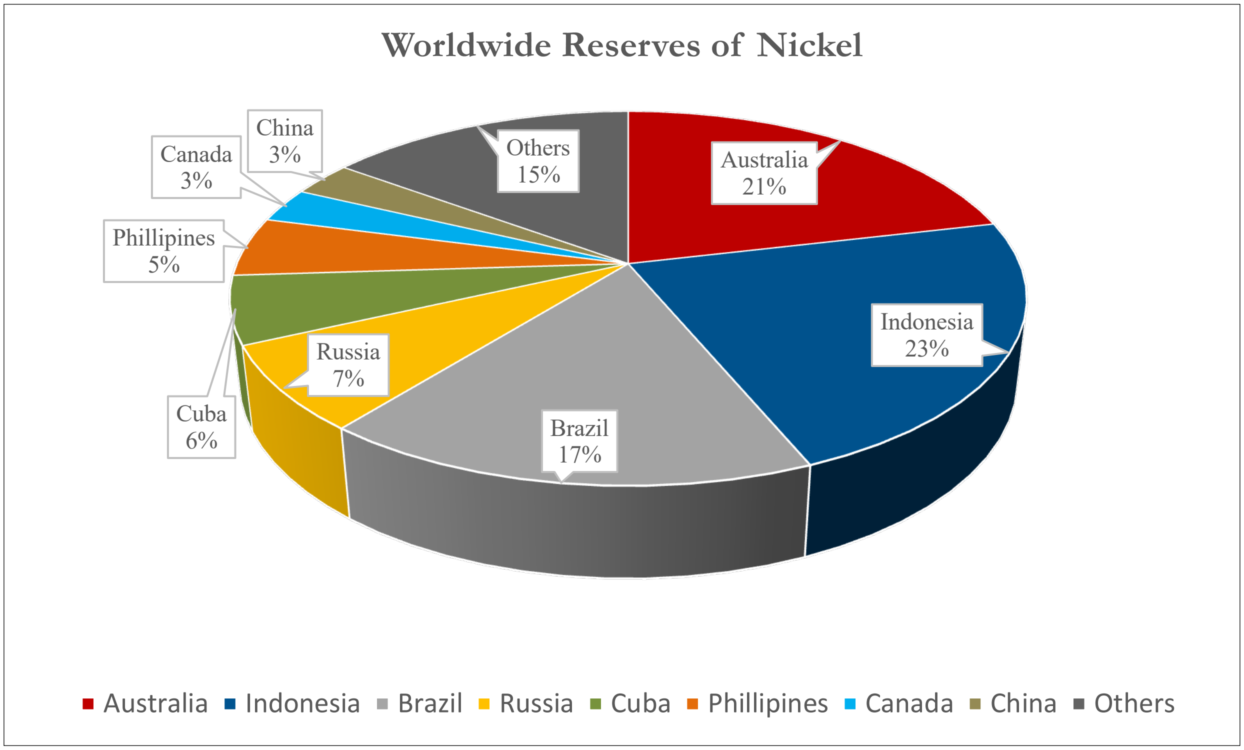


Figure 2: Share of Countries in the Nickel Reserves
Source: https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-nickel.pdf

According to the estimates, the reserves of REEs worldwide are approximately 120 million metric tons. China has the largest reserves of REEs, with 44,000 metric tons, which is around 37% of the total world reserve. Brazil and Vietnam follow China, holding around 18% of the world's share. Russia and India also hold significant reserves with a share of 10% and 6%, respectively. Australia and the United States (US) also hold a decent amount of the reserves with 3% and 1.25%, respectively ("Rare Earths Statistics", USGS).

China sits on over one-third of the reserves and accounts for the largest share of global production. The reserves in China are concentrated in a hnadful of regions. The regions that account for the highest reserves are in the provinces of Inner Mongolia, Jiangxi, Hunan, Guangxi, Fujian, Guangdong, and Sichuan. These areas account for almost 98% of China's total REE production (Tse, 2011).

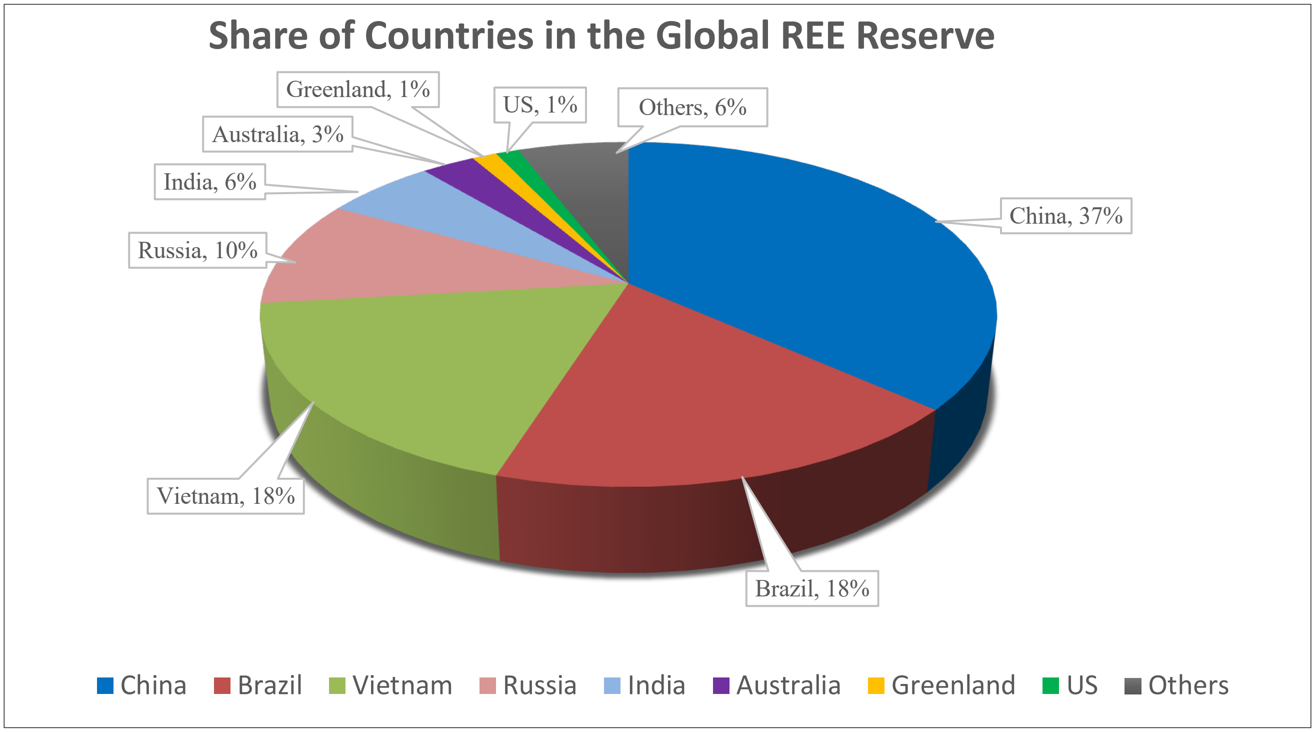


Figure 3: Share of Countries in the Global REEs Reserves
Source: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-rare-earths.pdf

India holds the world's fifth-largest reserve of REEs, with an estimated reserve of around 6.9 million metric tons (ibid). According to the estimates, the domestic supply chain of REEs in the country has the potential to produce an annual turnover of US$ 12 billion. In addition, the REEs industry has the potential to generate net capital employment worth US$ 16 billion (Deka, 2020).

Australia—with the sixth-largest reserve of REEs in the world—has the potential to become a significant player in global supply. These critical mineral reserves are spread on the country's east and west coasts. As of now, the reserves are largely untapped and only two mines are producing the critical minerals (Page and Coyne, 2021).

3.2 Analysis of the Exports and Imports

The production of REEs is not a new phenomenon. The metals have been produced for nearly a century now. However, the production base and the entire supply chain have been shifted from the US to China. In the last century, almost all the production of REEs was done at the Mountain Pass mine in California, US. With the increasing environmental regulations and the gradual shift of mining from developed countries to developing ones, the supply chain has been entirely shifted (Green, 2019).

China entered the market of REEs when the US was dominating it. The successful push by Beijing to become the global leader in the sector led to increased production. China has been dominating the global market of rare-earth for almost two decades now. The Chinese global share in the REE supply peaked at around 97% in 2010. With the availability of the labour market and low environmental protection standards, mining activities became economically viable for China (Mazumdar and Khurana, 2020). Other countries could not compete economically and were eventually pushed out of the global market. China has also developed the capacity in the downstream processes of the rare-earth industry.

The mining and production of crucial metals also played an essential role in the emergence of an electronics manufacturing nation (Schmid, 2019).

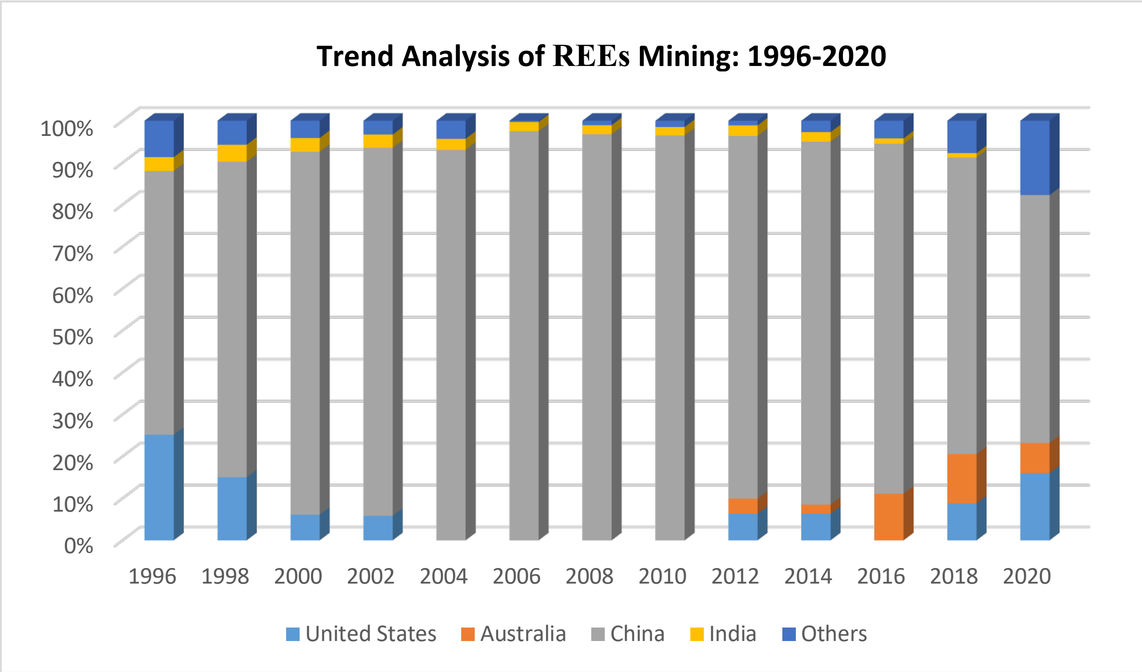


Figure 4: Trend Analysis of REEs Mining: 1996-2020
Source: US Geological Survey

In the present scenario, China is the leading producer of critical minerals and accounts for 60% of global production. India has around 6%, and the US has approximately 1.2% of the global reserve of REEs. Contrary to this, however, is the fact that the US mined 38,000 tonnes of these elements while India mined only 3,000 tonnes. Australia, holding around half the rare elements reserves compared to India, mined around 17,000 tonnes (ibid).

3.3 Vulnerabilities Associated with the Global Supply Chain of Mineral Resources

With the rising demand for rechargeable batteries, the need for cobalt is also expected to rise. Expanding cobalt demand can also cause disruptions in the global supply chain. Cobalt is generally produced as a by-product of copper and nickel mining. The Democratic Republic of Congo (DRC) holds the largest reserves and is the largest supplier of cobalt with around 50% of the total global supplies and dominates the supply chain. The DRC has been a victim of continuous political turmoil and has not yet placed itself as a reliable supplier of cobalt in the world. Poor governance, corruption, and the rule of law in a country are some critical factors in determining a resilient supplier of any commodity. On these grounds, the DRC projects itself as a poor supplier of cobalt in the global market.

The DRC accounts for around 88% of the global production and is the largest exporter of cobalt globally. The constant political instability adds to violent activities and the country has now become a breeding ground for terrorist organisations. Apart from violent activities, the lax environmental laws of the country are adding up to the degradation of natural resources. Australia has the second-largest reserves of cobalt in the world and holds a share of 19% of the world's cobalt. As of 2019, Australia is ranked third in the global production of cobalt and has contributed around 4% to global cobalt production. With its political and economic stability, Australia has great potential in this sector and can become a reliable cobalt supplier. With the increase in demand for cobalt across the world, there are expected to be new investments in the mining industry of cobalt globally.

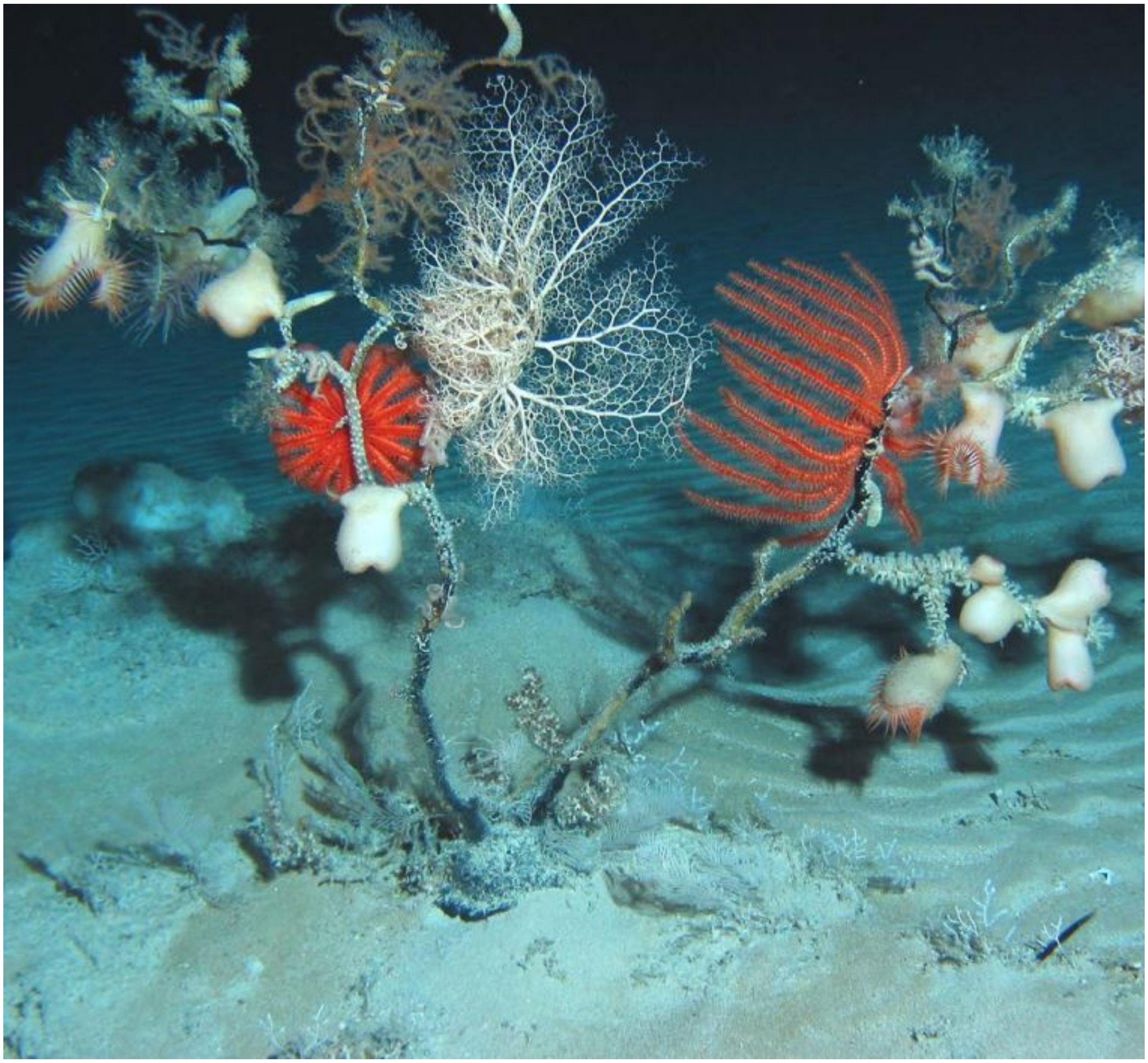
The refining processes of REEs are complicated. Only a few grams of ore are obtained from some tonnes of ore. Also, the techniques used to get these minerals are highly destructive. The process even leads to the generation of radioactive waste. Therefore, countries around the world have moved away from refining these elements. With the vast extent of inhabitable deserts and lax environmental laws, China was placed in a position where it could rule the global supply chain of critical elements. Eventually, the whole world, including the countries possessing the elements, started sending the ores for processing to China. For instance, the US ships the rare earth elements mined in the country to China for downstream processing and later buys the refined elements (Yu and Sevastopulo, 2021). In 1987, Deng Xiaoping, the former Chinese leader, said that while "*the Middle East has oil, China has rare earth*" (Hearty and Alam, 2019). This suggests that China was able to analyse the potential of the critical metals and started working towards increasing its capacity early on.

There came a turning point in the trade flow of REEs, and the Chinese monopoly could be seen at the forefront. In 2010, a Chinese fishing vessel was caught close to the Japan-administered Senkaku islands over which China claims its sovereignty. The commander of the Japanese vessel arrested the captain of the Chinese fishing boat, and, in retaliation, China stopped the supply of REEs to Japan. With the trade disruption, the price of these critical metals surged by nine times. China used its capacity as a deterrent against other countries to fulfil its strategic objectives (Wagner, 2019). It was only after this period that countries such as Australia entered the market of critical minerals.

In 2019, REEs became a key factor in the trade war between China and the US. The US fulfils 80% of its critical metal requirements from China. Seizing an advantage out of this particular vulnerability of the US, China imposed a 25% tariff on the export of REEs. The REEs' mining share in the US and Australia started increasing after this event, while the Chinese share in the global supply chain has continuously decreased. China has a hegemony in the supply chain of REEs, and due to this factor, China possesses the power to disrupt the supply chain of critical minerals worldwide.

The idea that deep-sea mining will aid in meeting the rising demand for metals like cobalt, nickel, and REEs—which are crucial for the transition to renewable energy and other green technology—is a potential benefit that is presently being debated on various international platforms. The demand for critical minerals is only going to rise in the future. The economics of the operations can partially explain whether the minerals will be extracted from the land or the deep sea. Deep-sea mining cost estimates require a variety of calculations and assumptions. Since deep-sea excavation requires different technology and procedures than land-based operations, terrestrial mining can only offer a limited amount of guidance. The expenses related to filing an exploration and exploitation contract with the International Seabed Authority (ISA) include creating Environmental Impact Assessments, consulting with lawyers and engineers, and acquiring an Economic Feasibility Assessment. To evaluate the operations' environmental impact, a thorough understanding of the ecosystems that may be impacted is necessary. Deep-sea mining is a new marine activity that—in contrast with current ocean uses—enables the precautionary approach to be incorporated into the regulatory framework before the start of commercial operations (Cuvyers et al., 2018).

Challenges for Sustainable and Equitable Utilisation of Marine Resources



4. Challenges for Sustainable and Equitable Utilisation of Marine Resources

4.1 Environmental Impacts of Seabed Mining

In the backdrop of increasing demand for marine resources (as underlined in the previous section), there has been a rapid increase in seabed mining and associated exploration activities. However, depending on these activities' nature, magnitude, location, intensity, etc., marine biodiversity is projected to be seriously impacted (Van Dover et al., 2017). For a long time, little thought has been given to the environmental consequences of commercially exploiting marine resources. To bridge this research gap, an overview of four critical environmental effects of seabed mining is provided in the following four subsections.

4.1.1. Effects of Minerals Extraction

Dredging systems are very commonly used in seabed mining activities today. There are several different ways of dredging for different types of resources, including simple suction, rotating cutter, and bucket dredges—which drag a bucket down the sea floor to extract valuable materials from the bottom of the sea (Niner et al., 2018). When the dredged material is placed in an onboard hopper in maritime mining, any remaining water and tailings are typically thrown back into the environment. Levin et al. (2016) point out that such mining activities may also cause the death of benthic, mesopelagic, and bathypelagic fish. Notably, benthic fauna is lost as a result of the impacts and disturbances of marine machinery in the water column caused by seamount mining. This can also have negative implications on the aggregations of pelagic species.

Deep water benthic impact tests—such as the unique DISturbance and reCOLonisation (DISCOL) experiment—have only been undertaken a few times. The impact of deep-sea mining on the benthic ecosystem was studied in DISCOL by ploughing an 11-square-kilometre portion of the seafloor at a depth of 4150 metres with a plough harrow regularly (Thiel et al., 2001). In 2015, 26 years after the impact had been documented, the DISCOL experimental area (DEA) was re-examined. To establish the long-term effects on the environment, research was conducted on benthic communities, their activities, and their sedimentary environment. Thiel et al. (2021) explained that the DISCOL experiment was carried out on an 11-square-kilometre zone in less heavily trafficked areas between railroads. As a result, biogeochemical services are expected to drop on a much larger spatial scale than previously assumed, thereby decreasing the chance of ecosystem recovery via lateral effects like redistribution of organic matter and recolonisation.

Examples of mineral resources are cobalt-rich ferromanganese and polymetallic nodules. Mining polymetallic nodules and cobalt-rich ferromanganese crusts—which have been formed over millions of years—can potentially lead to the death of some species which have been around for a long time (Gollner et al., 2017; Miller et al., 2018; Vanreusel et al., 2016). The removal of nodules and crusts, as well as compaction and elimination of seabed residues by drilling vehicles, threaten the sessile (non-mobile) species (Christiansen et al., 2020; Vonnahme et al., 2020; Zone & Pacific, 2011). However, mining the substrate and associated biodiversity, changing the topography and chemical composition, and making these areas unsuitable for recovery or recolonisation, could lead to faster re-formation of polymetallic sulphides at hydrothermal vents than polymetallic nodules or cobalt-rich ferromanganese crusts. Due to all these scientific findings, mining is widely recognised as a serious plan (Miller et al., 2018; Cindy Lee Van Dover, 2010). Overall, mining activities in nodule fields will affect microbial ecosystem services. In addition, existing studies also highlight that the activity scale of a vent field, as well as its nature of spread, can affect the biodiversity as well as its recovery time (Boschen et al., 2013; Chown, 2012; Miller et al., 2018; Niner et al., 2018). The dumping of tailings, for example, contributes to the issue. Once rare earth has been recovered, the tailings remain the ground-up materials. The radioactive thorium found in these tailings is not uncommon. A massive land impoundment is used to store tailings.

4.1.2. Effects of Benthic Sediment Plumes

Typically, the disruption of mining machines on the seabed generates sediment plumes, which degrade the water column and seafloor, kill organisms directly, and remove habitat substrate (Van Dover et al., 2017). Also, “collector plumes” can float on top of the water and move with the waves (Drazen et al., 2020; Rolinski et al., 2001). Consequently, in addition to influencing the mined seafloor, benthic mining plumes also extend their footprint to nearby locations and the water column (Christiansen et al., 2020; Luick, 2012; Rolinski et al., 2001; C L Van Dover et al., 2017). Smothering the bottom with these plumes might inhibit recolonisation and disrupt juvenile eating, respiration, or reproduction (Christiansen et al., 2020; Fallon et al., 2018; Knight et al., 2018; C L Van Dover et al., 2017). Moreover, the plumes, too, are likely to be hazardous (Bilenker et al., 2016).

4.1.3. Underwater Noises

The World Health Organization (2011) states that human-caused (anthropogenic) noise is a global contaminant that is second only to air pollution in terms of harm to humans. In that regard, the impact of underwater noise caused by deep seabed mining is not well understood. Several researchers, including Merchant et al. (2014), have examined dredging noise concerns earlier. Through existing studies, it has been deduced that dredging produces a wide variety of low-frequency sounds, which marine mammals try to avoid; fish can even hear these sounds from considerable distances. Undeniably, seismic surveys and pile driving are louder than dredging; dredging still needs to be considered a medium-impact activity (Todd et al., 2014). Besides, marine animals and birds may be harmed by collisions and entanglements caused by operating vessels—however, this has not yet been examined. Todd et al. (2015) state that collisions between dredgers and marine life are possible but highly unlikely. Aggregate dredging, a typical mining practice, has also been demonstrated by Firth (2006) to cause irreparable damage to shipwrecks and plane crashes.

4.1.4. Effects of Climate Change

The mining sector consumes a lot of energy and produces many greenhouse gases. However, the intensity of carbon emissions from the mining sector can differ significantly depending on the variety of material used and how it is mined (Rüttinger et al., 2016). It is well known that mining deposits are getting deeper and have fewer valuable ores, likely leading to more water needs and waste, more energy use, and more carbon emissions from the mining industry (Mudd et al., 2012). Deep-sea mining can potentially disturb some of the world’s largest carbon sinks, thus exacerbating climate issues. In addition, gas hydrate extraction could also occur, wherein the methane leakage during dissociation would have massive effects on our environment. Over the last century's experiences, it has been underlined that methane has a 28-fold greater potential for global warming than carbon dioxide (Jarraud & Steiner, 2012). In addition, the extraction of methane hydrates can cause seafloor subsidence and undersea landslides, which could exacerbate the instability of any residual hydrate deposits. When methane hydrate is destabilised and released, the temperature rises, resulting in a positive feedback between carbon dioxide emissions and climate change (Archer, 2007; Zhao et al., 2017). As a result of its pollutants and high energy consumption, deep-sea mining operations are intricately linked to the changing global climate.

4.2. Societal Impacts of Seabed Mining on Local Communities/ Fisherfolk

Even though the social consequences of onshore and offshore mining are nearly identical, the latter's impact on society is more complex and diverse (Roche & Bice, 2013). To accurately predict the long-term effects of mining on human societies, a wide variety of issues have to be measured. These would include, but are not limited to, a project's size and scope; its location; related industries; economic benefits; cultural norms and expectations; project alternatives and opportunity costs; and the regulatory framework in which the project is located. The following subsections provide an overview of three specific societal impacts associated with seabed mining.

4.2.1. Legal/ Ethical Concerns in Exploiting Resources in the High Seas (ABNJ)

Environmental and ethical factors must be considered when deciding whether exploitation strategies should be used (Banet, 2020). Due to this, the member countries which have been part of the three UN Conferences on the Law of the Sea (UNCLOS) have been deliberating on how to divide up sea space into zones and how to give each zone its own set of rules. The ISA (International Seabed Authority) was set up as part of the United Nations Convention on the Law of the Sea and signed in 1982. It is also crucial to mention that the international and national laws and policies for deep-sea mining are very different. Besides the international level, there are provincial and district levels at the national level and municipalities, prefectures, and other local administrative units within the national level (Bosselmann, 2005). In other words, every country has its own 'level of exploitation' policy. It has been the only authority to decide on exploration licenses, review environmental impact assessments, and make sure there is enough monitoring of mining in the area for the last 25 years. The term "area" refers to "the seabed and the ocean floor, as well as the subsoil thereof, outside of the jurisdiction of any one country" (Hallgren & Hansson, 2021).

An international framework of laws, procedures, and regulations has been established to protect the marine ecosystem from deep-sea mining. Still, no safeguards have been put in place to protect the ecosystem from deep-sea mining or to understand how the ecosystem is impacted by deep-sea mining (Bosselmann, 2005). An agreement with the International Seabed Authority (ISA) has been signed by governments interested in deep-sea mining after several years of deliberation and research. However, few countries still argue that joining the ISA and the United Nations Convention on the Law of the Sea is unnecessary (Groves, 2012).

4.2.2. China's Domination in the Market and Ongoing Investments in Other Countries

Seabed mining is projected to have huge socioeconomic repercussions. For instance, the jobs for experts and top scientists leaving government agencies or other organisations are expected to be competitive. Correspondingly, governments need to be careful not to over-emphasise seabed mining, as this could restrict the growth of other companies (Roche & Bice, 2013). Deep-sea mining's allocation of earnings, royalties, and taxes, as well as compensation and equal dissemination of economic improvements across the community, may raise concerns (Nugent & Lu, 2021).

In addition, Ericsson et al. (2020) highlight the initiatives being taken by China to increase its position in the global mineral resource market. China's geopolitical power can be seen in many ways, but one of the most important points is to know how much of its mining activities are done outside of China. This is because the security of mineral supplies is imperative for the national economy. By acquiring the next largest producers' mines and output, Chinese corporations are increasing China's geopolitical strength and economic leverage in the world market (Green & Liu, 2005). The environmental impact of China's rare earth element mining is a serious concern because of the poor mining procedures. Various consequences could arise if rare earth mining is not done correctly. As a result, many rare earth mines have been operating illegally and in an unregulated manner, resulting in environmental damage that only worsens the problem. Because of China's lax environmental regulations, the country is able to run its rare earth mines for a fraction of the cost. Government financing and enhanced control will also be required for China's environmental clean-up, which would likely cost billions of dollars in total.

In the third quarter of 2011, prices for rare earth elements (REE)—a collection of 17 nonferrous metals—increased by up to 600 per cent. This was worsened by territorial matters between China and Japan, the world's second-largest REE market (Kingsnorth, 2021). It also shows that China—which has developed as the largest environmental market for REE—is producing a substantial share (68 per cent in 2011) towards local consumption. China's natural resource dominance and desire to use it are well known examples (Sun, 2007). The defence, aerospace, electronics, and renewable energy industries use them, and they are very important. Australia is one of the top investment destinations for Chinese mining corporations. The key factors of these top investment destinations include their importance as mining countries/regions with tremendous resources, which are highly sought after by Chinese investors. Many investors are even willing to take on more risky exploration and mining projects, particularly in Australia, where the junior mining sector is thriving. The Johannesburg stock exchange has fewer junior exploration and mining companies listed than the ASX exchange does in Sydney (Ericsson et al., 2020). The story of China's dominance in rare earth elements fits well into the standard narrative of China's industrial growth. This industry's trajectory was growing at an exponential rate and at enormous environmental cost from the 1980s through the 2010s. Beijing began attempting to streamline a large sector in the 2010s to gain more control and oversight. As a result, since 2016, Chinese businesses have turned to the global market to boost their home output.

4.2.3. Geopolitical Rush for the Resources and Markets in Developing Countries

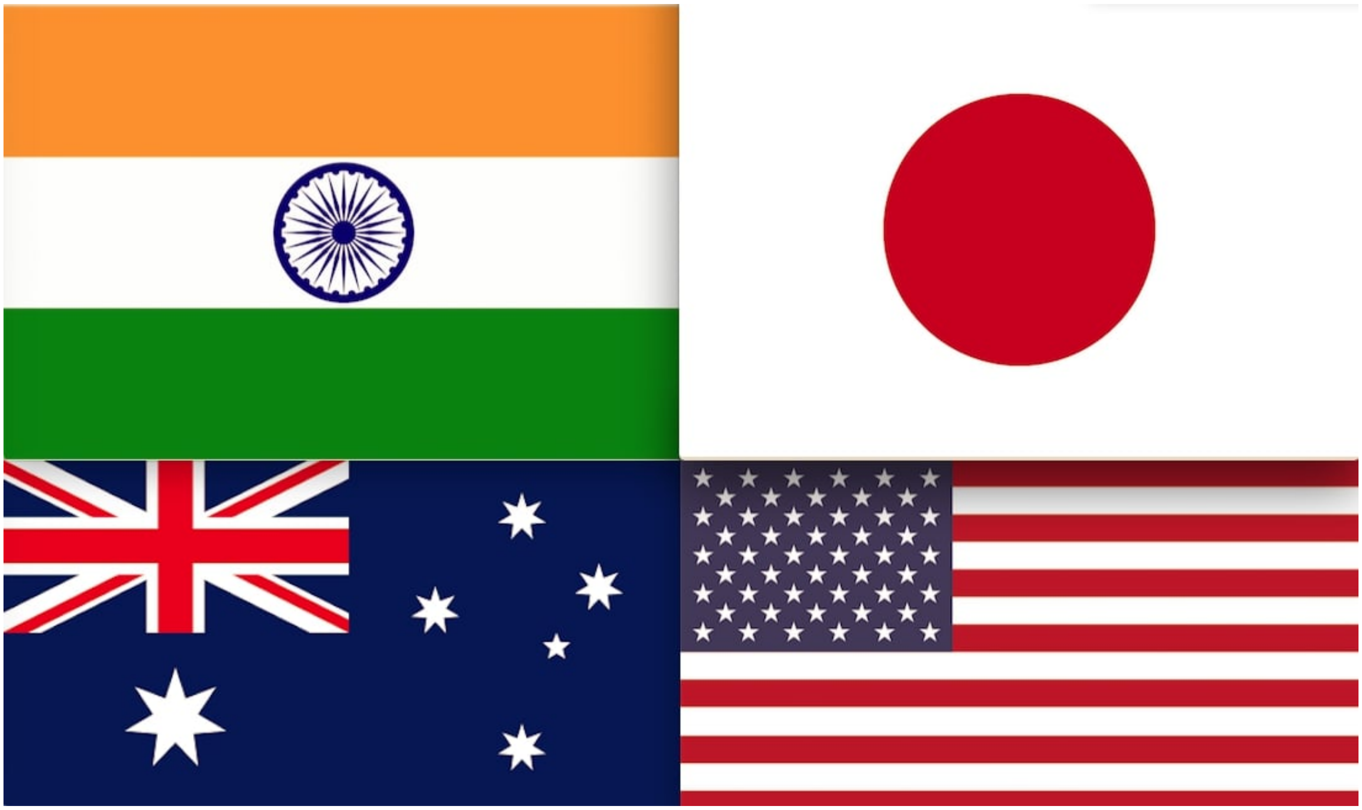
While the sea has been considered a place where natural resources can be extracted, it can also be considered a "theater of geopolitical rivalry and dominance"(Shim et al., 2018). Like many other aspects, the geopolitics of seabed mining is a tangled combination of multinational businesses, the state, civil society groups both locally and globally, and more-than-human elements like the deep ocean itself. Proponents of seabed mining claim that it can help assure economic growth. Still, they also see it as the beginning of an alternative blue economy that might help lift people out of poverty and aid in the transition to green technologies (Hallgren & Hansson, 2021; Kim, 2017). In addition, with the current legal-political condition of deep-sea mining, new geopolitics can be investigated—one that goes beyond the conventional focus on interstate relations and embraces recent tendencies in critical social science and theory. As a first step, this entails letting go of the "flatness" and "fixity" of their geopolitical imagination, which comes from territorialising the planet's surface from a state-centred perspective (Childs, 2020).

Moreover, there are also different parts of seabed mining. A production support vehicle (PSV) is on the surface of the water above the mine site. The right mining equipment also needs to be used to get minerals from the seafloor. Countries with many marine minerals usually do not have the tools to get them out of the water. As part of their agreement, the developing countries need to work with a private mining company to mine the seabed.

In contrast, the prospects for rare earth elements are favourable. However, analysis and monitoring are still required. Global consumption is expected to reach 200,000 tonnes by 2014. Uncertainty remains, although when compared to land-based mines, it is claimed that seabed mining may require less infrastructure and transportation systems. Regarding sustainable seabed mining, restoration and mitigation techniques must be financially and ecologically sound. As seabed mining is less disruptive to humans, fewer local people will be forced to abandon their homes near mining sites, and mining workers' dangers will be lessened or eliminated.

To get a share of the money from mining, they will use taxes, fees, and royalties, among other things. In this case, the country will get a share of the mining company's money (Krutilla et al., 2020). Thus, economic progress in developing countries can be facilitated by mining, but there is a risk that mining activities will become social and economic enclaves or harm the environment (Drazen et al., 2020). The importance of government transparency and accountability cannot be overstated. As a result, due attention must be paid to both social and environmental concerns. Mineral resource management must be a top priority for governments, communities, and enterprises alike (Leal Filho et al., 2021).

Opportunities for the Institutionalisation of the QUAD Framework



5. Opportunities for the Institutionalisation of the QUAD Framework

5.1 Link to a Larger QUAD Economic Partnership Framework (Tokyo May 2022 Meeting)

The QUAD has had a long history concerning its geopolitics post its conceptual inception after the 2004 Tsunami. While the first Quadrilateral Security Dialogue—or QUAD 1.0—of 2021 suffered from changes in leadership, misaligned interests, and divergent views on the Indo-Pacific, QUAD 2.0 was regarded as a more effective engine for addressing incumbent and future challenges, with Chinese aggressive international policies being a major risk factor. The QUAD Framework 2.0 is a significant step toward a resilient, transparent Indo-Pacific region, which is in line with the vision of the US-led Indo-Pacific Economic Framework (IPEF) (USA, 2022). The agreement led by the United States of America has advocated for a long list—from security management to 5G technology management—and has promoted a more vicious and cautious approach to countering the Chinese invasion. The region—which holds 40% of the total population and 60% of the total GDP—has major trade routes and technology supply chains. The joint statement of QUAD 2.0 focuses on key critical areas that are imperative to generating coastal and ocean resource management (Ministry of Foreign Affairs of Japan, 2022). These include commitments to support climate change adaptation, infrastructure management, critical technologies, Maritime Domain Awareness and HADR, and space-related applications (ibid).

This is significant for a country such as India, which is battling the dominance of its Chinese counterparts in the Bay of Bengal, and so on, in relation to R& and D vessels, and so on (Pant, 2021). These can be achieved in a variety of ways. A critical breakthrough would be utilising the current opportunities for collaboration with the ASEAN, EU, and other institutions against Chinese dominance. There have been critical discussions on extending the QUAD framework to QUAD plus involving countries such as South Korea, Vietnam, and New Zealand (Rademaekers et al., 2015). Further, these discussions should involve generating platforms for maritime diplomacy and technology transfer, whereby deep engagements with friendly powers such as France and Japan on interoperability and critical strategic technology are a necessity. The Indian Navy should prioritise intelligence, information sharing, and maritime diplomacy in potential conflict zones such as the Bay of Bengal and should ensure Chinese-built R&D facilities are not used as supply hubs for Chinese warships and submarines (Pant, 2021; GC Newsdesk, 2022). Secondly, diplomatic stances on climate action planning and carbon offsetting, which involve key considerations of the growing Indian markets, need to be promoted as a part of this QUAD framework. This could further the country's Nationally Determined Contributions as well as reduce the growing dependency on Chinese exports. Further, these are essential as they can be crucial for mineral resources such as cobalt reserves in the Clarion-Clipperton Zone in the Pacific Ocean and the Central Indian Ocean Basin, which are critical for EV battery productions and are a part of future reserves (Gateway House, 2021). Besides, operationalising the data portals for common space databases and debt management systems may prompt countries from falling into the debt traps of the Chinese government, which can affect marine policies (Ministry of Foreign Affairs of Japan, 2022). Further, the QUAD can formulate policies whereby they can create deep-sea mining standards that consider the environmental impacts of such actions while taking advantage of the riches of the seabed. This is significant as Asian and North American countries have not formulated a regional contract/ framework for deep-sea related management, especially for gas hydrates, with fewer including Japan, China, India, and Malaysia for various minerals developing national policies (Kathryn A. Miller et al., 2018). These showcase critical insights into the regulatory gaps in the UNCLOS framework, including the unavailability of jurisdiction and poorly managed rules (Ringbom & Henriksen, 2017), and the need for proper management for the sustainable utilisation of deep-sea minerals such as cobalt crusts, and polymetallic nodule reserves in the Indian Ocean (Kathryn A. Miller et al., 2018).

5.2 Develop a QUAD Framework for Ensuring Supply Chain Management

The supply chain forms an essential aspect of the Indo-Pacific region, which holds around 60% of the world's entire economy (USA, 2022). With the novel challenges from COVID-19, it has become normal that a concentrated supply chain hinders the sustainability of the nations. With the advent of the Electronic Vehicle revolution to address climate change, the demand for certain mineral resources such as cobalt and other rare earth elements has increased. There are significant entry pathways for enhancing supply chain management in India (Pant, 2021; De et al., 2021). The first one concerns funding supply chain resilience, whereby QUAD-backed foreign direct investment policies are focused in India, in major fields such as electronics, manufacturing and so on. This is significant as these fields have a high compound annual growth rate or CAGR in the country and have futuristic applications with the growth of Artificial Intelligence (AI) and the Internet of Things (IoT) (Pant, 2021). This could eventually put India as an economic pivot for the QUAD nations in the region, thereby opening novel pathways for a better resilient supply chain independent of China. Secondly, India should engage in the manufacturing and supply of rare earth minerals, thereby reducing the Chinese dominance in the supply chain. Currently, China holds around 60% of the extraction of rare earth metals; having held 90% in 2016. It fell due to the improvement in the US and Australia's involvement in the market. With India (1% of the global supply) making nascent actions in the supply chain, this would help in breaking the over-dependence of minerals such as cobalt from China (De et al., 2021). Besides, research studies suggest a high degree of concentration and interdependence in supply chains for lithium-ion batteries, chips, and sophisticated displays between Japan, South Korea, Taiwan, the US, and China. With India being promoted as a potential zone for QUAD-led investment, it can address the concentrated market and support the QUAD nations from a future conflict with China (Pant, 2021). Further, India should focus on promoting an alternative sustainable energy manufacturing base such as solar, which could support other QUAD nations in achieving their green energy targets.

Another key focus on enhancing the resilience of the supply chain is by focusing on improving the capacity of renewable rare earth minerals. Currently, reports suggest that there has been poor development and capacity building in supporting rare earth mineral recycling in countries such as Australia (Hart, 2022). With estimates suggesting that there will be triple the demand for rare earth minerals to achieve the global climate change targets on renewable energy, it is crucial to build strong foundations and research in the area (Hart, 2022). A critical breakthrough has been made in the electrodeposition process, which can promote environmentally friendly recycling of minerals (Sanchez-Cupido et al., 2020). The process involves utilising a low electric current that causes the metals to deposit on the desired surface and is claimed as a breakthrough for rare earth recycling from spent motors in electric vehicles (ibid). While the initial trials have reported success, it may require further research to strengthen them, which the QUAD should put forth in terms of knowledge sharing, funding, etc. All these could foster a strong supply chain, with a counterbalance to Chinese assertiveness.

5.3 Transfer Technologies and Best Practices in the Mapping, Exploration, Extraction, and Processing of Deep-sea Minerals

Mapping, extraction, and processing of deep-sea minerals have been undertaken since their initial discovery in the 19th century during the expedition of *HMS Challenger* (1872–1876) when the expedition leader C.W. Thomson and chemist J.Y. Buchanan discovered large beds of pure manganese oxide (Sharma, 2017). The unravelling of the economic potential concerning these minerals in the second half of the 20th century led to further investments in the field, resulting in technologies to support the process (ibid). Various technologies have been in use ever since. For example, in recent years, predictive mapping using satellite datasets and techniques involving the combination of bathymetry, Artificial Neural Networks, and associated modelling has been undertaken to generate the map of reserves. Further, the availability of modern and adequately equipped ships—which are central to deep-sea exploration and exploitation—have propelled the process (STOA, 2015).

Deep-sea minerals are exclusive, with each mineral posing a significant challenge in its extractions. For example, Seafloor Massive Sulphides or SMS require significant extraction force due to their location, rendering operational challenges concerning Remotely Operated Vehicles or ROVs owing to their terrain. This is entirely different from polymetallic nodules that require a suction mechanism to undertake extraction and are available on the surfaces (ibid). These result in different approaches to mining. Seafloor Massive Sulphides are accumulated by ROVs on the seafloor and then piped up to the surface to ship for further processing. While the readily available manganese nodules are collected through an ROV functioning like a vacuum cleaner, manganese crusts are acquired by large ROVs that grind through the hard crust, creating a mixture containing the valuable minerals, which is piped to the surface. Besides these challenges, constant technical issues exist concerning mining site delineation, system development, and so on (Sharma, 2017). Technology development is still occurring; however, a set of innovations and technological advancements have been developed to address the opportunities and challenges (Miller et al., 2018). The following discusses key elements of deep-sea mining (Yang et al., 2020):

- **Deep-sea Heavy Operation Equipment**: Deep-sea heavy operation equipment consists of three sub-components: ore mining, ore crushing, and collection equipment (Yang et al., 2020). Ore mining equipment is used to strip bedrock from core deposits. This equipment may differ based on the minerals and perform cutting and tunnelling operations. A key example is SMS's auxiliary cutting machine or cutter (Kang & Liu, 2021). On the other hand, ore crushing equipment performs the crushing and decomposition of large ores by mechanical means for collection. These involve equipment such as spiral drum cutting machines for Seafloor Massive Sulphides and Cobalt Rich Crusts. Finally, ore collection equipment is robotic equipment used to collect the crushed smaller pieces of ores to the storage tank or transfer the particles to the sea surface support equipment through conduits.
- **Ore Transport Equipment:** The purpose of ore transport equipment is to transfer the collected ore to the sea surface support vessel (Yang et al., 2020). This consists of the pump-pipe lifting equipment or riser and lifting system that transport the ore–seawater

mixture from the mining equipment to the sea surface at controlled flow rates and concentrations. Transport equipment is allocated further with an underwater buffer station to address the uniform ore-sea water mixture and is equipped with a heavy compensator to prevent the pump system motion due to wave motion.

- **Sea Surface Support Equipment:** The sea surface support equipment for deep-sea mining involves a surface support vessel, a cooperative control system, geographic positioning and navigation systems, ore pre-processing equipment, ore storage–transport equipment, and a launch and recovery system (Yang et al., 2020).

Currently, India has been involved actively in deep-sea mining. The International Seabed Authority (ISA), UN has allocated an area of 75,000 sq. km in the Central Indian Ocean Basin (CIOB) to mine polymetallic nodules from a depth of 5000-6000m. Besides, the country is funding the 'Deep Ocean Mission' to support the future demand for minerals and energy. The innovation concerning deep-sea mining and exploration has been spearheaded by research firms such as the National Institute of Ocean Technology and other stakeholders (Vats, 2021). Various novel technologies have been developed as a part of the innovation, such as ROVs capable of 6000m exploration; there has been work on technologies such as 'Manned Submersibles' for scientific sampling. However, with competitors such as China and its specialised agency—China Ocean Mineral Resources Research and Development Association or COMRA being a well-established competitor, having rights to 4 out of 29 seabed contracts—the country requires quicker adaptations to grow further (ibid).

With key challenges such as technical readiness of instruments and nascent R&D on deep-sea minerals, it is imperative to frame strong pathways for the future. Some of the key recommendations for the country to improve its competencies are as follows:

- **Promoting Research and Development around the Deep-sea Mining Ecosystem:** Deep-sea mining ecosystem is complex with multiple equipments/ key elements. Pieces of literature studies indicate that there is a huge thrust in research concerning riser and lift platforms. There are existing opportunities in areas lesser researched, such as mining platforms, or ore handling (Sharma, 2017). Besides, evaluating novel technologies and innovations such as 3D sensing, robotic manipulators, smart AI-based equipment, and vehicles for the extreme environment adopted from space missions for their technical readiness could also be carried out, all of which require critical investment. Therefore, governmental agencies should look into strengthening such investments to promote the goal of the Indian Deep-Sea Mission.
- **Strategic Partnerships with QUAD Members such as Japan and USA:** Japan and the US have been involved in deep-sea mining and have formulated significant technologies such as formulating roller mining methods for cobalt-rich crusts in the 1990s (Kang & Liu, 2021; Okamoto et al., 2018). With strong regional competitors, strategic joint ventures in scientific research and design concerning deep-sea mining technologies, mining activities, and so on could prove to be effective for India and its mission. These could involve knowledge sharing, training, support, technology co-creation, licensing, etc.
- **Sustainable Exploitation and Environmental Protection of Mining:** The deep-sea mining sector is considered a key challenge to the seabed and associated ecosystems.

Therefore, it is essential to generate an ecosystem involving green policies and carbon-zero technologies. A key example would be working on green mining; stable, intelligent control; and highly efficient heavy operation equipment or generating plans for the sustainable environmental protection of ultra-long-distance deep-sea ore transportation in the case of ore transport. Besides, these should extend to innovation that addresses the key challenges in the budget, such as in the case of expensive research cruises (STOA, 2015).

- Developing an autonomous body on deep-sea technology of the National Institute of Ocean Technology like the COMRA of China would also help strengthen the deep-sea mission of the country. Currently, the department is under the MOES or Ministry of Earth Science. These would involve more support from the Government in carrying out the process.

With India having a long coastline and great geopolitical advantage in the Indian Ocean, it is imperative to generate a well-defined strategy that is based on the strong foundations of investment in human resources, research, development, and technology. This can guide India in due course of time. Further, a key strategy is deriving economic diplomacy. Anthropogenic activities in the ocean are defined by the United Nations Convention on the Law of the Sea or UNCLOS, which is the main legal framework governing the oceans. As per UNCLOS, there are three boundaries for seas and oceans. The initial 12 nautical miles or 22 km from the coast of a state is defined as the coastal territorial sea, which is under complete state authority on water, air, and subsoil (Christiansen et al., 2019; Miller et al., 2018; Ringbom & Henriksen, 2017). The coastal states, however, have rights and jurisdiction of resources extending up to 200 nautical miles or 370 km, with certain cases extending, taking into consideration continental shelves as the base of measurement. The area beyond these is referred to as Area Beyond National Jurisdiction or ABNJ (Ringbom & Henriksen, 2017). UNCLOS defines ABNJ as the common heritage of humankind and has legal frameworks pertaining to the sustainable exploration of deep-sea mining. Further, it has assigned the International Seabed Authority or ISA as its proprietor. ISA currently has 167 members and has over 29 contracts with competing states for seabed exploration, whereby an area is allocated for mineral exploration, which is mineral subjective. Besides ISA, certain regional authorities have been formulated by interested countries to promote harmonies, such as the MIN-Guide initiative in the European Union Deep Sea Mineral Project by the Pacific Islands and EU (Miller et al., 2018).

While these initiatives have been formulated in various zones, Asian and North American countries are yet to formulate a regional contract/ framework for deep-sea-related management, especially for gas hydrates (Miller et al., 2018). However, national policies have been developed by coastal states, including Japan, China, India, and Malaysia, for various minerals (ibid). This is critical as major research reports criticise the regulatory gaps in the UNCLOS framework, such as unavailability of jurisdiction, poorly managed rules, and so on (Ringbom & Henriksen, 2017). These issues need to be managed properly to sustainably utilise deep-sea minerals such as cobalt crusts and polymetallic nodule reserves in the Indian Ocean (Miller et al., 2018). A critical breakthrough can be achieved by promoting a common regional authority similar to the EU’s partnerships with the Pacific Islands. The primary requirement concerning this regional cooperation is to generate a framework for the Indo-Pacific islands concerning the legislation, extraction, and exploitation of the minerals.

The framework should also address UNCLOS's challenges, such as jurisdictional issues and poor management of rules. The promotion of autonomous regional dispute settlement authority and effective participation could be a way forward for addressing the crisis and promoting sustainable exploitation of resources. Besides, joint ventures whereby competing authorities align for common goals such as addressing sustainable development goals should also be a key consideration for the framework. This can also initiate entry points for financial investments in the region by QUAD nations, owing to their current status, such as India moving towards its deep-sea mission. These would prompt partnerships in addressing the technical requirements of the mission, and so on. Besides, these can support the Net-Zero Target by 2050.

5.4 Enhance Sustainable Mechanisms to Reduce Post-mining Impacts in the QUAD and Partner Countries

Mitigating deep-sea mining and ecosystem restoration after mining will be difficult and impossible (Niner et al., 2018). Landscape changes in post-mining regions frequently differ from surrounding landscapes (Wirth, 2020). Understanding the potential biodiversity loss affected by deep-sea mining will necessitate much more boundary understanding than is currently available, as well as an understanding of the technology used and its direct and indirect impacts (Clark et al., 2020; Miller et al., 2021). The seas with their particularly vulnerable deep-sea species—for example, shrimps, crabs, and even cold-water corals—remain poorly understood (Kim, 2017; Van Dover, 2014). The relationship between deep-sea habitats and ecosystem function is not well understood.

One of the essential strategies suggested for the QUAD countries is developing a comprehensive sea mechanism to protect, develop, and sustainably use the oceans. The full recognition that environmental protection is essential for the long-term sustainable use and development of the oceans by sound marine industries, as well as for socio-economic stability that includes marine industries, are also new directions that needs to be aligned with environmental protection, ocean development, and utilization. A developing a win-win relationship between environmental protection and sustainable development is essential. Among the QUAD countries, Australia has developed a leading-practice mining industry sustainability program. Among the topics covered by this program are best practices in Indigenous community engagement, biodiversity, water and tailings management, hazardous materials management, and product stewardship. Furthermore, it is crucial to promote sea management and sustainable marine usage following international law, as well as in recognition of national ocean management initiatives and UN summit action requests for implementing the SDGs on ocean management (Groves, 2012).

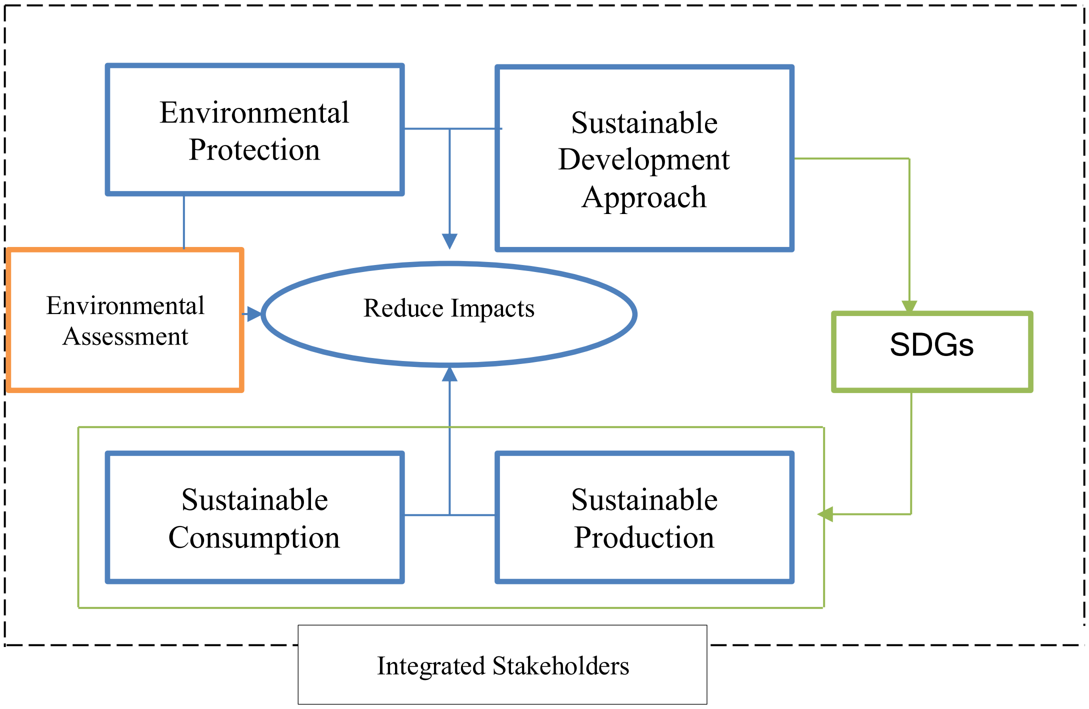


Figure 5: Sustainable Mechanism Framework (source: Authors)

Globally, achieving all of the United Nations' sustainable development goals requires a shift toward sustainable consumption and production practices (Bengtsson et al., 2018). An initial practical step in assessing the potential need for mineral deposits required to transition to a sustainable mechanism is to converse among all stakeholders in deep-sea mining. Many stakeholders could understand better the uncertainties and inconsistencies surrounding the projected demand for relevant materials. It may be beneficial for researchers to reorient their efforts to improve future technology's long-term viability and longevity. A successful transition will necessitate a combination of consumer education and city planning policies to encourage public transportation use within the QUAD and partners. A cooperative partnership approach that promotes the best practices and collaboration between local and national actors is a model for the QUAD countries to benefit from their mineral resource development.

However, the additive impacts of marine exploration and mining are still almost entirely undetermined. They can only be delivered by improving knowledge of deep-sea ecosystems' basic and systemic biology, and a better understanding of the complex biological interactions that allow them to function efficiently. In addition, environmental impact assessments or strategic environmental assessments at a regional level are mandatory to maintain sustainable mechanisms. It can help in the development and implementation of techniques for establishing whether projected exploration activities in the region would have a significant negative impact on vulnerable marine ecosystems or communities (Jaeckel, 2020).

Mapping the biology and geophysics of the landscape is required for environmental impacts and mitigation strategies. This map includes benthic communities, marine life, sedimentary structures, and those accessible to currents and those on the mining site itself (for example, used by desalination plants or leisure). All potential negative environmental effects must be thoroughly investigated. To achieve the goal of sustainable seabed mining, mitigation strategies must be developed to minimise and/ or compensate for environmental impacts. There are several options, including reserve areas, relocation, and re-colonisation. To minimise environmental impact, ensure ecosystem restoration, and reduce the risk of biodiversity and endemism loss, the pilot project must propose and test mitigation strategies. Emergency response plans must be developed to reduce the impact of natural disasters and unplanned events.

5.5. Enhance Communities' Awareness, Capacities, and Engagement for a Sustainable Coastal Environment.

Understanding this heterogeneity in the local community and other social science disciplines is essential. Roche & Bice (2013) said that community interactions could occur across time, space, and scale and require various parties who may disagree with one another. They fear national or regional discourses on ownership, authority, and cultural rights may come into conflict with local community discourses (Roche & Bice, 2013). Nobody denies that community can be problematic because it has the potential to confuse or ignore already existing differences, hierarchies, and power relations (Roche & Bice, 2013b; Ryan et al., 2020). At this point, it appears that deep-sea mining will not have the same direct impact on nearby groups as terrestrial mining. During this early phase, all parties must consider the impact of the project and devise processes that include local communities in determining whether the balance between benefit and impact is acceptable (De Vita, 2007).

Due to the minimal skill constraints, lack of regulations, and basic technology, seabed mining is several communities' primary income source. However, such communities face environmental consequences as well as threats to their health and well-being (Cuya et al., 2021). In addition, economic exploitation for resource extraction may harm local communities' reliance on resources for food and revenue, as well as ecotourism and other alternative livelihoods (Quevedo et al., 2021; Rahadiati et al., 2019). Regarding resource extraction, the only significant international component relates to the International Seabed Authority (ISA), which states Parties govern the Convention and are in charge of the entire system. Land-locked countries may lose income due to seabed-based manufacture, and the International Seabed Authority is in charge of ensuring that a portion of profits is repaid to the international community as compensation. However, as mentioned in the previous section, calculating the mining impacts on the community is a complex task that will vary from site to site and differ on various considerations. Communities are most concerned about the impact of seabed mining because there is so little data and experience to go on in this area. In addition, there is a common lack of community knowledge about the deep seabed and its environments (Boughen et al., 2010; Mason et al., 2010).

Community capacity can be activated if a change in risk or impact perception is combined with an institutional framework that encourages networking (Adger, 2006). To enhance community awareness and capacity due to mining in the QUAD countries, it is suggested that the community's perception of the risks associated with a particular sector or valuing community views of risk operations is as important in their impact on a community as the real risks reinforced by scientific data (Haines et al., 2011; Marlowe et al., 2022; Todd et al., 2014). The community concerned about these risks has legitimate reasons to react in a particular way to business activity and practices. Management, scientific, and clamming community collaborations are critical towards enhancing knowledge and building community capacity (Bogdan et al., 2021; Roche & Bice, 2013b). A new approach to community engagement can be pioneered by this industry, which emphasises local understanding, values two-way interaction, and delegates some policymaking and responsibility to the community at large. These ideas can help raise a community's awareness of its responsibilities and the dangers it faces.

6. Conclusion

Due to the rampant industrialisation of the world in the last few centuries, the global average temperature has reached a level where it has become a threat to the ecological balance of the planet. The world community is working towards limiting the global average temperature rise to 1.5-2°C above the pre-industrial level through the Paris Agreement. The commitments of the Paris Agreements emphasise the sustainable transformation of the global economy. The transformation towards the low carbon-sustainable economy from the fossil fuel-based economy largely depends on the shift toward renewable energy sources such as wind turbines, solar panels, tidal energy, wave energy, and rechargeable batteries.

The demand for the mineral resources that are a part of the supply chain of this renewable energy equipment is set to increase in the future, and there is a possibility that the vulnerabilities associated with the supply chain of these mineral resources will make the availability of these resources difficult. Hence, a shift towards marine mineral resources is expected in the future.

The near-shore regions are in a nation's ‘national jurisdiction’ while the deep seabed is in the ‘area beyond national jurisdiction’ (ABNJ). Presently, the rules and regulations are only applicable to the national jurisdictions, and the ABNJ is guided by the International Seabed Authority (ISA). The rules of exploitation of the seabed are still in the draft stages by the ISA for better mapping and exploitation of mineral resources. The existing ‘knowledge gap’ of the coastal nations—specifically the small island nations—must be addressed, and the technical knowledge must be shared.

The environmental sustainability of deep seabed mining must be analysed before undertaking any seabed mining projects. The commercial viability of seabed mining and environmental sustainability must be considered while drafting the national and international rules and regulations related to deep seabed mining. The process of seabed mining must be inclusive, resilient, and economically sustainable in nature.

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