Impossible Metals Frequently Asked Questions (FAQ) for website

v2.0

Please contact our team if you have any questions that aren't covered here or would like to discuss your questions or feedback with Impossible Metals.

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A. Market for Deep Sea Critical Minerals

A.1 Why do we need more critical minerals than what we mine on land today?

The demand for nickel, cobalt, copper, and manganese, materials crucial for producing advanced technologies in defense, energy, and infrastructure, has skyrocketed. Projections from the World Bank indicate that demand for these metals will increase by 500% by 2050, raising concerns about their availability and sustainability on a global scale. Without deep-sea minerals, 388 new mines must be built by 2030 to provide the necessary minerals to meet this demand.

A.2 Can recycling replace the need for deep sea minerals?

Recycling can be a part of the solution, as metals are highly reusable, but it is insufficient. A new electric vehicle (EV) won't be scrapped for 10 to 15 years. Its battery pack, while no longer able to power a vehicle, can last 15 to 20 years and may find a second life by storing wind or solar energy before being recycled. The International Energy Agency forecasts that the secondary supply of batteries and the reuse of nickel will represent just 3% of total demand in 2030 and 10% in 2040. To help close the demand gap, mining for new metals will still be essential.

A.3 Can reducing demand replace the need for metal mining?

Proposals to reduce demand fall into two categories:

The first category is to reduce demand by reducing car dependence in wealthy nations, which sounds doable in theory but can have significant implications for GDP and the economy. For example, in the U.S., that could require the migration of 50% to 75% of the population from rural and low-density communities to medium-density communities to take advantage of cycling, biking, walking, and mass transit. This migration would impact hundreds of millions of Americans and require significant policy, urban, infrastructure, and transportation changes that could take decades to implement and bring their own challenges.

The second proposed solution would limit access to modern technology like air conditioning (AC) and electric vehicles (EVs) in developing countries like India and in Africa. While climate change affects the entire planet, poorer countries are more severely affected, and their need for AC to reduce heat stroke and improve daily life is already significant. When Harvard China Project researchers modeled future air conditioning demand, they found an enormous gap between current AC capacity (2.8 billion people live in the hottest parts of the world, but only 8% of them have home AC) and the AC capacity needed by 2050 to save lives. In addition, a World

Bank study of 20 developing countries found that EVs would be an economic and environmental win for more than half of those countries. While it is essential to dig into how to reduce the overall demand for critical metals to attain net-zero goals, it's clear that the solution needs to be more practical and humane.

A.4 Will new battery chemistries eliminate the need for deep sea minerals?

While new battery chemistries are emerging, nickel and cobalt are likely to remain important for longer-range EVs and many non-battery uses.
Nickel and cobalt are used in many but not all battery chemistries. Today, they are mainly used in lithium, nickel, manganese, cobalt oxides (NMC), and lithium nickel, cobalt, aluminum, and oxides (NCA). Lithium iron phosphate batteries (LFP) are popular in China and do not use nickel or cobalt. However, LFP batteries are also significantly heavier, resulting in less range in an EV. Manganese-rich NMC could be a cheap alternative to LFP/LMFP, avoiding dependency on Chinese supply chains without sacrificing range. Cheaper, sustainably mined Cobalt from deep sea minerals would make high-voltage mid-nickel NMC an additional alternative. Nickel and cobalt are also used in many non-battery energy transition applications, including solar, wind, and nuclear power.

External industry analysts, such as Roland Berger, Benchmark Mineral Intelligence, etc., forecast that L(M)FP will account for around 35% of North American EV batteries in 2030. North American EVs will also use nickel-based (NMC) and iron-based (LFP) batteries. LFP is better for small pack sizes and cheaper vehicles, which are very popular in China. NMC has higher energy density and is best for long-range vehicles with bigger pack sizes.

LFP is primarily a Chinese technology today, so North America has no volume manufacturing. If you buy a car with Chinese batteries, you do not qualify for the Inflation Reduction Act (IRA)'s $7,500 tax rebate because they contain materials from a "foreign entity of concern." For example, the lowest-cost Model 3 Teslas, which use LFP batteries currently do not qualify for the credit,but the long-range vehicles do qualify, making them cheaper on an after-tax basis than the LFP-based vehicles and offering almost 100 more miles of range. LFP also has a very low recycling value. NMC has large recycling values; if you factor in the end-of-life recycling value, NMC is cost-competitive.

Finally, while additional battery chemistries are being developed today, some of which will not require nickel and cobalt, they are unlikely to make a significant impact on climate goals in the next one to two decades. It typically takes 20 years after a new battery chemistry is invented before a Western automotive manufacturer deploys it at scale. Western automotive manufacturers need many years of samples from the volume production factory before the battery cells will be qualified.

For more details, see our blog post, "Inconvenient Facts About LFP Batteries."

A.5 How long does it take for a land-based mineral deposit to get into production?

According to S&P Global, mining companies take an average of 23 years from discovery to production; in the US, it's 29 years.

A.6 Can deep sea minerals be cost-competitive with land-based mining?

Deep sea minerals will significantly lower recovery costs compared to new land-based mines. Given the high ore grade, four metals in one ore, and low infrastructure costs, deep sea minerals extracted from polymetallic nodules will be the lowest cost of all forms of mining. In addition, the ocean seabed is the world's largest source of nickel, cobalt, and manganese, and selective harvesting will have the lowest environmental impact. For more details, see this blog post, "Why Will Deep Sea Mining Be Less Expensive Than Traditional Land-Based Mining?"

A.7 Will selective deep-sea mining match the production rate of land mining?

Yes. The known reserves of Ni, Co, and Mn in the ocean are between 3x and 10x the known reserves on land. Our parallel fleet of underwater robots can collect substantial amounts of critical materials, and replication of a single project can increase productivity.

A.8 Is deep sea mining economically viable compared to low-cost land-based nickel production?

Yes, We estimate that our system will be 15x lower cost than the average nickel mine in 2024. See this blog post to learn more.

A.9 Will deep sea minerals replace new land-based mines?

Yes. Existing land-based mines will continue to operate, but new land-based mines will not open after deep sea minerals ramp into production. This is because of the cost advantages of extracting deep sea minerals, the size of the resource, and the lower Environmental, Social, and Governance (ESG) impacts.

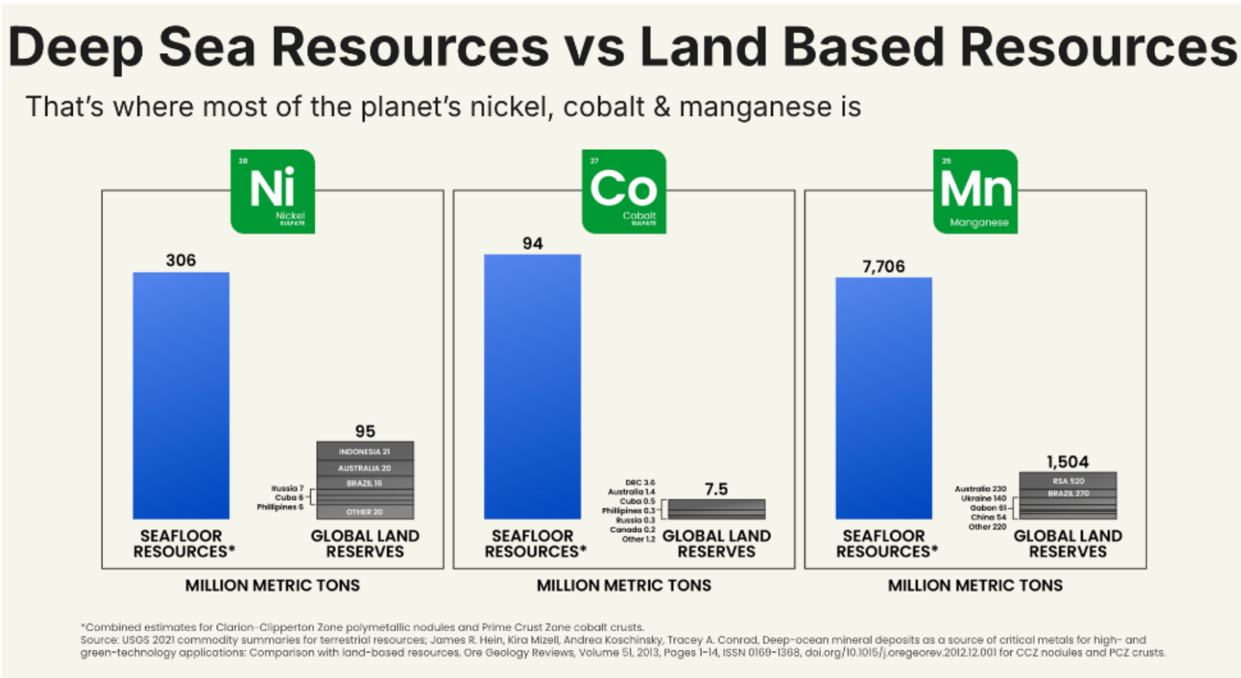
A.10 What are the different types of deep sea minerals?

There are four potential sources of deep sea minerals: polymetallic nodules, cobalt-rich ferromanganese crusts, seafloor massive sulfides, and rare earth element muds.

Polymetallic Nodules (PMN) contain nickel, cobalt, copper, and manganese. These potato-sized rocks are found on the abyssal plains lying on the seabed sediment. They do not require cutting, blasting, or tunneling. This is the exclusive focus of Impossible Metals. Cobalt-rich Ferromanganese Crusts (CFC) mainly contain cobalt. They form on sediment-free rock surfaces around oceanic seamounts, ocean plateaus, and other elevated features. Seafloor Massive Sulfides (SMS) mainly contain copper, lead, zinc, and some gold and silver. They appear on and within the seafloor when mineralized water discharges from a hydrothermal vent. The hot, mineral-rich water precipitates and condenses when it meets cold seawater. Most proposed mining is focused on extinct hydrothermal vents. Rare Earth Element Muds (REEM) mainly contain rare earth elements in the seabed sediment.

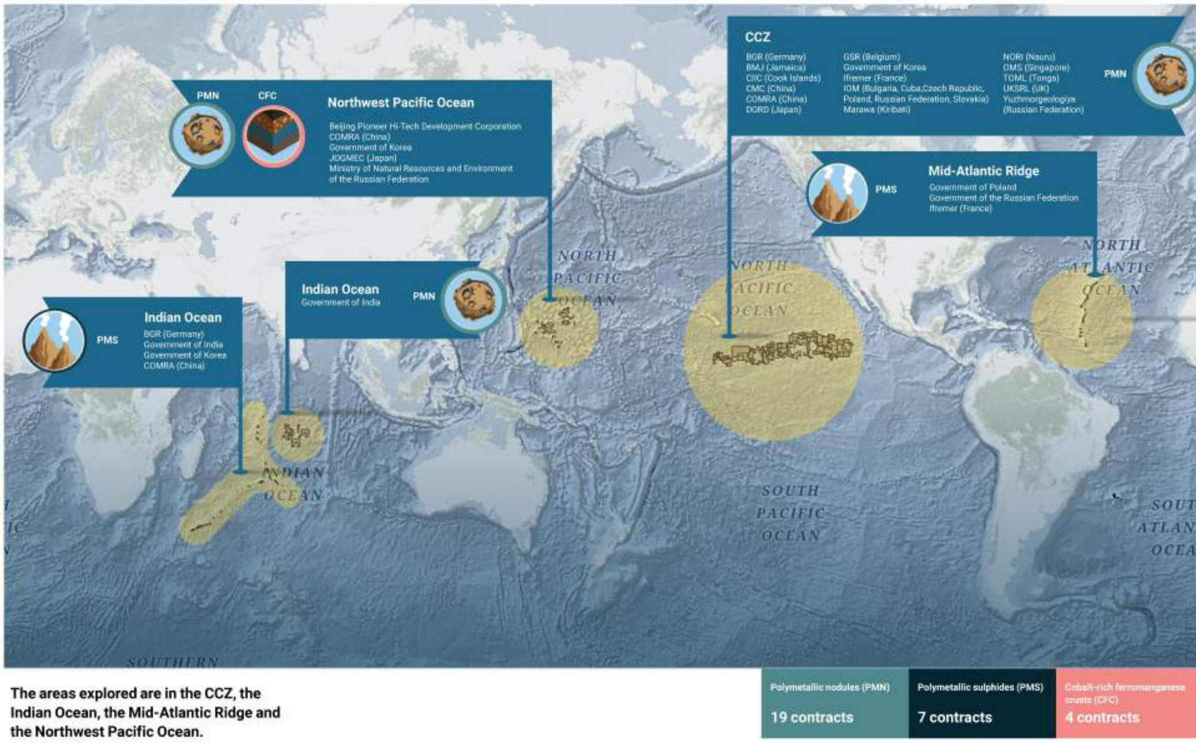
A.11 How significant are the reserves for deep sea minerals vs land-based reserves?

71% of our planet's surface area is oceans, and only 29% is land. We have mined on land since the Bronze Age, so the world's oceans contain significantly more nickel, cobalt, and manganese reserves.

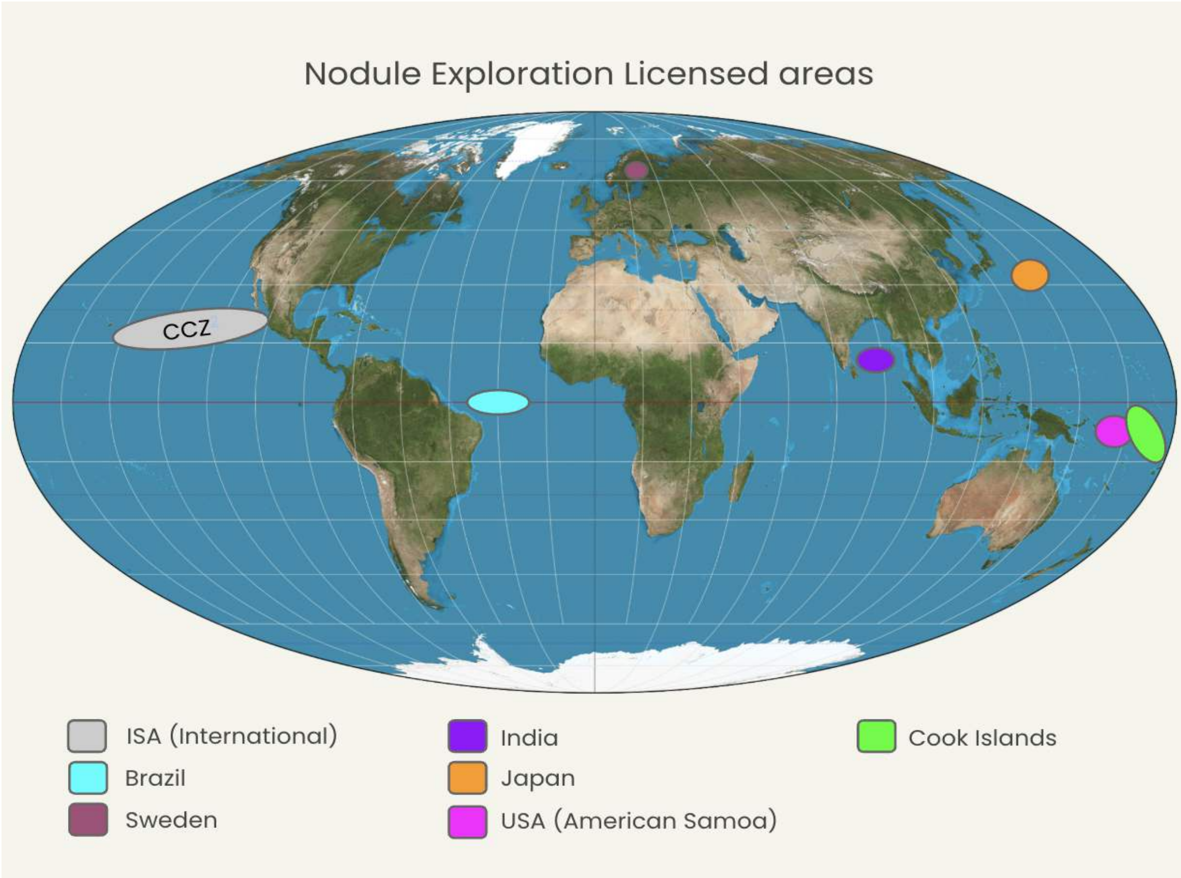


A.12 Where are deep sea minerals found?

All of the world's oceans contain deep sea minerals. The international seabed area, under ISA jurisdiction, has issued exploration licenses in the Clarion-Clipperton Zone (CCZ), the Indian Ocean, the Mid-Atlantic Ridge, and the Pacific Ocean.



Many countries contain deep sea minerals within their EEZs, such as the Cook Islands, Norway, Japan, Sweden, India, the Kingdom of Saudi Arabia, American Samoa, Papua New Guinea, Chile, the United States, Brazil, and China. See [countries developing subsea minerals in their EEZs](#).

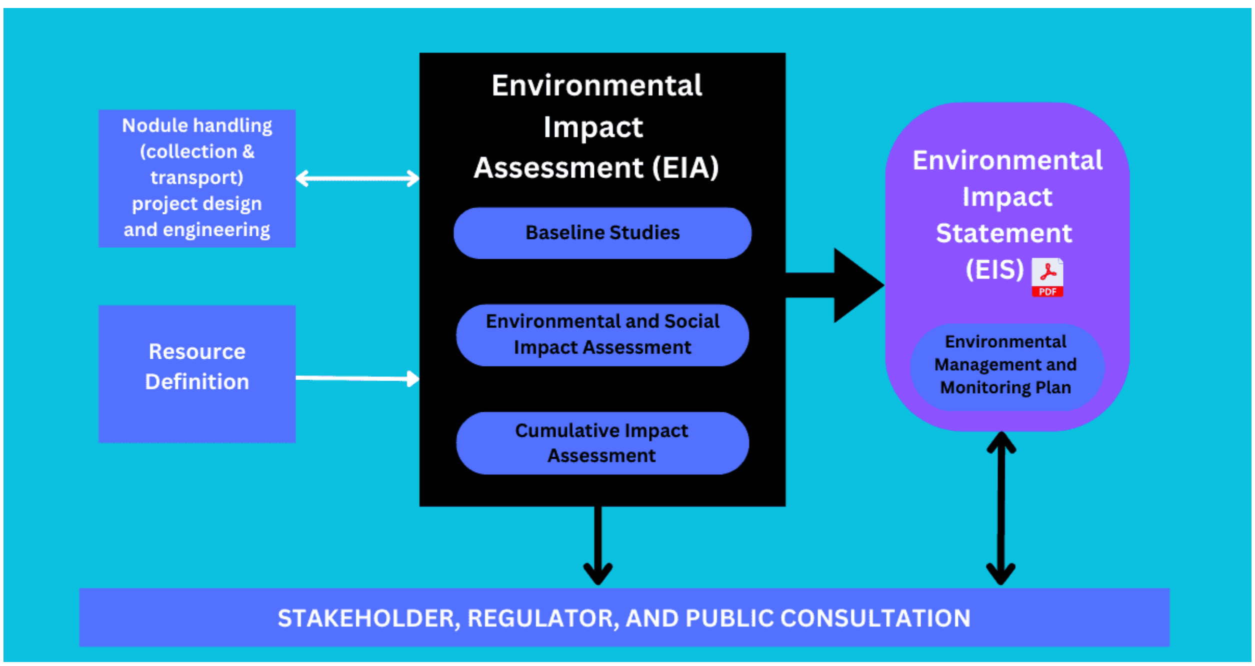

Nodule Exploration Licensed areas
CCZ
ISA (International)
Brazil
Sweden
India
Japan
USA (American Samoa)
Cook Islands

B. Environmental and Social Responsibility for Deep Sea Mining

B.1 How do we know what the environmental and social impacts will be from deep sea mining?

That is the purpose of the Environmental Impact Assessment (EIA), which must be conducted before any mining is approved. This work typically takes 3-5 years and is performed under an exploration license that does not allow commercial mining. The cost is typically around $30–80M USD and requires many baseline studies with hundreds of scientists. All this data is made public. A regulator will decide if deep sea mining can start commercial operations only after the impacts are known.

For more details on the EIA, see this blog post.



B.2 How much of the seabed will likely be mined in the next 30 years?

There are 22 exploration-licensed areas for nodules. Let's assume all areas go into production and no new areas are added. The average size of each licensed area is 75,000 sq km. Only 50% of that area is mined due to sea slopes, leaving marine protected areas. So the impacted area is approximately 22 * 75,000 * 50% = 825,500 sq km over 30 years. The total surface area of the world's oceans is approximately 361 million square kilometers. So deep sea mining for nodules will likely be just 0.23% of the world's oceans after 30 years.

In the case of Impossible Metals, we have committed to leave 30% of the nodules undisturbed by weight which is 60% by numbers, so the number would reduce to 577,850 sq km. or 0.16% of the world's oceans.

Every year, 1.4% of the ocean is impacted by trawling fishing, according to a paper published in nature.

B.3 Will carbon stored in the ocean be released into the atmosphere and have an impact due to deep sea mining?

No. Although the ocean is the largest carbon reservoir on Earth, holding significantly more carbon than the atmosphere or terrestrial biosphere, sequestering about 25% of the annual anthropogenic CO^2 emissions released into the atmosphere.

Less than 1% of the CO^2 sequestered in the ocean's upper layers reaches the deep sea floor annually. As the carbon-based organic matter sinks to the bottom of the ocean, much of it is processed before reaching the ocean floor. Due to lower productivity and reduced input of organic matter, deep-sea sediments have an overall low organic carbon content of approximately 0.05% of the dry weight of the sediment. Nodules do not sequester CO^2 and do not contain a meaningful amount of carbon. Sediment disturbed by the collector vehicle has no pathway to the atmosphere. Local sediment disturbance has shown not to rise more than a few meters, many meters away from phytoplankton, which need light for photosynthesis. Impossible Metals has no riser system with a discharge plume, so this will not impact phytoplankton photosynthesis.

Impossible Metals has committed to Net Zero, so we will either offset any emissions from the ships, charging of the underwater robotics and metal refining, or use new technology to remove these emissions.

See more details in the ISA Fact-check 2024/1 – The carbon cycle in the Area.

B.4 Will fishing be materially impacted by deep sea mining?

No. 90% of global fishing activities are carried out within Exclusive Economic Zones (EEZ) and Extended Continental Shelf (ECS). Most deep sea mining exploration is in areas beyond national jurisdiction ('area'), although the Cook Islands and India will have deep sea mining within their EEZ. Local sediment disturbance has been shown not to rise more than a few meters, many meters away from phytoplankton (food for fish), which needs light for photosynthesis. Impossible Metals has no riser system with a discharge plume, so this will not impact phytoplankton photosynthesis.

See more details in the ISA Fact-check 2024/2 – Status of fishing activities in the Area**.**

B.5 What are the environmental concerns related to deep sea mining?

There are a few categories of concerns about the potential impacts of deep sea mining. Impossible Metals' approach from our founding has focused on removing or minimizing these concerns to create the most environmentally responsible form of mining.

1. **Loss of Biodiversity**: Identifying new species during deep sea exploration is common. These creatures may hold unknown discoveries for science or medicine, and there is concern that deep sea mining could result in their loss before we know they exist. Although "protected areas" (the ISA calls them "areas of particular environmental interest" [APEIs]) are left as non-mining areas, these protected areas are significantly distant from the mining areas, so the biodiversity in these areas differs from the mining areas.
2. **Sediment Disturbance & Pollution**: Deep sea mining may disturb sediment, which can have various impacts, such as:
    a. Disturbance of animals that live in the sediment. These are typically small (or very small) creatures that spend all or part of their lifecycle under the upper layers of the very fine deep sea sediments.
    b. When sediment is disturbed, it sinks to the seafloor, which can smother animals that cannot move out of the way, like deep sea corals.

c. Increasing toxicity in the water can harm marine organisms and bioaccumulate/magnify. This could impact fish food sources.
d. Potential for release of stored carbon in sediment.

3. **Noise & Vibration Disturbance**: Equipment used in the ocean may have sounds or vibrations associated with them, from the motors running dynamic positioning (DP) systems to keep ships in place to electromagnetic waves from various monitoring or communication systems. Plenty of sea creatures use particular wavelengths to communicate, like whales. Noise and vibration from deep sea mining have the potential to impact this communication, which could result in changing behaviors or migratory pathways.
4. **Light Disturbance**: The abyssal plains where nodules form are very deep (4-6 km) and, therefore, very dark. There is concern that the introduction of light sources could impact sea creatures.
5. **Loss of Hard Surface**: Polymetallic nodules often represent the only hard surface in these abyssal ecosystems, where the rest of the seafloor is composed of very fine sediment. Some animals attach to the nodules, like deep-sea corals and sponges. Other animals use the nodules to move around, similar to how it takes less energy for a person to walk on a sidewalk than on soft sand.
6. **Emission of Greenhouse Gasses:** Management of emissions will be a key task for the deep sea mining industry. Ship fuel will account for a significant proportion of emissions, providing energy for ship movement and the variety of tasks the ship will perform. This includes ship dynamic positioning (DP) and the riser system in a traditional architecture.

B.6 What is Impossible Metals' plan to protect the marine environment?

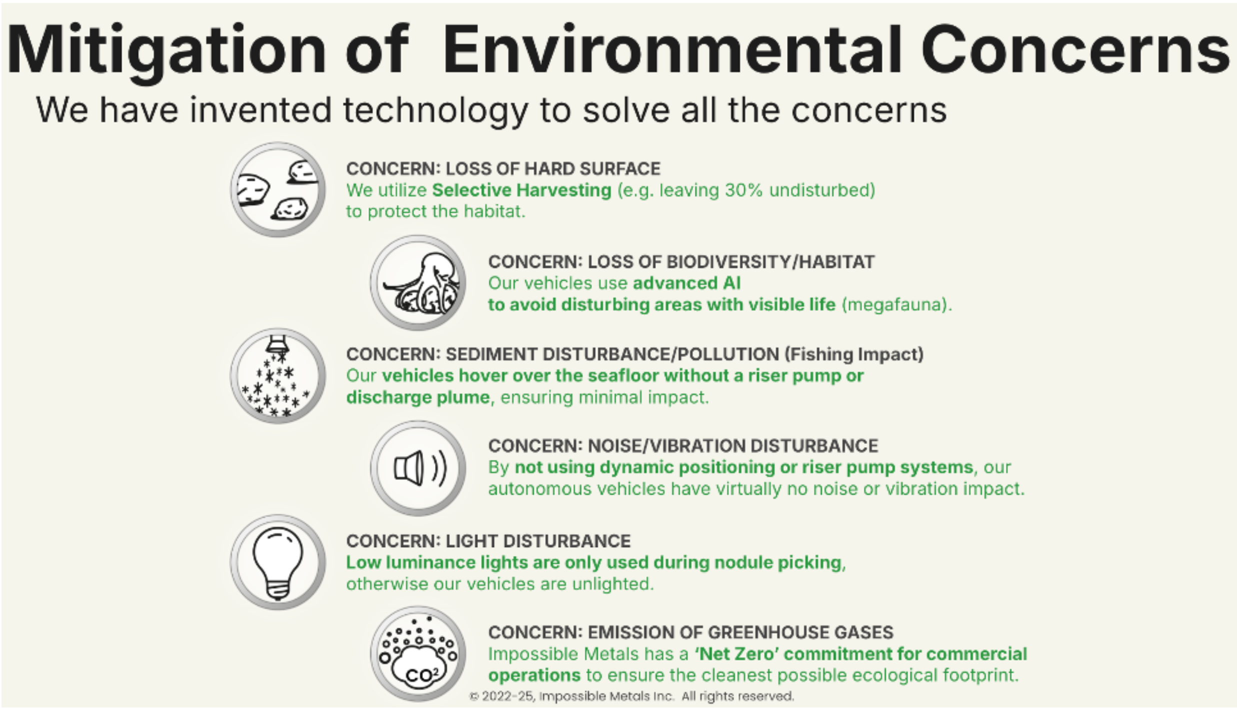
Impossible Metals was explicitly founded to address the environmental concerns surrounding deep sea mining of polymetallic nodules, so here's how we address each of the concerns listed in the previous answer:

1. **Loss of Biodiversity**: By avoiding picking up visible life (megafauna) and leaving behind a percentage of nodules, our system minimizes the potential for destruction of animals for their own sake, for the ecosystem, and for any potential human uses.
2. **Sediment Disturbance & Pollution**: Our underwater robots—formally known as Autonomous Underwater Vehicles (AUVs)—have a variety of features that minimize sediment disturbance:

a. Our AUVs hover over the seafloor so they do not disturb sediment from landing or driving over the seafloor.
b. The buoyancy engine makes the robot positively buoyant while it hovers over the seafloor, meaning thrusters push upward, not downward into the sediment.
c. Robotic arms/claws pick up nodules individually, minimizing sediment pickup.
d. The AUVs move up and down the water column avoiding the need for a riser pump system and its discharge plume.

3. **Noise & Vibration Disturbance**: Our sound emissions are relatively low. Most sound subsea will come from the acoustic communication system, subsea thrusters, and buoyancy pumps. The surface sound will be from the ship and the launch and recovery operations of the underwater robot. As part of our equipment's environmental design basis, we have aimed to generate minimal sound. In particular, we have aimed for minimal sound compared to dredge-based equipment. Substantial sound comes from DP {Dynamic Positioning) ships and the riser system. We do not require DP or risers. Our sound profile is small compared to other technologies.
4. **Light Disturbance**: Today, we use visible white light. We are working with marine scientists to determine the best wavelength (color) to have the least impact. In production, we may reduce the light power by using more sensitive sensors in our cameras. We will work with scientists to measure the effect on the marine ecosystem.
5. **Loss of Hard Surface**: Selective harvesting allows us to leave behind a percentage and/or pattern of nodules that maintain the ecosystem's hard surface and avoid nodules with attached visible life (megafauna). Our current economic models assume we will leave 20% of nodules behind, but this estimate will be refined through study and discussion with scientists.
6. **Emission of greenhouse gasses:** Our plan for producing responsible metals includes a commitment to net zero. This means we will minimize emissions as much as possible, and use carbon offsets for any remaining impacts. We report annually on our environmental impact. Our selective harvesting system design minimizes emissions in the following ways:
   a. AUVs are electric, and we are investigating renewable energy sources for battery charging
   b. No riser pump, ship-to-ship transfer, or onboard separation of nodules from sediment and water

c. We are working on a launch and recovery system that does not require our ships to have dynamic positioning.



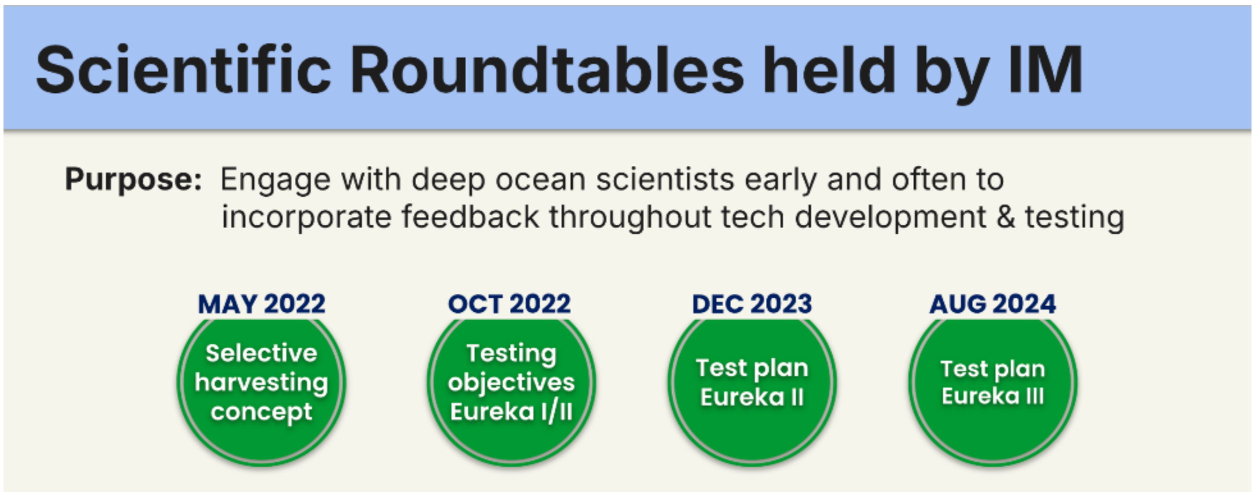
B.7 How will Impossible Metals prove selective harvesting has a lower environmental impact than competing technologies?

The only way we can prove our impact level is to collect nodules from the seafloor, so that is what we will do. We will carry out a test where our robot picks up nodules, typically called “component testing” or “test mining,” depending on scope. During this test, there will be a wide range of environmental monitoring to characterize the environmental impact, including sediment monitoring and a photomosaic with detailed imagery before and after the test. Before the test, sediment modeling will be carried out to estimate the sediment disturbance. Impossible Metals is committed to transparency about all modeling and monitoring results.

Impossible Metals is collaborating with BGR to test our hovering selective harvesting robot for collecting critical metals from the seabed. See the press release.

B.8 How does Impossible Metals work with marine scientists?

Impossible Metals started engaging with marine scientists early in our company's history, with initial discussions about selective harvesting in April and May 2022. Since then, we have continued to engage scientists to discuss vehicle testing and monitoring and will continue to carry out this engagement as we develop our technology. Additionally, we will leverage the expertise of marine scientists to monitor the environmental impacts of selective harvesting during testing. See the roundtable summaries.



B.9 What are the standards that Impossible Metals has committed to following for responsible metals sourcing?

- Protects safety and human rights.
- Are carbon neutral.
- Maximizes the potential for recycling and circularity.
- Eliminates toxic waste.
- Avoids widespread habitat destruction.
- Avoids water scarcity.
- Avoids loss of biodiversity.
- Avoids displacing Indigenous people or communities.

B.10 What data has Impossible Metals published?

Impossible Metals has published the following data to its public data folder:

- ESG Annual Reports
- Eureka I Demo Days May 17-18, 2023
- Eureka II Demo Days Nov 12-13 2024
- Eureka III BGR test in CCZ

- MediaKit
- Ocean Deployment - Public Data
- Public Presentations
- Scientific Engagement Round Table Reports
- Techno Economic Analysis (TEA)

B.11 What is Impossible Metal's commitment to the UN Sustainable Development Goals (SDGs)?

- SDG Goal 5 – Achieve Gender Equality and Empower All Women and Girls.
- SDG Goal 6 – Clean Water and Sanitation.
- SDG Goal 7 – Affordable and Clean Energy.
- SDG Goal 9 – Innovation, Industry and Infrastructure.
- SDG Goal 12 – Responsible Consumption & Production.
- SDG Goal 13 – Climate Action.
- SDG Goal 14 – Life Below Water.
- SDG Goal 15 – Life on Land.

B.12 Do we know enough about the deep ocean to start deep sea mining?

If you were to point to a random point in the deep ocean, we likely would need more information to start mining there. However, the areas proposed for deep sea mining are some of the best-explored areas of abyssal plains in the world. In international waters, at least three years of environmental baseline information must be collected, characterizing biodiversity and the ecosystem, the physical and chemical characteristics of the water and sediment, and their interactions. Some exploration permit holders have been doing baseline studies for over 20 years! For more on this topic, check out our blog, "Data from the Deep Seabed - What Do We Know?"

B.13 What are the most significant human impacts on ocean life?

Currently, deep sea mining is not occurring. Existing industries that impact ocean life are fishing (particularly bottom trawling), oil and gas, offshore wind, and shipping. Bottom trawling is of particular concern as it scrapes the ocean floor, destroying and disrupting habitats and ecosystems. Bottom trawlers catch 26 percent of the total global marine fisheries catch. Additionally, many industries contribute to the global issue of climate change, which impacts the ocean through warming, deoxygenation, and ocean acidification.

B.14 What are the environmental & social impacts of land-based mining for nickel?

Land-based nickel mining has significant environmental impacts, with the severity varying based on the regulatory frameworks in different jurisdictions. Indonesia and the Philippines produced 58.2% of the world's nickel in 2022, largely from deposits located beneath rainforest ecosystems. In addition to environmental destruction, poor social protections put local communities at risk, including Indigenous communities, which have the right to free, prior, informed consent under the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP).

Watch a video about Indonesian nickel mining (BBC News)

Watch a video about Philippines nickel mining (FRANCE 24)

B.15 What are the environmental & social impacts of land-based mining for cobalt?

The Democratic Republic of the Congo (DRC) supplies an overwhelming 68% of the world's cobalt and has half of global land reserves, so the significant impacts in the DRC are especially notable. Amnesty International reports that cobalt (and copper) mining in the DRC has led to *"the forced eviction of entire communities and grievous human rights abuses including sexual assault, arson, and beatings."* Additionally, it is well-documented that DRC mines use child labour. The US Department of Labor states that, "*While mining is on the DRC's list of hazardous activities for which children's work is forbidden, the majority of cobalt mining in the DRC is done informally, where monitoring and enforcement are poor."* These social issues in the DRC are compounded by environmental hazards, such as deforestation, toxic tailings, and soil erosion/degradation that further threaten human health and wellness.

To learn more, check out "Cobalt Red", a book by Siddharth Kara.

B.16 What is Impossible Metals' stance on calls for a deep sea mining moratorium, pause or ban?

We want the environmental bar to be set high and for the industry to innovate to reach it. A ban would stop innovation and remove significant funding for scientific research. It is well established that we will need a lot of critical minerals for the energy transition away from fossil fuels (e.g. IEA, World Bank Group). Deep sea mining represents an opportunity for environmentally and socially responsible access to these resources. Consumer demand for responsibly sourced materials is rising, so we should define what that looks like and empower the innovators to do their work. We also feel that a holistic approach to critical minerals is required. A deep sea mining moratorium, pause, or ban would only result in more land-based mining impacts and will make it impossible to achieve Net-Zero by 2050.

B.17 NGOs cite that many countries and companies have signed up for a moratorium, pause, or ban. What is Impossible Metals' view on this?

A number of countries are listed as having signed up for a moratorium, pause, or ban. Although these countries may have made public statements, the vast majority have not passed legislation. In fact, these countries have signed UNCLOS, which legally commits them to deep sea mining regulated by the ISA. Some of these countries have sponsored exploration applications. If they legally supported a moratorium, pause, or ban, they would be in violation of their legal obligations and could lose their exploration areas.

A number of companies are listed as having signed up for a moratorium, pause, or ban. The wording says, “Before any potential deep seabed mining occurs, it needs to be clearly demonstrated that such activities can be managed in a way that ensures the effective protection of the marine environment.” This is the purpose of the Environmental Impact Assessment (EIA), which must be approved by the regulator before any mining can start. After a regulator approves an exploitation application, the EIA will provide for protecting the marine environment. So, any companies that have signed the moratorium will be free to purchase deep sea minerals. Also see this blog post for more information.

C. Deep Sea Mining Regulations

C.1 Is deep sea mining happening right now?

The exploration phase of collecting deep-sea minerals has begun. So far, no commercial collection has taken place in the deep sea. To date, approximately 40 exploration licenses have been awarded: 31 by the International Seabed Authority (ISA) and the remainder by different governments within their exclusive economic zones (EEZ). There are 22 exploration resource areas for nodules: 19 from the ISA and 3 from the Cook Islands.

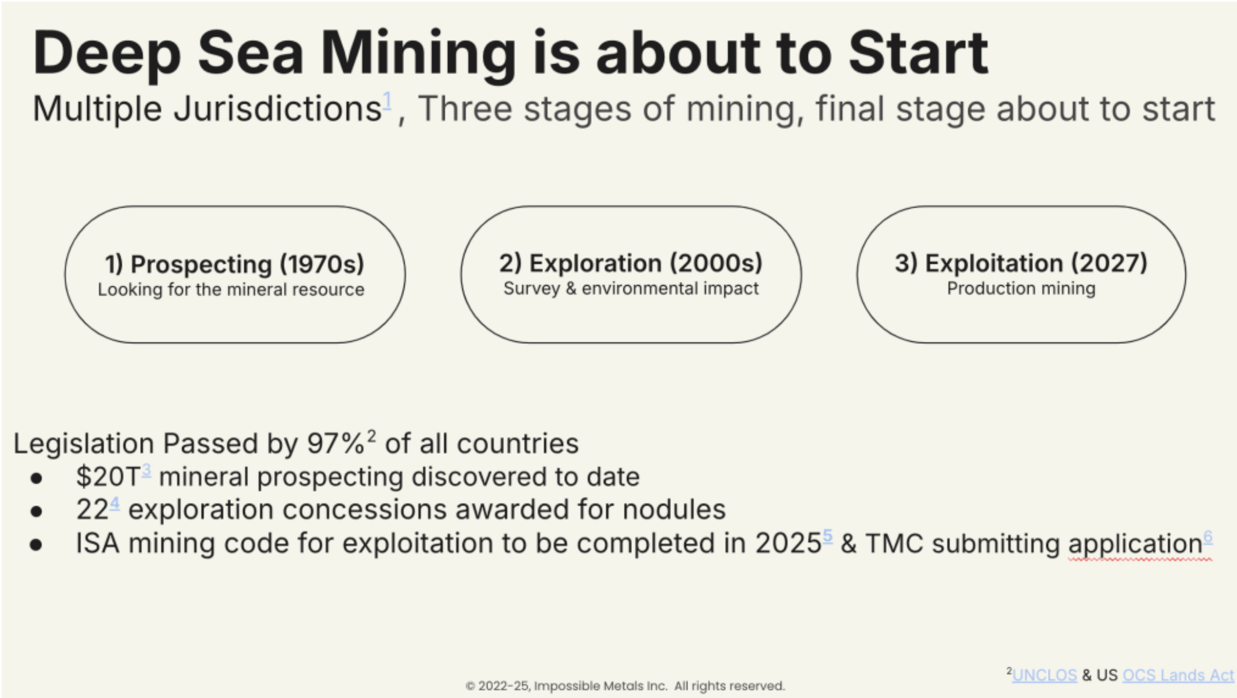
C.2 Who regulates deep sea minerals?

Individual countries govern the deep sea minerals within their EEZs. In international waters, deep sea minerals are governed by the United Nations (UN) through the "United Nations Convention Law Of the Sea (UNCLOS)." 169 countries, including the European Union, are signatories of UNCLOS. UNCLOS is controlled and enforced by the International Seabed Authority (ISA), an autonomous organization within the United Nations common system. For more details, please see the blog post "Current Status of Deep Sea Mining Regulations."

C.3 What is the current status of deep sea mining regulations?

Exploration regulations have been in force for many years. Exploration includes analyzing deposits, testing systems, and equipment, and completing environmental baseline, scientific, technical, and economic studies; no commercial activity is permitted under exploration.

Exploitation (commercial mining) regulations have been under development for many years. The ISA has stated that the exploitation regulations will be adopted in 2025. Multiple countries, including the Cook Islands, have awarded exploration licenses within their exclusive economic zones. For more details, please see the blog post "Current Status of Deep Sea Mining Regulations."



C.4 Does a comprehensive baseline have to exhaustively measure every ecosystem component and solve every aspect of ocean science? If so, how can this be achieved in 3–5 years?

No. No single baseline for any development project can hope to solve ocean science and answer every question. A baseline project is not an unbounded ocean research exercise. The scope of a baseline project is defined by an EIA Scoping Study that identifies the parameters essential to assessing impacts and that directly connect to monitoring key indicators. However, there is an interface between a baseline project and regional and global ocean science objectives. By aggregating results across several individual baseline projects using consistent methods, regional assessments are made, and by integrating across information sources, the knowledge of global ocean science is improved. Publishing the objective findings of baseline studies is a key global knowledge enhancement process.

C.5 How are nodule-rich areas mapped and identified?

Nodule-rich areas are mapped and identified as part of the mining prospecting and exploration phase (not our focus). A traditional AUV with wideband sonar and box core samples performs the mapping. The essential data is nodule abundance measured in kg per square meter and metal grade. The metal grade is by collecting multiple box core samples and sending the nodules to the lab to measure the ore grade. Multiple NI-43-101 resource estimations have been completed for deep-sea minerals. The resource estimations are much more complex on land as the resource is three-dimensional compared to two-dimensional on the seabed. Holes are drilled, and an estimate of the three-dimensional resources is calculated.

C.6 How much does it cost, and how long does it take to run the Environmental Impact Assessment (EIA) program for deep sea mining?

Collecting and analyzing the data and writing the Environmental Impact Statement (EIS) report typically take three to five years. This is the primary purpose of the exploration license, which typically costs around $30–80M.

C.7 Do stakeholders and the public get a say in the EIA?

Yes. Stakeholders are engaged throughout the EIA process. EIS submission typically involves a public consultation period during which any parties can provide comments registered by the regulator and proponent and require assessment.

C.8 What else does an EIS (Environmental Impact Statement) contain?

Additional elements of an EIS include stakeholder consultation outcomes, Environmental Management and Monitoring Plans, closure plans, and adaptive management measures. An EIS typically assesses project alternatives and states the no-development case. A level of Cumulative Impact Assessment (CIA) is typically required.

For more details on the EIA, see this blog post.

C.9 **If EIAs are paid for or authored by the proponent, can they be objective and trusted?**

Yes. Environmental Impact Assessment (EIA) is a branch of environmental science performed by objective professionals with the necessary qualifications and experience. Given the oversight in modern EIA practice, project approvals do not benefit from poor-quality EIAs or overt client advocacy. EIA specialists do not engage in client advocacy. Furthermore, independent reviews, panels, committees, and hearings are standard practices in EIA.

C.10 Once an EIA is submitted, is the regulatory body forced to award an environmental permit?

No. The award of an environmental permit is contingent on a variety of factors. These include the comments from the public consultation period, independent reviews, and regulators' internal assessment processes.

C.11 Can a contractor do whatever they want if an environmental permit is awarded?
No. The permitting process involves setting a range of conditions. Permit conditions can include a range of measures, including additional studies, revised modeling, additional monitoring requirements, etc. Regular reporting and independent monitoring are also part of the checks and balances applied.

C.12 Does approval require consensus?
No. EIS does not seek consensus among all parties, and the award of an environmental permit does not require a response to every public comment on every topic.

C.13 When do you expect exploitation contracts to be awarded?

Exploitation regulations are in the final stages of being adopted by multiple regulators. It is anticipated that the earliest date an exploitation contract could be awarded and production mining started is 2027.

C.14 Why has the United States not ratified UNCLOS?

169 countries, plus the European Union, have ratified UNCLOS. This represents 7.5 billion people (93%) of the world's population. In the United States, there has been a vigorous debate over the treaty's ratification, with criticism primarily coming from political conservatives who raised concerns about the Convention's impact on U.S. sovereignty.See more details in the 60 minutes TV program from March 2024.

C.15 Will there be a royalty for deep sea mining?

Yes. All mining typically has a royalty, paid for access to the resource. The ISA Finance Committee is working on equitable finance sharing from deep seabed mining. This is likely to result in a royalty. See the blog post "For All Mankind: How Deep Sea Minerals Could Pay Children in Africa to Go to School Instead of Mining**"** for more information.

C.16 What deep sea mining legislation has been passed?

- US Outer Continental Shelf (OCS) Lands Act, 1953
- US Deep Seabed Hard Mineral Resources Act (DSHMRA), 1980
- International UNCLOS, 1982
- India Offshore (Development and Regulation) Areas Mineral Act, 2002
- Cook Islands, Seabed Minerals Act, 2019

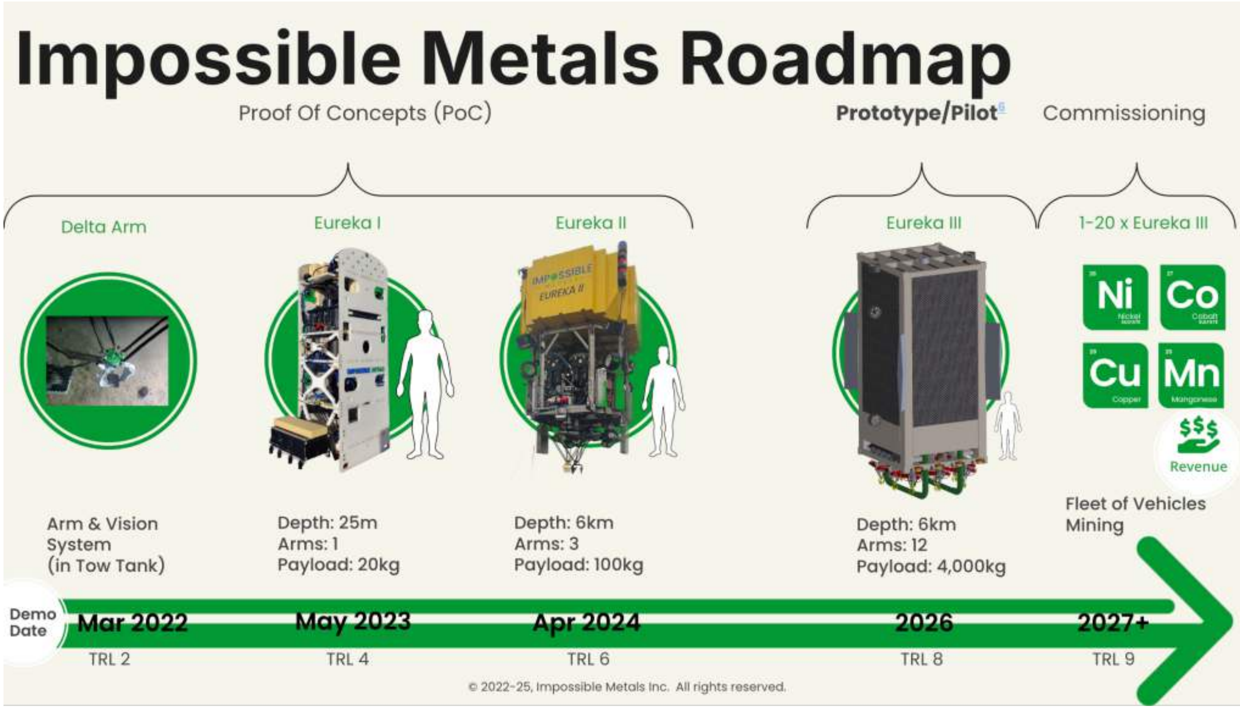
D. Impossible Metals Technology

D.1 How is Impossible Metals technology different from others?
Impossible Metals leverages advanced autonomous robotics and AI technology to conduct underwater mining with minimal environmental impact. Unlike traditional methods that rely on destructive dredging, our underwater robots—formally known as Autonomous Underwater Vehicles (AUVs)—selectively harvest critical minerals while preserving marine ecosystems. Our technology ensures sustainability and efficiency, setting a new standard for responsible underwater mining. A list of deep sea dredging tractors + Eureka II AUV is here.

See this video: Compare Impossible Metals vs Conventional Dredging for Deep Sea Mining

D.2 What technical risks do Impossible Metals still have to mitigate?
Our primary technical risks include ensuring the durability and resilience of our robots in harsh underwater conditions, refining our AI algorithms for optimal target identification and resource recovery, and maintaining reliable communication systems between our robots and surface operations. We are actively working on mitigating these risks through rigorous testing, continuous improvement, and strategic partnerships with leading technology providers.

D.3 When will your technology be ready for commercial mining operations?
Our technology will be ready for commercial mining operations by 2027. As of mid-2025, we are in the final stages of testing and validation, ensuring our systems meet all performance requirements. We also engage with potential customers to align our development with market needs and expectations. We have also completed the design of Eureka III, the full-size production system.



D.4 How do you scale to high rates of production?

Our latest economic model is v6. Each Eureka IV, our planned production-scale underwater robot, will be able to deliver 12 dry metric tonnes of nodules to the transport ship every 4.3 hours. The same vehicle performs over 5.5 trips per day to deliver an average of 66 metric tons to the transport ship. 100 Eureka IV robots operating in parallel would harvest 6,600 tons per day. No fundamental limit exists on how many underwater robots and transport ships are deployed. We anticipate a volume production per location of around 6.8 million dry tons of nodules annually.

D.5 How reliable will your technology be?

Reliability is a cornerstone of our technology development. Our robots are designed with multiple fail-safes, redundancy systems, and real-time monitoring capabilities to ensure consistent performance in various underwater conditions. We conduct extensive testing under simulated and real-world conditions to validate the reliability and durability of our systems.

See also this blog post: [Prioritizing Reliability: Reducing the Mean Time Between Failures](#).

D.6 How do you deal with the complexity of your technology?

We address the complexity of our technology through a modular design approach, enabling easy maintenance and upgrades. Our interdisciplinary team of experts continuously collaborates to integrate cutting-edge robotics, AI, and marine engineering advancements.

D.7 How is the robot (AUV) controlled?

A mission plan is uploaded to each robot before deployment. The robot is fully autonomous and completes the mission plan based on sensors and programming. The robot's progress is monitored through an acoustic modem (USBL) that tracks the robot's position and provides low bandwidth status information. The fleet management software on the surface will automatically send essential speed and course adjustment information to the robots in the water to support synchronization of the robotic vehicle launch and recovery. Additionally, the operator on the surface vessel can provide override commands when required.

D.8 Why is your underwater nodule collection robot untethered?

To allow many robots to operate in parallel, we need to eliminate the need to manage a tether (cable) to each of the robots. Each robot is battery-powered.

D.9 What are the size ranges of nodules that the underwater robot’s robotic arms pick up?

The current end effector and internal nodule conveyor can accommodate a wide range of nodule sizes from 2 cm to 11 cm diameter. Refinement to the end effector design and conveyor for the production system will be customized to the nodule distribution in the field of operation. Our current v6 concept economic model assumes targeting the largest nodules in the field picking nodules 6.5 cm diameter and larger. An average nodule collection diameter of 8 cm is assumed based on available size distribution data.

D.10 How does the underwater robot maintain its position and orientation on the ocean floor? What technologies facilitate the underwater robot's underwater navigation and mapping?

The underwater robot incorporates several standard environmental awareness sensors, such as DVL (Doppler Velocity Log), pressure sensors, USBL (ultra-short baseline), and Stereo Cameras, which are fed into the INS (inertial navigation system), where the information is fused to develop a state estimation for the AUV. As multiple AUVs begin to operate concurrently, a dynamic LBL (Long BaseLine) positioning approach will also be employed.

More information about subsea positioning

The state estimation accuracy for the AUV will be highest at the seafloor, where it is in proximity to other AUVs that have maintained a high accuracy, and near the surface, where it is close to the surface vessel-based USBL. When at the surface, the position will be based almost exclusively on USBL. When at the seafloor, the dynamic LBL combined with DVL and vision tracking of the seafloor will dominate. The stereo cameras on the front of the AUV map out the locations of any nodules and any macro life for the arm control algorithms to determine how to handle them.

D.11 How does the underwater robot adapt to changing seabed topography during its mission?

As the underwater robot travels through the mission, it adjusts the operating mode from having a desired depth while it travels down through the water, and then, as the acoustic sensors and optical sensors begin to observe the seafloor, the vehicle autonomously transitions to altitude control. Altitude control will be active while collecting nodules. The vertical thrusters adjust the force they exert to maintain the set altitude for the AUV over the seafloor. As nodules are collected, the buoyancy engines on board the AUV pump water out of the tanks to maintain the same small desired downward force from the vertical thrusters.

The seafloor's typography, where we will collect nodules, gradually changes, and the vehicle travels relatively slowly. A forward-looking sonar provides feedback to the system for topography changes that are too much for the vertical thrusters to manage.

D.12 How will multiple underwater robots coordinate to avoid overlapping or interfering with each other's missions and paths?

Each underwater robot will be provided with a mission as part of pre-launch communications. Through the ship-based USBL and seafloor dynamic LBL positioning, the robot will move to the desired target starting location. At the start and end of each path, the robot will perform a small visual survey. When arriving at the start of a run, the robot will survey the area briefly to ensure that the positional alignment of the new path is correctly positioned relative to the start or end of the robot from past paths. It will use the distinctive pattern of nodules in the survey as a fingerprint to understand any centimeter-level misalignments that the navigation system is experiencing relative to the navigation system from other robot trips to the same location.

D.13 What is the typical operational lifespan of the underwater robot?

Our current economic model is v6. In our economics, we model a 25-year effective life for the underwater robots. Underwater vehicles, when maintained, can last well beyond 25 years. The JASON ROV, launched in 1988, is a good example of this. We will spend about 10% of the total CAPEX each year on the maintenance of our equipment. This high degree of maintenance ensures that continued operation is similar to an airplane.

D.14 What factors influence the lifespan of an underwater robot, and how can it be extended?

The main factors that influence underwater robots in general are maintenance management for:

- Corrosion: Low-corrosion materials and sacrificial anodes are used and replaced as needed.
- Biofouling: The ongoing maintenance will include a maintenance schedule for clearing acoustic and optical surfaces to prevent biofouling build-up.
- Moving component wear and tear: The primary cost factor for maintenance is rebuilding components due to wear and tear or in the event of failure, and we've incorporated it into the economic model. (Learn more about analysis in this blog post.)
- Electronics failure: In the event of a complete loss of power or control, the robot will always remain positively buoyant and float to the surface.

Since we are operating a large fleet of underwater robots, we can collect performance and required maintenance data on a statistically significant scale and employ maintenance insights based on this information.

See also this blog post: Prioritizing Reliability: Reducing the Mean Time Between Failures.

D.15 How is the mission assigned to the underwater robot?

Before deployment, the mission is wirelessly uploaded via WiFi to the underwater robot while on deck. During operation, deviations from this initial plan can be uploaded to the robot via the acoustic link. The plan that is initially uploaded and the following deviations are provided by the master software, which is constantly developing updated operational optimization.

D.16 What is the efficiency of the underwater robot's collecting system?

Eureka III delivers four dry metric tons of nodules every 3.8 hours. Eureka IV delivers 12 dry metric tons. The breakdown of the mission time for Eureka III is as follows:

1. Launch Eureka from transport vessel to ocean: 1 minute
2. Dive Eureka to seabed at 4.7km depth: 68.8 minutes
3. Harvest nodules to fill Eureka payload: 53.1 minutes
4. Rise Eureka up the 5km water column: 68.8 minutes
5. Recovery of Eureka from the ocean to the transport vessel using our Smart Launch and Recovery System (SLARS): 4 minutes
6. In parallel on the vessel: 30 minutes
7. Unload Eureka payload of nodules to the transport vessel
8. Eureka battery swapped for fully charged new battery pack
9. Eureka vehicle maintenance
10. Download of mission data
11. Upload of next mission

Total = 255.6 minutes or 3.8 hours

Please also see Question **D.4 How do you scale to high production rates?**

D.17 How are the underwater robot's lithium-ion batteries recharged? What is the power source?

Today, we use a diesel generator to recharge the batteries. In our economic model, we capture the carbon from the diesel generator or pay for carbon offsetting. In the long term, we will look for a renewable power source, such as waves, wind, etc.

D.18 How will the underwater robot respond to emergencies or system failures?

The response of the underwater robot depends on the nature of the emergency or failure. Awareness of emergencies and failures external to the individual robot will be communicated acoustically through the USBL, and the updated desired behavior of the robot will react accordingly. For example, suppose the surface vessel becomes unavailable due to incoming weather conditions or an onboard emergency such as a fire. In that case, the communication signal will be sent to the robot to change its course or hold in place until the weather has passed or operations can be resumed in extreme cases with the second ship in the operations.

For small internal failures to the robot, such as loss of connection to certain computers or components, an isolated power reset will occur to re-establish the connection. If the error persists, the mission will abort. Other small failures, for example, could be a break to an arm, and in these cases, the robot is expected to complete the mission and have the damage repaired at the surface.

Each vehicle has a high degree of redundancy, and there are limited single points of failure. An example of a failure that will result in an aborted mission and an emergency ascent is if a leak detection sensor is triggered.

A final active emergency response if the robot is not rising to the surface due to loss of power to achieve this or for any other reason, it will release the load in the hopper; actively attempted if control electronics and power are available or triggered passively using a time delay corrosion fuse that will release the load after approximately 1.5 weeks have passed.

In all cases, a locating beacon on a separate power supply will ping to inform the surface ship of its position if the beacon loses communication with the rest of the vehicle.

See also **D.32 How long can the robots remain underwater to deal with weather and emergencies?**

D.19 Are there any specialized tools or equipment for the maintenance of the underwater robot?

While no substantially specialized tools are required for maintaining the underwater robots, while onboard the vessel, it is impossible to travel to the hardware store to pick up what is needed, so a complete set of required tools and redundancies will be available on the vessel.

D.20 Are there any limitations to the large-scale deployment of underwater robots?
No, the limitation of our operations is the rate at which the underwater robots are lifted onto the vessels. By increasing the number of vessels concurrently operating, the number of underwater robots doesn’t have limitations.

D.21 What is the data storage capacity of the underwater robot?

Many terabytes of storage will be available onboard the underwater robots, providing more data storage capacity than is required. Additionally, redundancy will be in place to protect against corrupted drive failures.

D.22 What communication protocols enable data exchange between the underwater robot and its mothership/operating center?

An acoustic link (USBL) transmits basic telemetry and status information between the underwater robots and the surface ship. Due to the low bandwidth of the acoustic link, we are limited in terms of what data is transmitted while the robots are submerged. Once a robot has surfaced as part of its on-deck servicing, the onboard data is transferred off the robot and into the on-ship data center. Data is exchanged between the ship and the cloud-based servers via TCP/IP connection over satellite. Lastly, upon arriving back at port, any data that has not been wirelessly transmitted into the data center is physically connected and transferred into the data center. A prioritization scheme will be developed to transfer the most critical information first.

D.23 What recovery protocols are in place if the underwater robot loses communication with the operating center?

The mission is downloaded to the underwater robot at the start of the mission. We don't need real-time communication. In an emergency, the robot will go to the surface and use WiFi or satellite communication to communicate with the operating center.

D.24 What will the effect of temperature and salinity be on the underwater robot?

Temperature and salinity at the depths at which we operate are very consistent. This impacts the index of refraction for our optical and acoustic systems, and variation in these values at the depth and through the water column is compensated for during operation.

D.25 How do harsh marine weather conditions affect the reliability and efficiency of underwater robot deployment and recovery operations?

A common practice for docking autonomous underwater vehicles is securing them below the water's surface so surface waves do not impact them and changing weather conditions. We are using this approach for the underwater robot's recovery operations.

Our techno-economic models assume 40 days a year when we are in a 'weather hold' condition and cannot operate.

D.26 How does the underwater robot withstand extreme ocean pressures?

We design for this using pressure vessels to protect the components and, in other cases, oil-compensate when the internal electronics are pressure tolerant but need to be isolated from the seawater. These are both common techniques for design in underwater robots.

D.27 How does the underwater robot's design and propulsion system handle strong ocean currents?

From the extensive exploration data, we know that there are very few currents in the deep ocean. We have thrusters and control surfaces for navigating the underwater robot in the water column. Also, in the mission control software, we receive the sensor data in real-time via USBL and update the mission parameters.

D.28 What is the accuracy and resolution of the vision system?

At the altitude of 1 meter where we are currently operating, the resolution ranges from 1.25 mm to 0.38 mm on the seafloor, depending on which camera and where in the camera field of view is being considered. The goal for the vision system is to detect life larger than 1 mm with 95% accuracy.

D.29 How does the underwater robot vision system adapt to underwater environments such as turbid water, varying seabed types, etc?

The nodule location is a consistent environment with a flat seabed and clear water. The underwater robot does not need to adapt to different environments autonomously. The size and shape of the nodules can vary from one region with nodules to another, and the algorithms for these new environments will need to be adapted. Still, this adaptation takes place at the development level, not in the autonomous behavior of the underwater robot.

D.30 Won't local sediment disturbance obscure the vision system from identifying nodules and life on the nodules?

The design of the robotic arms, the claw, the arm's movement, and the claw's position on the nodule are optimized to minimize local sediment disturbance. Even so, some local sediment disturbance can occur when the nodule is picked. The cameras identify the location of the nodule in front of the vehicle. The nodule's location is tracked relative to the robot through precise tracking of the vehicle position. Even with the nodule out of sight from the camera, because the robot's position is precisely tracked, the nodule's location is understood, enabling the arm to pick it. With the nodule under the vehicle, the arm picks it, and any disturbed sediment is well behind the camera. Additionally, the vehicle will travel primarily into any current that exists. Between the vehicle motion and the surrounding currents, any sediment distributed under the vehicle will remain behind the vehicle.

D.31 How can you scale to millions of tons of nodules?

Each Eureka IV robot has approximately 12 arms with a 12-metric-ton payload. The Eureka IV can be reused every 3 hours. So, in 24 hours, 8 missions can be completed, delivering 8 * 12 = 96 metric tons per 24 hours. A fleet of 200 Eureka IV robots can deliver 19,200 metric tons per 24 hours using 4 vessels, which translates to 6 million metric tons per year, assuming ~312 production days a year. (Assuming around 53 days a year when a weather hold is in operation.)

Future Eureka Versions

Eureka III
Depth Rating: 6,000m
Payload Capacity: 4,000 kg
Arms: 12
Dimensions: 5.1m x 2.4m x 2.6m
Weight in Air: 4,950kg
Battery Capacity: 135 kWh
$1.8M Cost
$147 Cost per dry tonne to shore

Eureka IV
Depth Rating: 6,000m
Payload Capacity: 12,000 kg
Arms: 16
Dimensions: 12.2m x 2.4m x 2.6m
Weight in Air: 11,250kg
Battery Capacity: 400 kWh
$3.2M Cost
$124 Cost per dry tonne to shore

E. Transport Vessels

E.1 How is the payload secured and stabilized on the ship once off-loaded from the AUV?

Nodules are offloaded from the AUVs into storage onboard the vessel. The current economic models assume the use of bulk ore transport vessels. We continue to explore alternative novel methods, such as containerizing the nodules onboard the vessel. This method could eliminate vessel stability concerns related to liquefaction of the load. This also provides economic benefits, increasing the number of ports where the nodules can be transported.

E.2 A**re there backup systems for critical functions?**

Yes, a minimum of two vessels operate in the field, and while one is transiting to port, the other is servicing the robots. This inherently provides a level of redundancy if critical systems for one of the vessels take one ship out of operation. Additionally, parallel operations on each vessel are planned, with 36 launch and recovery systems on board each vessel and parallel materials handling equipment on each vessel, eliminating single points of failure.

E.3 Are there any alternative or renewable energy sources to power the vessels?

We hope so, and our architecture and commercial model for the vessels enable us to use the best available technology. People are working on batteries, Hydrogen, and Ammonia energy systems for ships. Others are working to capture the carbon from the engines. We will adopt the best technology that is available.

E.4 Do you require dynamic positioning (DP) vessels?
Yes, our current expectation is that some level of DP will be needed, and we continue to reduce this requirement with a target to minimize the use of this capability and ideally eliminate the need for installation of this capability. Our smart launch and recovery system (SLARS) has been designed with self-mobility of the hook to engage with the AUVs at a distance from the ship, enabling the potential for minimal use and capability of the ship's DP, and potentially the elimination of this functionality altogether.

E.5 Does Impossible Metals architecture require a production support vessel?

No. We avoid the cost and complexity of a production support vessel (PSV). Impossible Metals retrofits our smart launch and recovery system (SLARS) to the transport vessels. This has a massive saving in costs.

E.6 Does Impossible Metals require a ship-to-ship transfer in the ocean?

No. As we do not require a production support vessel (PSV) we do not need to do the following transfers to the Shuttle Transport And Resupply Ship (STARS):

- Transfer of nodules from the PSV
- Transfer of fuel to the PSV
- Transport of equipment, and provisions to the PSV
- Transfer of personnel to and from the PSV per crew rotation.

This will be very expensive, and there are safety concerns. It will also reduce the number of days a year the mining operation can operate.

For more details, see [STARS; the missing link in dsm supply chain.]

E.7 How many days a year do you expect to be harvesting?

As we do not have any tethers and have a smart launch and recovery system, we can operate in a much wider range of sea states. V6 of our economic model assumes we can operate for 325 days a year.

F. Impossible Metals Company

F.1 When was Impossible Metals incorporated?

Impossible Metals was incorporated in 2020 as a Delaware B Corporation, a public benefits corporation ("B Corp").

F.2 What is Impossible Metals' public benefit?

The corporation's specific public benefit purpose is to deliver responsibly mined and processed battery metals to the market in a manner that promotes sustainability, transparency, and accountability and to render a public benefit by accelerating the world's transition to sustainable energy to mitigate the climate crisis.

F.3 What is Impossible Metals' vision?

Accelerating clean energy by delivering the most sustainable critical metals.

F.4 What is Impossible Metals' mission?

To harvest and process critical metals from the seabed while protecting the environment.

F.5 What are Impossible Metals' Core Values?

1. Planet comes first: environment and people before profit.
2. We are determined, striving to make the impossible possible.
3. We encourage, share and respect all perspectives.
4. We move fast, separating what must be done now from what can be improved later.
5. We embrace and learn from every success and failure.
6. We act as owners, managing resources responsibility and efficiently.

F.6 How much seed funding has Impossible Metals raised to date?

Around $15M. We closed our seed round in May 2022 of $10M and pre-seed round of $2M in September 2021.We have also received government grants and additional investor funding.

F.7 Who are Impossible Metals' investors?

Chalet, Y Combinator, Justin Hamilton, and many smaller funds and individuals.

More details: https://impossiblemetals.com/about/partners/

F.8 Where is Impossible Metals based?

HQ: San Jose, CA, USA

Design centre: Collingwood, ON, Canada

F.9 Who are the leadership and board members of Impossible Metals?

See the leadership team here.

See the board members here.

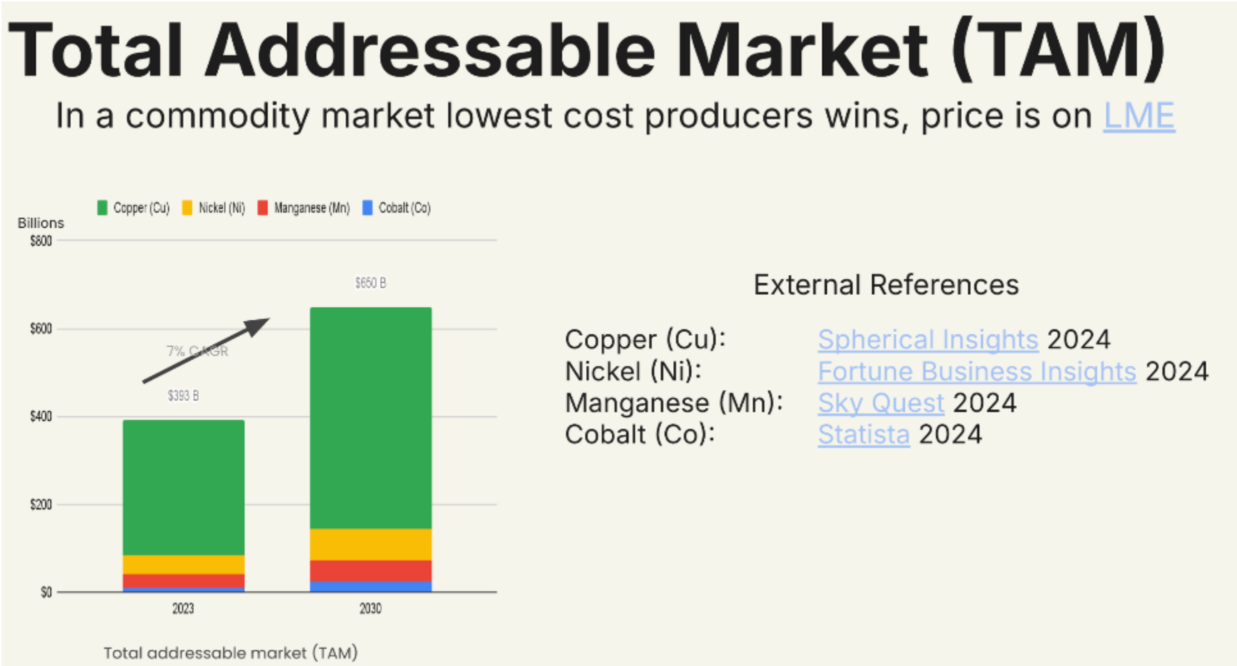
F.10 What is Impossible Metals' business model?

Impossible Metals intends to partner with companies that hold deep-sea mineral exploration areas, leverage third parties to process (refine) the metals and sell the resulting offtake. In the longer term, Impossible Metals intends to apply for its own exploration areas.

F.11 What is the total available market (TAM) for Impossible Metals?

Polymetallic nodules contain four metals (nickel, cobalt, copper, manganese). The TAM for the four metals in 2023 was $393B per year, and will be $650B in 2030. The market is growing at a compound annual growth rate (CAGR) of over 7%. External references:

Copper (Cu):	Spherical Insights 2024
Nickel (Ni):	Fortune Business Insights 2024
Manganese (Mn):	Sky Quest 2024
Cobalt (Co):	Statista 2024



F.12 What happened to the mineral processing team?

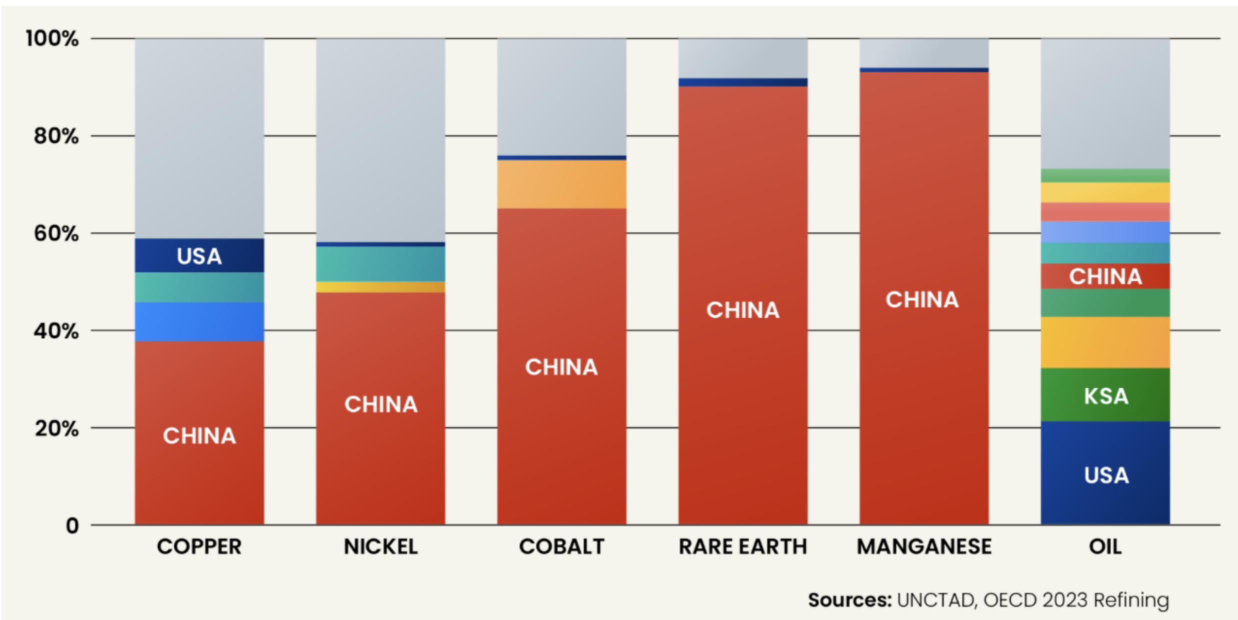
In April 2024, this team was spun out into a new company called Viridian Biometals. Impossible Metals maintains a minority holding in Viridian Biometals.

G. Impossible Metals Competitors

G.1 Who are Impossible Metals competitors?

Impossible Metals has competition from land- and ocean-based mining companies for nickel, cobalt, copper, and manganese.

G.2 Which countries control land-based mining for critical metals?



G.3 Who makes competing dredging tractor and riser systems?

A list of deep sea dredging tractors + Eureka II AUV is here.

See this video: [Compare Impossible Metals vs Conventional Dredging for Deep Sea Mining]

G.4 What technical risks do competing dredging tractor and riser systems still have to mitigate?

A number of companies have conducted dredging tractor and riser system deep sea trials; however, the ship-to-ship transfer of the nodules has not been tested. The ship-to-ship transfer of the nodules in the ocean is complex and will likely require very specialized transport ships, including dynamic positioning (DP) and dewatering technology. This article includes more details on this topic.

G.5 How does the cost of Impossible Metals technology compare to dredging technology?

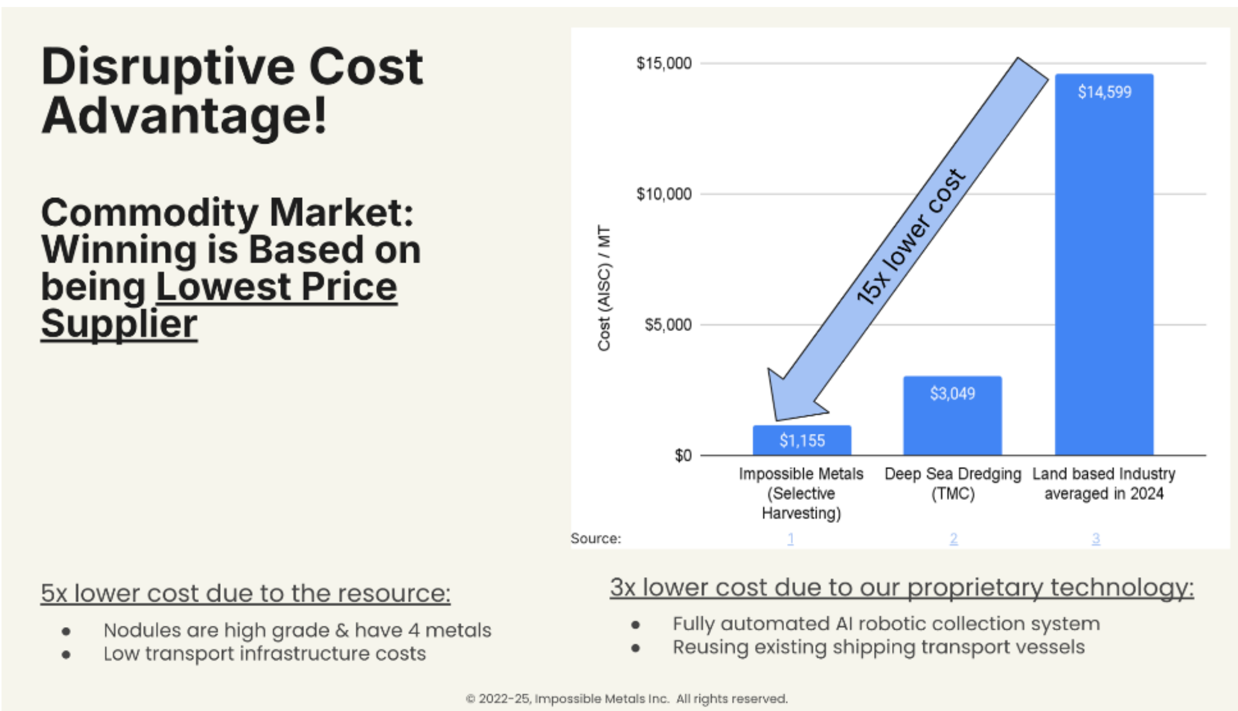
We expect Impossible Metals' approach to be the lowest-cost method for deep-sea mining. A fleet of robots has three primary economic benefits compared to dredge and riser-based systems.

The first is the improved economics for a fully operating system. This is achieved through reduced capital expenses (CapEx) by eliminating the need for a dedicated surface production vessel to support equipment such as a riser system. With the Impossible Metals approach, the transport ships pull the robots from the water, collecting the ore without needing ship-to-ship ore transfer.

The second benefit is the ability to scale the system through the incremental addition of CapEx. A small-scale operation can become operational with a relatively modest initial capital investment. As additional capital is invested, the fleet of robots and, thus, the material throughput can be scaled.

The third economic benefit is the lack of single points of failure. While there are increased points of failure with the fleet of robots, there are no single points of failure, ensuring that the selective harvesting architecture remains operational through these failures.

We estimate our costs for a production-scale operation will be about ¼ less costly than the cost of a dredging tractor with a riser system for the same rate of production.



G.6 Why do we refer to our competitors as using dredging tractors with riser pumps?

The U.S. Army Corps of Engineers defines dredging as “A dredge is a machine that scoops or suctions sediment from the bottom of waterways...” ≈

Although companies are using the ‘Coanda effect’, it is still dredging. The leading dredging companies have built polymetallic nodules collection systems. e.g. All Seas, DEME/GSR, Royal IHC, etc. Dredging tractors for deep sea mining were first described in a 1965 patent 3,456,371.

G.7 How do you compare on scaling with your competitors?

Fleet Production Scaling

Collector	Number of Collectors	Riser Pipe Systems	Production Support Vessel	Days a year of Production	Annual Production Rate (dry tonne million)
Eureka III (Impossible Metals 4MT)	194	No	No	325	2.3
Eureka IV (Impossible Metals 12MT)	245	No	No	325	6.8
Patania III (GSR/DEME)	1	1	1 (70 people[1])	216[1]	1.75[2] (2.5 million wet tones)
Hidden Gem upgraded (The Metals Company)	2	2	1 (130 people[3])	Unknown	2.1[3] (3 million wet tonnes)

[1]Kris Van Nijen 2018 mode, [2]UMC 2024 GSR prestation (4x Patania II), [3]TMC Press Release

H. Mineral Processing of Polymetallic Nodules

H.1 How do you process (refine) nodules into high-purity metals?

Mineral processing is the process of separating commercially valuable minerals from their ores. The first step is called comminution, which involves reducing solid materials from one average particle size to a smaller average particle size, typically through crushing or grinding. The next step is either Pyrometallurgy (the use of heat) or Hydrometallurgy (the use of acid) to separate the valuable metals from the ore. A novel technology using living bacteria to separate metals from ore is in development. One example is Viridian Biometals, which spun out of Impossible Metals.

It has been demonstrated that existing pyrometallurgy and/or hydrometallurgy processes can be used to process nodules. Typically, existing mineral processing plants require modifications to extract multiple metals from the nodules.

H.2 What should be the strategy for mineral processing of the nodules?

Impossible Metals plans to outsource the mineral processing of the nodules. We will pay a fee for each ton of nodules that are refined into high-purity nickel, cobalt, copper, manganese, and possibly rare earth elements. We see three phases:

1. Create a strategic stockpile of nodules in the US to stimulate processing investments.
2. Upgrade existing nickel processing facilities in friendly nations, such as Japan, Australia, and Canada, to process nodules. Efficiency is likely to be around 75%.
3. Build bespoke nodule processing facilities in the US and friendly nations, such as Canada. Efficiency is likely to be around 95%.

H.3 What testing has been done to refine nodules?

The Japanese company Pacific Metals (PAMCO) has processed over 2,000 tons of nodules. Other companies, such as SGS and Hatch, have also developed flow sheets.

<Embedded Webinar by SGS on mineral processing of nodules>
https://youtube.com/watch?v=ajfbHNnrV9U

H.4 What are your requirements for future refining facilities in North America?

Ideally, these facilities will be collocated with deep-water ports, avoiding the need for land transfer of the nodules. The location would ideally have access to low-cost, really clean energy and be geographically close to the customers for the metals.

Deep Sea Mining & Other Industry Glossary

Abyssal plains = underwater plain on the deep ocean floor, usually found at depths between 3,000 and 6,000 meters.

AUV (Autonomous underwater vehicle) = underwater robots that can explore the ocean without a pilot or tether. Battery powered.

Biodiversity = biological diversity among and within plant and animal species in an environment.

Bulk carrier or bulker vessel = merchant ship specially designed to transport unpackaged bulk cargo such as nodules.

CAGR (compound annual growth rate) = business, economics and investing term representing the mean annualized growth rate for compounding values over a given time period.

CCZ (Clarion-Clipperton Zone) = large area in the Pacific Ocean from Hawaii to Mexico.

Container ship or box ship = cargo ship that carries all of its load in truck-size intermodal containers.

CFC (Cobalt-rich Ferromanganese Crusts) = 'Crusts' which form on sediment-free rock surfaces around oceanic seamounts, ocean plateaus, and other elevated features.

Critical Minerals or Metals = Copper, nickel, and cobalt which are essential components in many of today's rapidly growing clean energy applications. Many governments maintain a list of critical minerals.

DP (Dynamic Positioning) = computer-controlled system to automatically maintain a vessel's position and heading by using its own propellers and thrusters.

DSM (Deep Sea Mining) = process of extracting minerals from the deep sea..

ECS (Extended Continental Shelf) = area of the ocean which is part of a continental shelf that extends more than 200 nautical miles from the coast.

EEZ (Exclusive Economic Zone) = area of the ocean, generally extending 200 nautical miles beyond a nation's territorial sea, within which a coastal nation has jurisdiction over both living and nonliving resources.

EIA (Environmental Impact Assessment) = series of baseline and technical studies, modeling, and analysis that aims to understand the receiving environment, the nature, and scale of impacts, identify mitigations, consult and liaise with regulators and stakeholders, interface engineering design and mine planning with environmental risks, assess optionality and weigh various alternatives. An EIA provides a formalized and transparent impact assessment that outlines how project pressures cause effects, how those effects work individually or in concert to cause impacts, and predicts the consequences of impacts in terms of their expected magnitude and duration.

EIS (Environmental Impact Statement) = tool for decision-making. It describes the positive and negative environmental effects of a proposed action.

Eureka I, II, III. IV = Underwater robots (more formally called autonomous underwater vehicles, or AUVs) designed by Impossible metals for selective harvesting of polymetallic nodules from the ocean floor.

EV (electric vehicle) = vehicle that uses one or more electric motors for propulsion.

LARS (launch and recovery system) = device that helps safely launch and recover autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs) from a ship.

ISA (International Seabed Authority) = autonomous international organization that organizes and controls all mineral-resources-related activities in the Area for the benefit of humankind.

L(M)FP (Iron, manganese, phosphorus) = battery chemistry cathode

Megafauna = animals of a given area that can be seen with the unaided eye.

NCA (nickel, cobalt, aluminum) = battery chemistry cathode

NMC (nickel, manganese, cobalt) = battery chemistry cathode

PMN (Polymetallic Nodules) = 'nodules' also known as manganese nodules, are mineral concretions on the ocean floor that contain valuable metals. See Wikipedia.

PSV (Production Support Vessel) = large surface ship that serves as the central facility for deep sea mining operations. PSVs are typically modified from dynamically positioned drillships used in the oil and gas industry. Their primary functions are to:

- Collect, gather, lift, and temporarily store polymetallic nodules
- Store, maintain and control the dredging tractor and riser system
- Dewater the nodules
- Provide power, control, and guidance to the subsea collector
- House the crew that monitors and runs the operations

The temporary storage of nodules only has capacity for a few days of storage. When full, a Shuttle Transport And Resupply Ship (STARS) is required to transfer the nodules to port.

Note Impossible Metals does need PSV.

REEM (Rare Earth Element Muds) = ‘Muds’ mainly contain rare earth elements in the seabed sediment.

ROV (Remotely Operated Vehicle) = free-swimming submersible craft used to perform underwater observation, inspection and physical tasks. The vehicle is tethered to the vessel.

SLARS (Smart Launching and Recovery System) = Impossible Metals technology which allows full autonomous operations of the LARS with a vessel without DP and in a wide range of sea states.

SMS (Seafloor Massive Sulfides) = ‘Vents’ appear on and within the seafloor when mineralized water discharges from a hydrothermal vent.

STARS (Shuttle Transport And Resupply Ship) = specialized ships with DP used to supply the mining Production Support Vessel (PSV). Key tasks performed are:

- Transfer of nodules from the PSV
- Transport of those nodules to the processing facility
- Transport of equipment, fuel and provisions to the PSV
- Transfer of personnel to and from the PSV per crew rotas

Note Impossible Metals does need STARS.

UNCLOS (United Nations Convention on the Law of the Sea) = established a comprehensive international legal framework to govern activities related to the global oceans.
USBL (ultra-short baseline) = method of underwater acoustic positioning as GPS does not work underwater.
TAM (Total addressable market) = metric that estimates the maximum revenue potential for a product or service if it were to capture 100% of a market.