Perspectives on the development of a deep-sea mineral industry in Norway

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Foreword

As companies and nations continues to search for new sources of metal resources, the deep sea has emerged as a potential new frontier for the exploration and extraction of energy transition metals. Norway, with its extensive coastlines and deep-sea territories, is well-positioned to be at the forefront of this emerging industry.

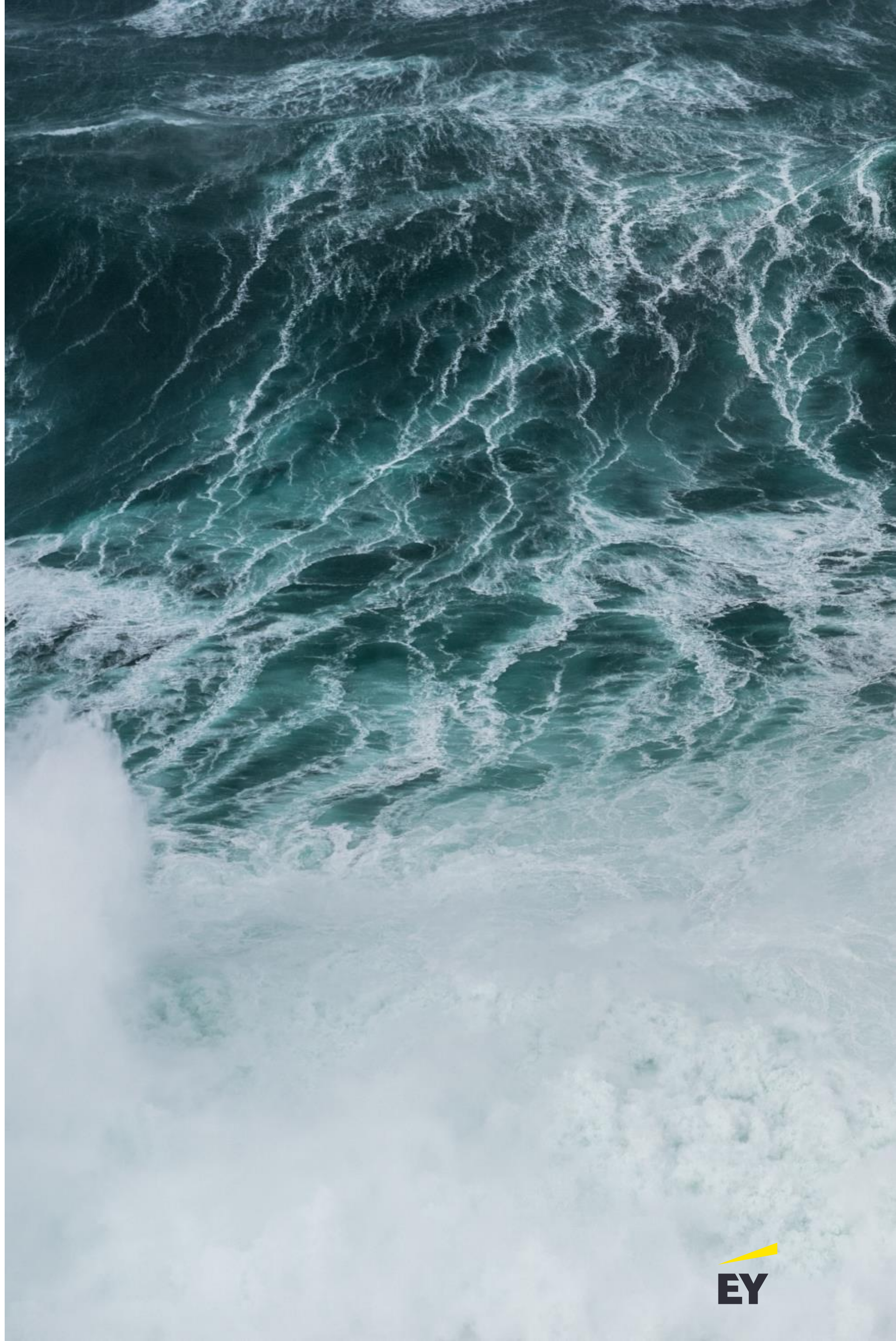
This report provides an overview of the drivers, trends, and potential for deep-sea mining in Norwegian waters, including cases that highlight technological capabilities, address environmental concerns, and the economic feasibility of such operations.

The report highlight the significant potential for a holistic value chain related to the deep-sea mining industry in Norway, but also underscore the need for careful planning and consideration of the potential impacts on the marine environment.

The development of test infrastructure is one of the identified critical success factors for advancing the industry. This infrastructure can provide a platform for the industry to test and refine new technologies and techniques for deep-sea mining, as well as to evaluate the potential environmental impacts of such operations.

As the industry move forward, it will be important to balance the need for economic growth with the need to protect the ecosystems of the deep sea.

29.03.2023



Summary (1/2)

Drivers

As society progresses towards large-scale decarbonization and electrification, securing the supply of energy transition metals will likely require significant investments in new projects. As the traditional on-land sources of these metals come under the pressure of ESG and geopolitical considerations, deep sea mineral deposits may become a key to meeting the demand.

Industry potential

With extensive deep-sea territories and offshore capabilities, Norway is well-positioned to be a leader in this emerging field. Following a comprehensive opening process Norwegian continental shelf may be opened for mineral activity in 2023.

Scenarios

The report outline different scenarios for the potential evolution of the deep-sea mining industry in the Norwegian sea, taking into account various factors such as market demand, technological developments, and regulatory environment. We note that the feasibility and profitability of deep-sea mining in the Norwegian sea remains uncertain, and it is currently unclear if the industry will be able to generate significant revenue from these operations

Summary (2/2)

Investment needs

Deep-sea mining is currently in the early stages of development and will require significant investments, both offshore and onshore, to reach commercialization. These investments are estimated to be in the range of more than 10 000 million NOK.

Speed of progress

In order to fully utilize the potential of the Norwegian sea, it is critical to accelerate the advancement of deep-sea exploration, technology development, research, and environmental mapping. Delays in the development of the industry may have consequences for the ability of the industry to capture international market share.

Infrastructure development

The development of shared infrastructure is key to supporting the growth of a deep-sea mining industry in the Norwegian sea. This includes investments in the extraction, processing, handling, and transportation of materials, as well as addressing environmental concerns.

1. Background

The pace of investment in renewable deployment and electrification has drastically accelerated

Accelerating the transition to renewable energy necessitates a strengthening of the supply chains that support it

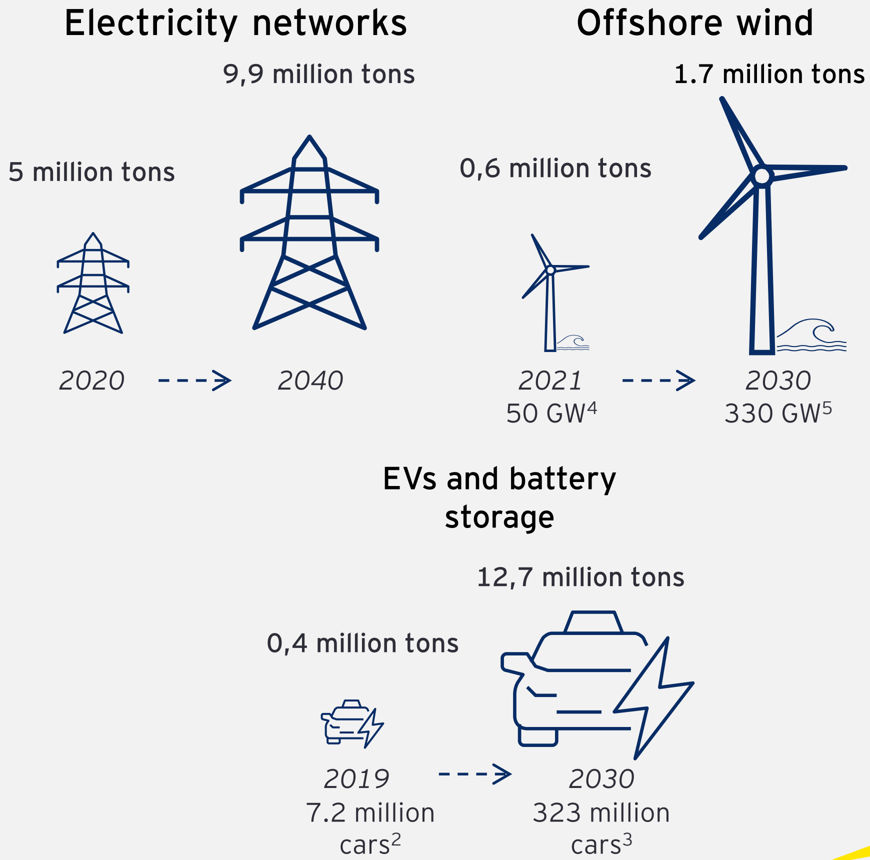
Electric vehicles uses electricity as their primary source of power and are powered by batteries. They are a key technology to decarbonize the transportation sector. Copper is used in the construction of the vehicle itself (~53.2 kg per car), while cobalt is used in the production of the batteries (6-12 kg per car)[1].

Wind energy, and the offshore wind industry, has seen significant growth in recent years. The construction of offshore windmills is highly metal intensive, requiring close to 8000 kg of copper per MW of installed capacity[1]. In addition, rare earth elements are needed for the permanent magnets in the generators.

Electricity networks are vital infrastructure that play a crucial role in delivering electricity a variety of end uses and will be needed regardless of what technologies will be used for power generation. To build and maintain these networks, a wide range of materials are used, including a significant amount of copper.

Technologies where the pace of deployment may hinge on the availability of metals

The numbers in bold refer to the total amount of metals needed for the deployment of various use cases in a sustainable development scenario[1].



Source: 1) IEA (2021). The role of critical minerals in clean energy transitions.2) IEA (2020). Global EV Outlook 2020. 3) Wood Mackenzie (2020). Electric car forecast to 2040. 4) Offshore Wind Market Report: 2022 Edition 5) Wood Mackenzie (2022). Sea Change: Navigating the trillion dollar offshore wind opportunity

However, obtaining the required energy transition minerals from land-based activities faces significant ESG and availability risks

Mining is resource-intensive and have a significant material footprint.

The dramatic increase in raw materials since the 1970s has resulted in a quadrupling of the global material footprint[1]. However, because many of the metals that are essential for decarbonization technologies are often found in regions rich in biodiversity, there is growing recognition of the need to discover alternative sources of these materials.

It's important to note that the extraction and processing of raw materials are resource-intensive, requiring large amounts of energy and water. Furthermore, the process results in the generation of waste materials, such as tailings and slag, which can have a negative impact on the environment.

Energy security

52%

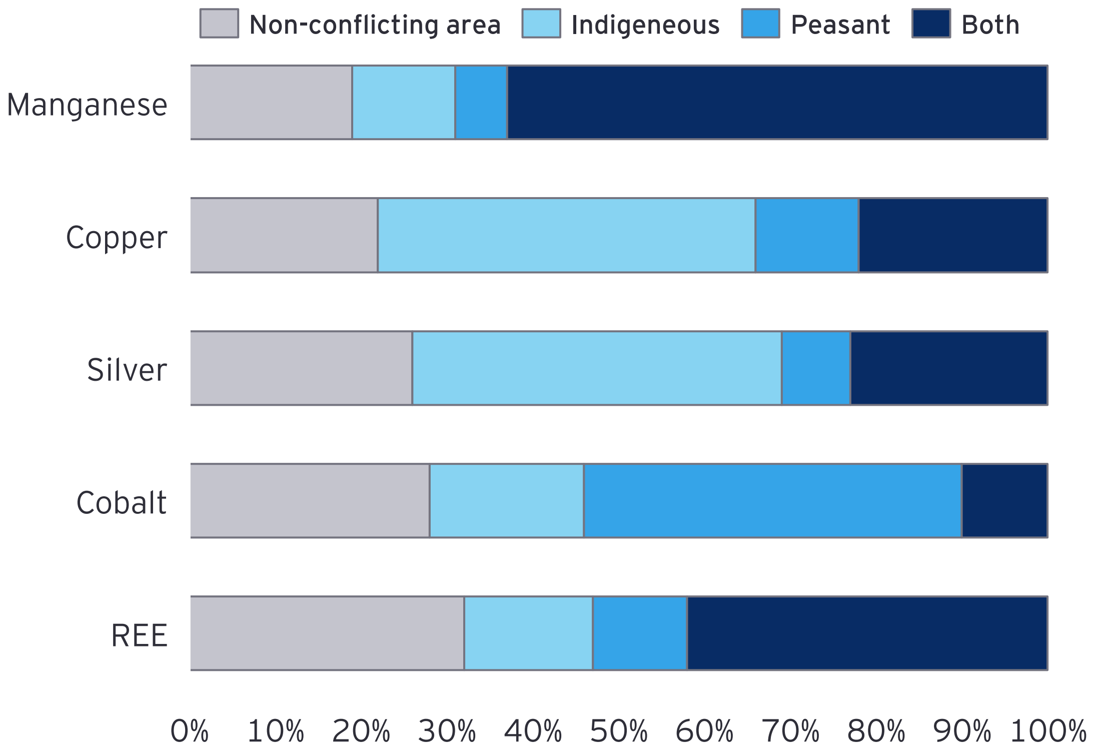
Of the world's mining area is concentrated in only six countries: Russia, China, Australia, the United States, Indonesia, and Brazil[2]. Between 35% and 87% of the energy transition metal processing occurs in China[3].

Biodiversity

50%

Of the global mining-related biodiversity loss occurs in Indonesia, Australia, and New Caledonia[4]

Over 68% of all greenfield mine projects for copper, cobalt and rare earth elements (REE) are located on or near indigenous land[4]



Source: **1)** Lenzen, M., Geschke, A., West, J., Fry, J., Malik, A., Giljum, S., ... & Schandl, H. (2022). Implementing the material footprint to measure progress towards Sustainable Development Goals 8 and 12. Nature Sustainability, 5(2), 157-166. **2)** Maus, V., Giljum, S., da Silva, D. M., Gutschlhofer, J., da Rosa, R. P., Luckeneder, S., ... & McCallum, I. (2022). An update on global mining land use. Scientific data, 9(1), 1-11. **3)** IEA (2021). The role of critical minerals in clean energy transitions **4)** Cabernard, L., & Pfister, S. (2022). Hotspots of Mining-Related Biodiversity Loss in Global Supply Chains and the Potential for Reduction through Renewable Electricity. Environmental Science & Technology.

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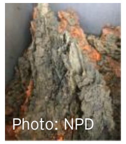
The Norwegian Continental Shelf may contain many of the required metal resources in the form of sulfides and crusts

Sulfides

Mid-ocean ridge setting



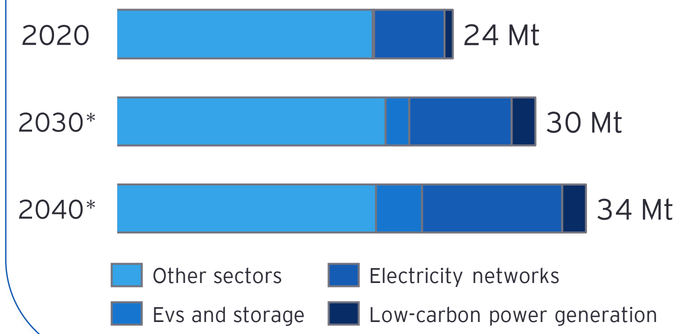
27 Co	30 Zn	47 Ag	79 Au
55 955 EUR	2 863 EUR	663 591 EUR	55 930 000 EUR
0.17 Mt	13.0 Mt	0.24 Mt	0.03 Mt

29 **Cu**

7 900 EUR

21.0 Mt

Global copper demand[1]



Crust

Seamounts

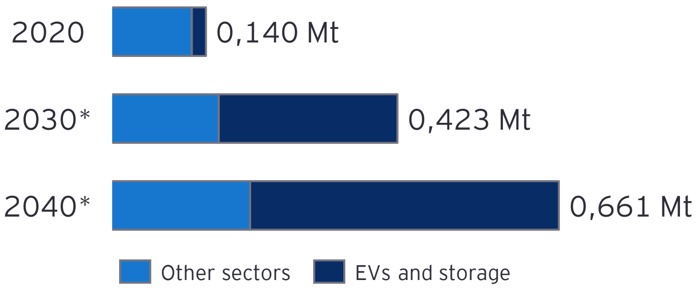
25 Mn*	REE
6 EUR	126 286 EUR
20.0 Mt	0.28 Mt

27 **Co**

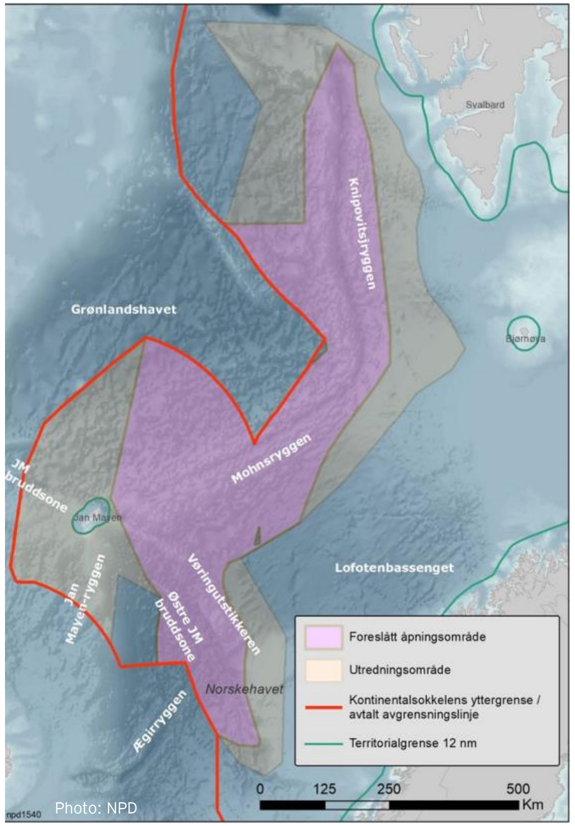
55 955 EUR

0.17 Mt

Global cobalt demand[1]



The area proposed for opening covers approximately 250 000 km^2



Global production in 2022 in million tons

Price in EUR per ton as of 01.12.2022

Sources: 1) IEA (2020). The role of critical minerals in clean energy transitions. 2) OD resource assessment. 2) Sahlström, F., Palinkaš, S. S., Dundas, S. H., Sendula, E., Cheng, Y., Wold, M., & Pedersen, R. B. (2022). Mineralogical distribution and genetic aspects of cobalt at the active Fåvne and Loki's Castle seafloor massive sulfide deposits, Arctic Mid-Ocean Ridges. Ore Geology Reviews, 105261.*) CIF China 44% manganese ore price index. Photographs are from NPD.

The Norwegian approach is based on sustainable development of natural resources

National objectives

The worlds most sustainable mineral industry

Secure minerals for the green transition

Examples of relevant sustainable development goals[1]

Principles

Knowledge-based management

Ensure that extraction activities take place within robust environmental standards.

Precautionary measures

If there is uncertainty associated with damage to the environment and life, the precautionary principle must be applied.

Measures for land use and the environment

Extraction of seabed minerals must be carried out with minimal area and environmental impacts

Resource extraction shall benefit the public

Ensure that the industry benefits the community and welfare system through resource rent

Source: 1) ISA (2021). The Contribution of the International Seabed Authority to the Achievement of the 2030 Agenda for Sustainable Development

2. Scenarios

Probing the deep-sea mining industry and the potential for Norwegian companies to capture market share

To better understand the development of the deep-sea mining industry, it is useful to examine some possible future directions of the industry and evaluate the potential for Norwegian companies to gain a share of the market through their participation in international and national initiatives. We use scenarios to consider the possibility for Norwegian companies to capture market share through their involvement in international and national initiatives.

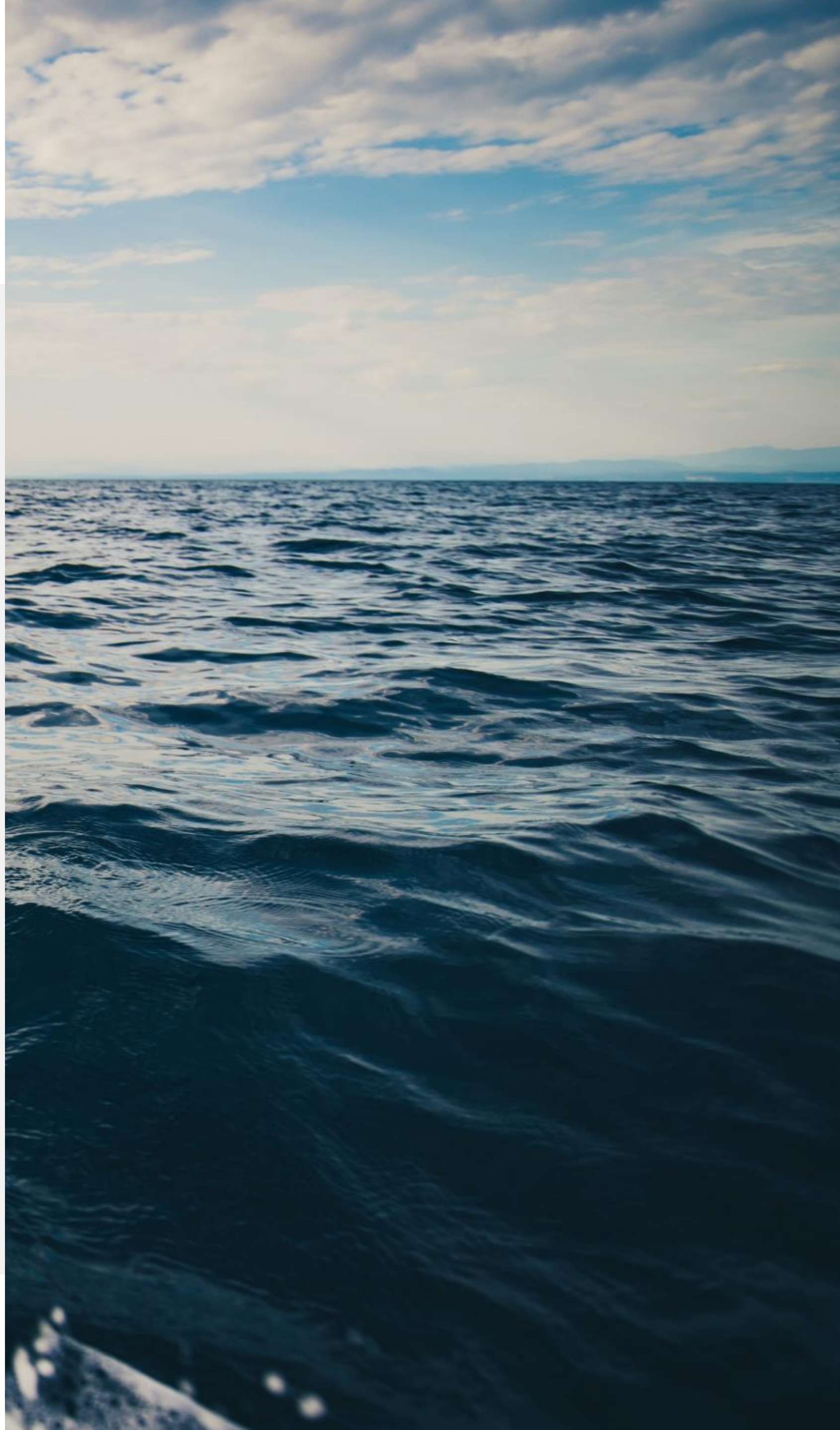
For a national Norwegian-based mining industry to emerge, there are several key points that must be addressed:

A new industry based on seafloor mining would likely involve the construction of specialized vessels and equipment for sustainable extracting of metals.

This will require significant investment and expertise, as well as collaboration between companies, organizations, and research institutions.

The industry will need to establish regulations and standards to ensure that the mining operations are carried out safely and responsibly, while at the same time take steps to mitigate and reduce negative impacts.

As the industry grows it should be accompanied by the development of new technologies and processes for refining and processing the metals.



Key factors for developing a new mineral industry on the Norwegian Continental Shelf

For a marine mineral industry to be developed it is a pre-requisite to have a resource base that can be extracted.

Current estimates of the resource base on the Norwegian Continental Shelf are highly uncertain. Assuming an estimated available resource base of around 40 million tons of copper and zinc[1,2] from sulfides, and up to 1450 million tons of manganese crusts[1,2] containing up to 4.4 million tons of cobalt, the total resource potential may be significant.

The financial sustainability of a marine mineral industry depends on the availability of economically recoverable resources that are of substantial size and has high metal concentrations. The expected commercial resource base may be significantly lower than the total resource potential. In addition, high upfront costs of the operations, coupled with a delay in generating revenue, may lead to a negative net present value when discounted over time[3]. To determine the commercial potential, it is therefore essential to conduct further exploration and assess the resource potential.

As the mineral industry is in its early stages, it is critical to build upon existing subsea techniques and competence to take advantage of cost-reduction opportunities.

By building upon existing world-leading technology and offshore competence, we can develop efficient and effective deep-sea operations. It is essential to take advantage of best practices in the field to stay competitive and drive down operational and development costs. By investing in the development of the existing subsea expertise and technological capabilities, Norway can position itself for both national and international market opportunities.

Key factors promoting mineral extraction on the NCS

Demand

Global demand

Geopolitical strategic goals

Decarbonization

Higher ambitions lead to increased mineral demand

Size and content

Size of discovered resources

Metal content

Nature of resources

Number of resources and their vicinity

Challenges to succeed with mineral extraction on the NCS

Financial barriers

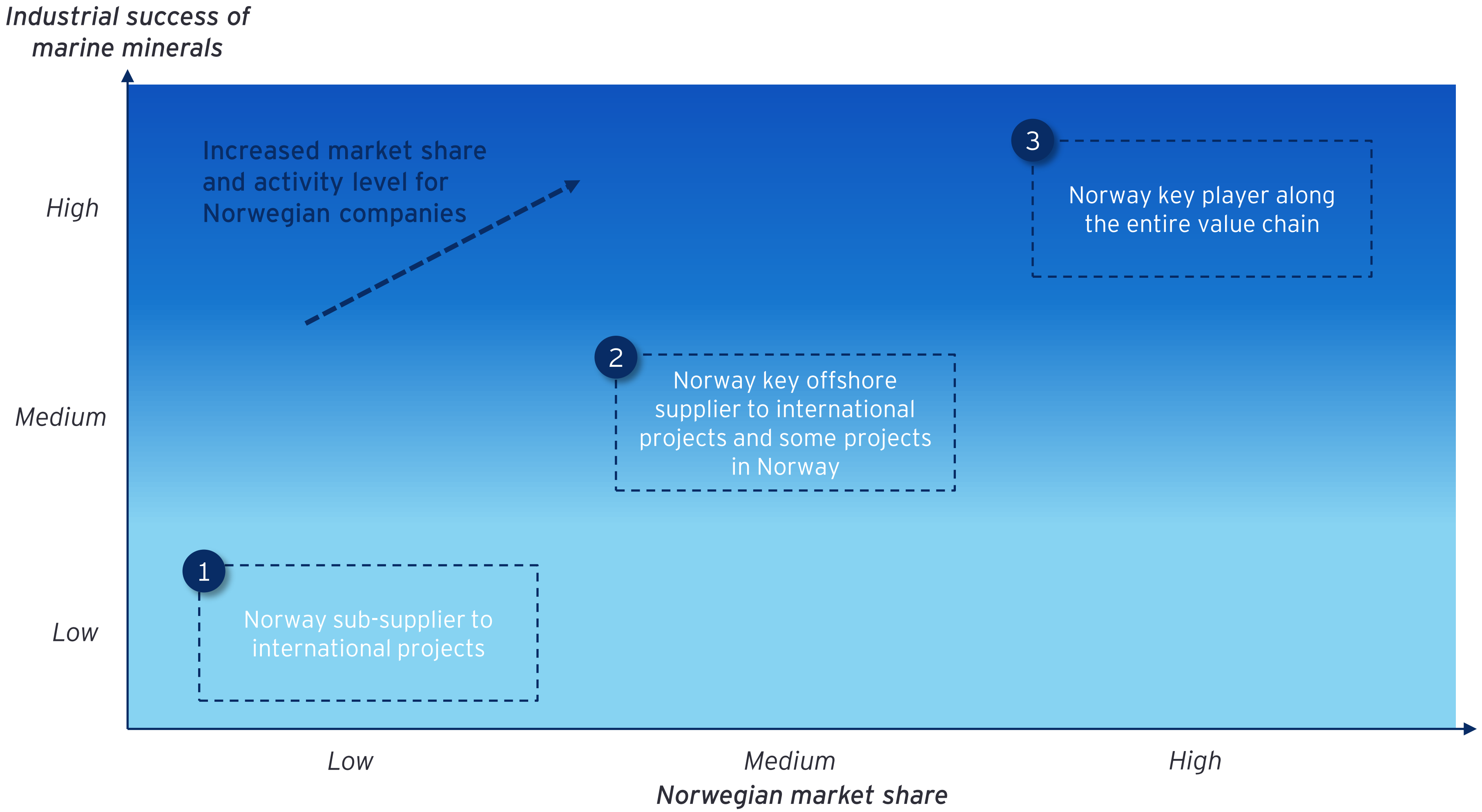
Environmental challenges

Resistance in public opinion

Technological barriers

Source: 1) NPD (2023) Ressursvurdering havbunnsmineraler. 2) Geoforskning (2021, in Norwegian) Forgylte skorper kan dekke EUs mineralbehov. 3) Perspectives on exploration and extraction of seafloor massive sulfide deposits in Norwegian waters

Scenarios for how a deep sea mining industry involving Norwegian companies could unfold in the coming years



Scenario #1
Norway sub-supplier to international projects

Primarily development and industrialization of nodules

In this scenario, the deep sea mining industry is dominated by international companies who become the main players in exploration and exploitation. Norwegian companies may be involved in projects as sub-contractors, providing a range of services such as engineering, environmental monitoring, development, and logistics support.

There is no industrialization on the Norwegian continental shelf, as either 1) more favorable mineral deposits are available elsewhere, 2) we fail to make necessary cost-reductions to reach profitability, 3) unclear regulations make it an unattractive business opportunity. As a result, the Norwegian market share becomes small. Despite this, Norwegian companies may still be able to benefit from their involvement in international projects through the gain of expertise and experience.

National development is important, but it is also important for Norwegian companies to consider international opportunities. The potential of global expansion within deep sea mining is significant and involvement may lead to substantial business opportunities.

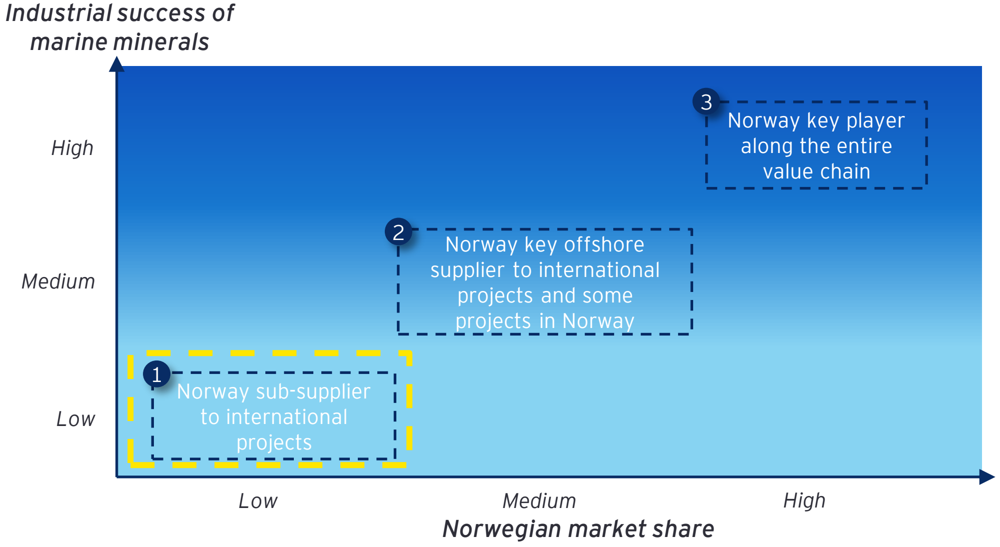
However, the potential for value capture and profitability is limited compared to the scenarios where the national industrialization means that Norwegian companies play a more central role, and the development of a holistic value chain leads to significant ripple effects.

To be an international player time is of the essence

"In a globalized economy, it will be more the exception than the rule that most of the most important subcontracts to a business activity requiring advanced equipment and technology will come from one country. So far, Norwegian players have not been involved in the development of the concepts that appear to be most mature for seabed mineral extraction, but some Norwegian players have relatively mature solutions that can be further developed and adapted to extraction from the seabed."

- *Asplan Viak (2022) Samfunnsmessige virkninger av havbunnsmineralvirksomhet*

Norwegian companies capture a low market share



Scenario #2
Key offshore supplier to international projects and some national projects

A couple of discoveries on the NCS, Norway becomes a key offshore supplier

In this scenario, Norwegian companies may play a central role in providing services to international projects, while also taking on a limited number of development projects on the Norwegian Continental Shelf.

The technological drive and development is moderate, but mining activities are controlled and focus on safe and sustainable operations. The focus on minimizing the environmental impacts, transparent governance, and public engagement leads to social license to operate.

The mineral activity in Norway as described in this scenario would lead to the potential extraction of 0,9 million tons of copper + 2,4 million tons of zinc from sulfides plus 201 000 tons of Co, and 134 000 tons of REE from crusts.

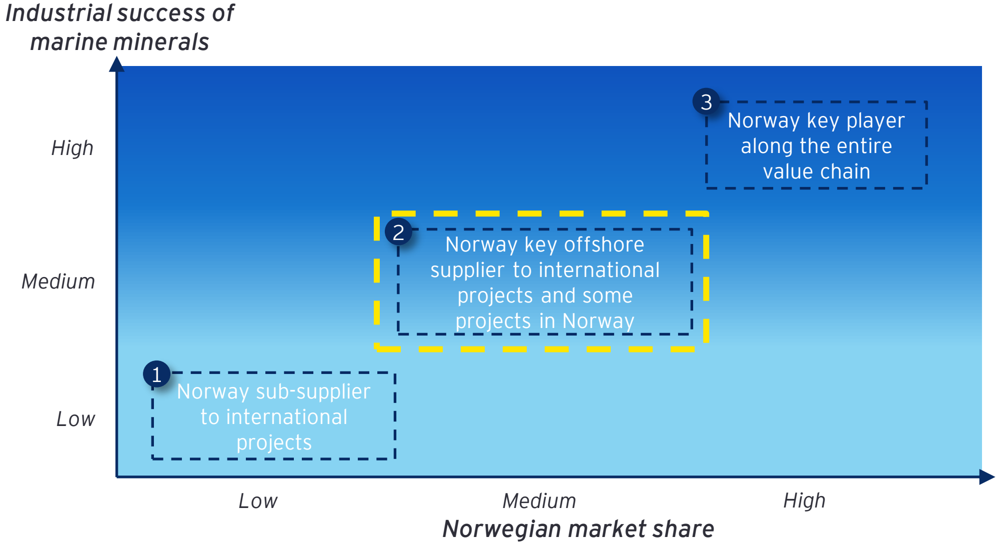
These metals are used for a variety of purposes, including the production of high-tech materials, renewable energy technology, and batteries. The depicted development of the NCS would support:

- Enough Cu to develop 113 GW of offshore wind[1] (enough energy to power about 6 million households[3]).
- Enough Co to supply between 17 – 34 million EVs[2].

A few commercially viable mineral deposits are exploited on the NCS[4]

	Sulfides	Crusts
Number of projects	10	5
Expected area use (km²)	0,06 - 3,0	100 - 200
Possible economic value (USD million)	20	28

Norwegian companies capture a moderate market share



Source: 1) Assuming 8000 kg of copper per MW installed capacity. 2) Assuming an annual power use of 20 000 KWh. 3) Assuming between 6 and 12 kg Co per electric car battery. 4) The expected area and potential economic value in the scenarios depend on many unknown factors and should be regarded as hypothetical examples.

Scenario #3
Norway key player along the entire value chain

Many discoveries on the NSC, Norway becomes a key player along the entire value chain

In this scenario, multiple deep-sea mineral deposits are discovered on the Norwegian Continental Shelf, leading to the involvement of several companies in the extraction. These companies may also play a significant role in supporting international projects by providing expertise in areas such as exploration, extraction, and environmental monitoring.

The development of the industry is supported by rapid technology development which ensures efficient and safe operations. The environmental impact of the activity is carefully monitored and managed to minimize the negative effects on marine ecosystems.

The mineral activity in Norway as described in this scenario would lead to the potential extraction of ~1,8 million tons of copper + 4,8 million tons of zinc from sulfides plus 400 000 tons of Co, and 270 000 tons of REE from crusts.

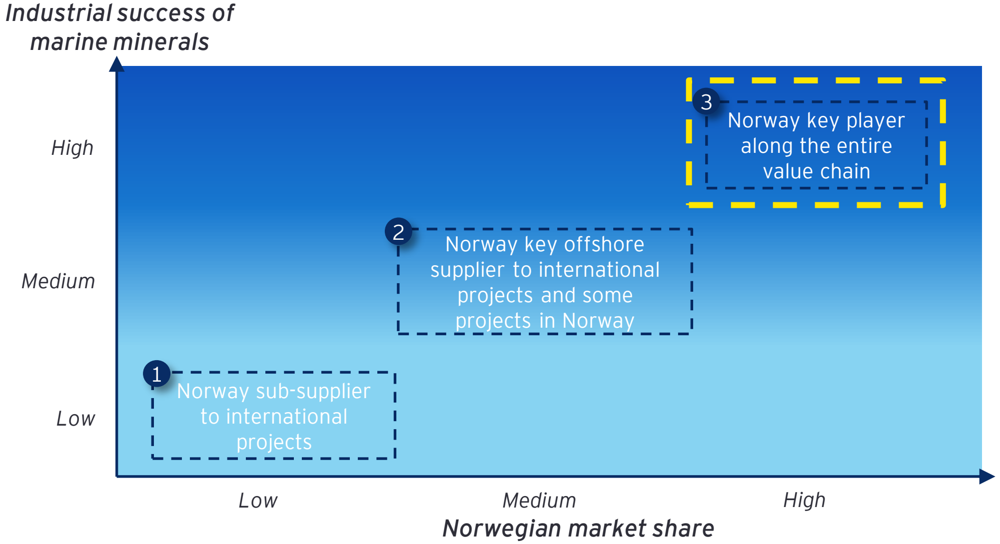
These metals are used for a variety of purposes, including the production of high-tech materials, renewable energy technology, and batteries. The depicted development of the NCS would support:

- Enough Cu to develop 225 GW of offshore wind[1] (enough energy to power about 11 million households[2]).
- Enough Co to supply between 33 and 67 million EVs[3].

Many commercially viable projects on the NCS[4]

	Sulfides	Crusts
Number of projects	20	10
Expected area use (km^2)	0,12 - 6	200 - 400
Possible economic value (USD billion)	40	55

Norwegian companies capture a high market share



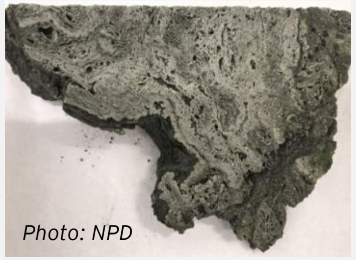
Source: 1) Assuming 8000 kg of copper per MW installed capacity. 2) Assuming an annual power use of 20 000 KWh. 3) Assuming between 6 and 12 kg Co per electric car battery. 4) The expected area and potential economic value in the scenarios depend on many unknown factors and should be regarded as hypothetical examples.

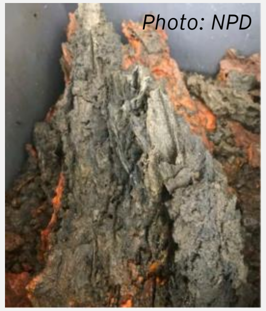
Unknowns and assumptions related to the size and concentration of sulfides

The size of the mineral deposits and the metal concentration are the two key factors in determining the overall impact of seabed mining operations.

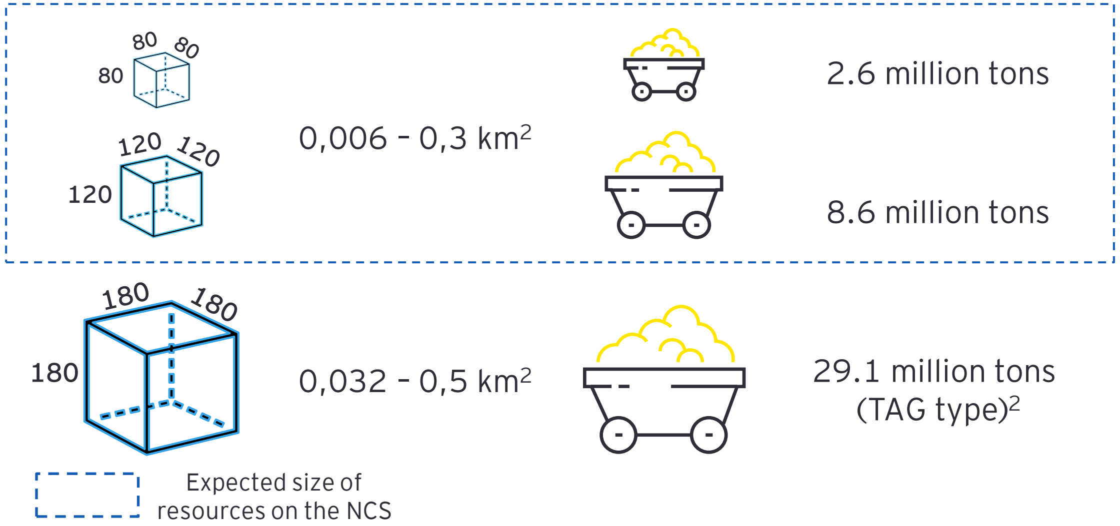
A higher concentration of metals means that less material needs to be mined and processed, potentially leading to lower environmental impacts and a smaller footprint.

Due to the uncertainty surrounding the size and metal concentration of sulfide deposits on the Norwegian Continental Shelf, any predictions made will have a low level of confidence.

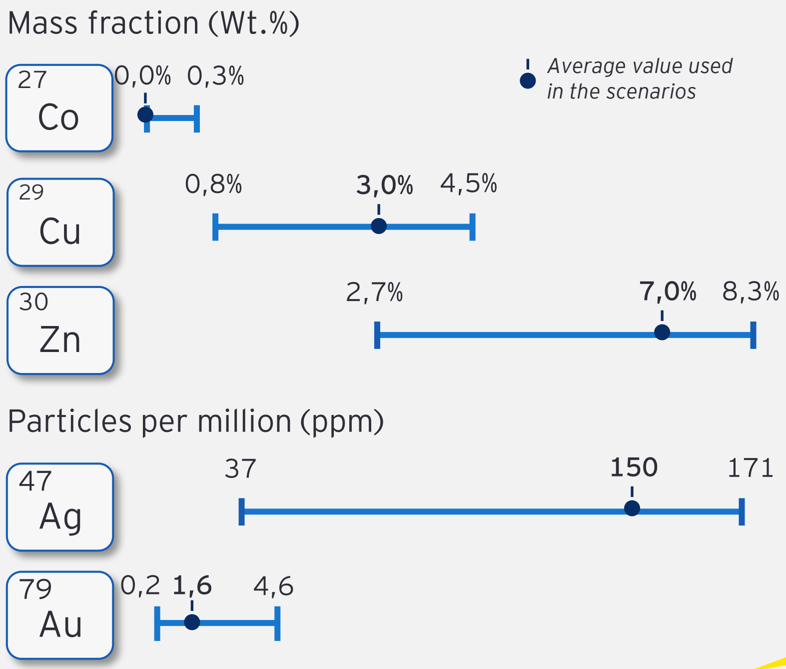




Potential size of sulfide deposits on the NCS[1]



Expected and potential range of metal concentration in sulfides on NCS



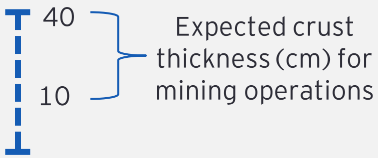
Source: 1) The estimated area for the ore deposits is based on the assumption of homogeneity, but it is unlikely that this will be the case. According to the resource assessment from the NPD, the expected area of the ore deposits is between 0.001 and 0.5 km^2. 1) Largest known SMS deposit to date. Values range between 14 Mt and 54 Mt.The volume of potential resources are calculated by the formula volume (m^3) x density of the minerals (kg/m^3). The volume calculations assumes a density of sulfide mineral of 5000 kg/m^3 but this can vary and NPD resource assessment assumes density values of between 3500 and 4000 kg/m^3 .

Unknowns and assumptions related to the size and concentration of crusts

In contrast to sulfide deposits, manganese crusts cover a larger area meaning higher potential for interference with biodiversity.

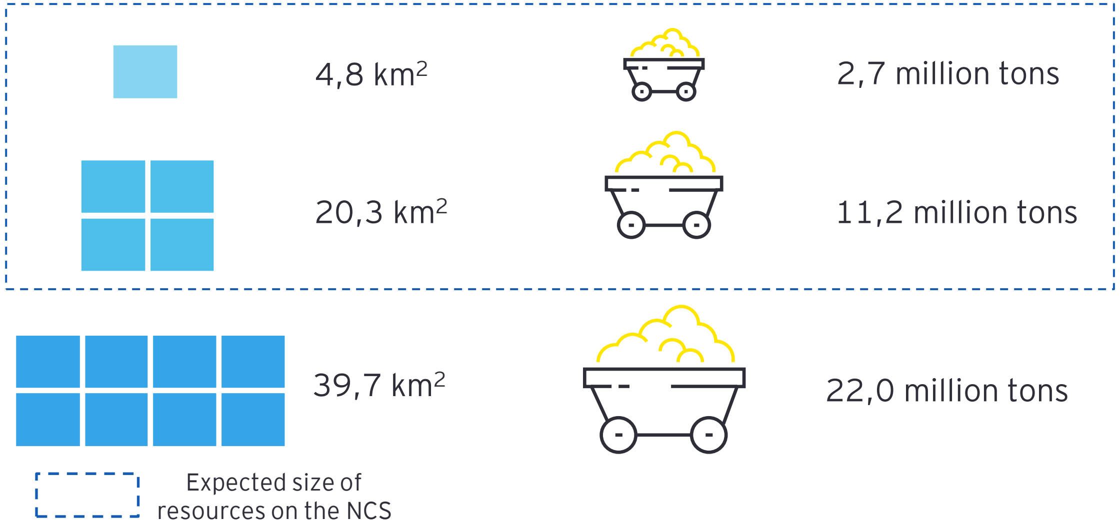
Higher concentration of metals means that less mass must be removed and processed yielding potentially lower areal use and environmental impacts.

The uncertainty in the size and concentration of the crust metal deposits on the NCS means that any prediction will have a low degree of confidence.

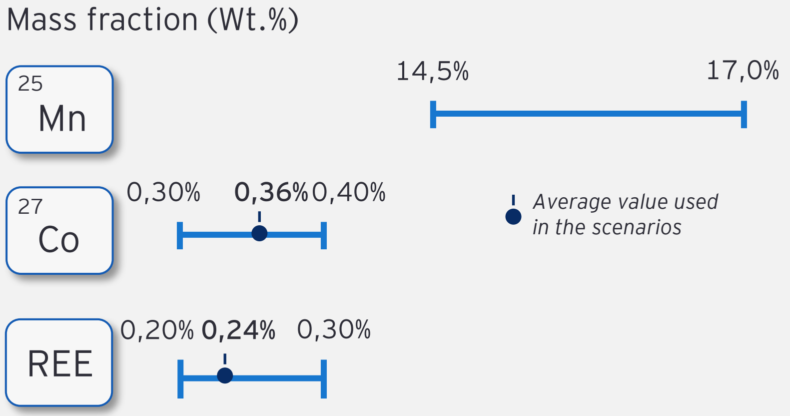


Crusts grow from seawater at a rate of approximately 1 cm per million years.

Potential area and mass of crust deposits on the NCS



Expected and potential range of metal concentration in crusts on NCS



Source: Mass of crusts were calculated using a wet density of 1850 kg/m3 and a thickness of 30 cm. In the NPD resources assessment

The area that will potentially be mined on the NCS is a fraction of the exploration area

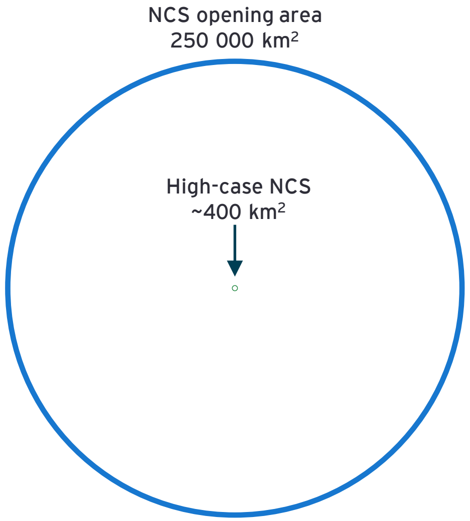
Mining of seafloor minerals on the Norwegian Continental Shelf is expected to be a highly regulated and limited activity.

Although the area opened for exploration is quite extensive, at approximately 250,000 km^2, the portion of area that will be used for mining is quite small in comparison.

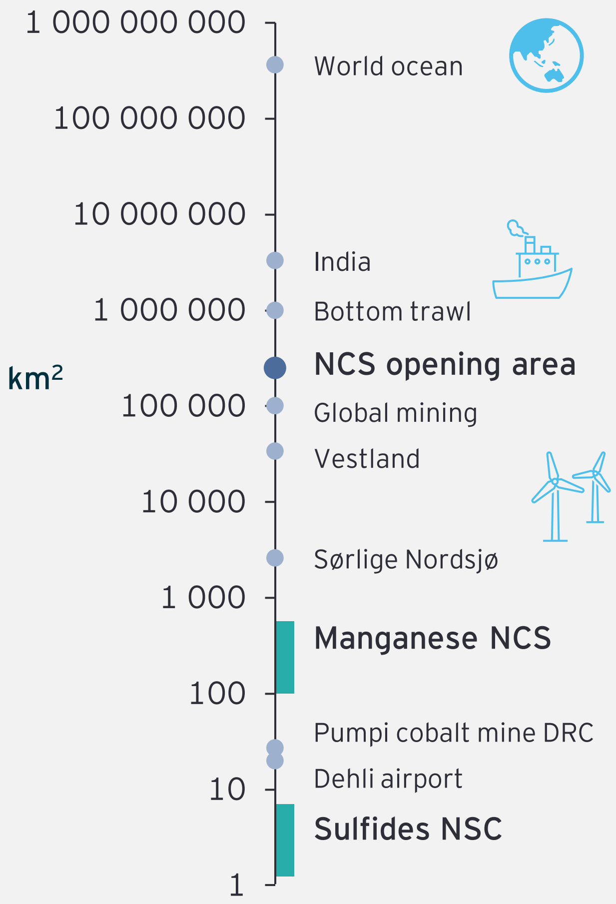
According to our scenarios, only a very small percentage of the total area opened for exploration, <0.002%, will be used for mining sulfides, while 0.08% will be used for mining crust. The estimated area is however, based on the assumption that the resources are homogenous, but it is unlikely that this will be the case. Therefore, it is likely that slightly larger numbers will be observed during actual exploitation.

Overall, the impact of inactive sulfide and crust mining on the Norwegian Continental Shelf is expected to be restricted by strict environmental regulations, carefully planned and managed mining operations, and the limited availability of resources in the area.

> "For **inactive** sulfide deposits, the impact level is evaluated as "small" based on an overall assessment of recovery time and impacted area with widespread benthic fauna."
>
> *- Akvaplan-niva - Virkninger for naturforhold, miljø og annen næringsvirksomhet relatert til konsekvensutredning for åpning av norsk sokkel for havbunnsmineralvirksomhet*



The amount of ocean floor that will be affected by the mining will be much smaller than the opening area



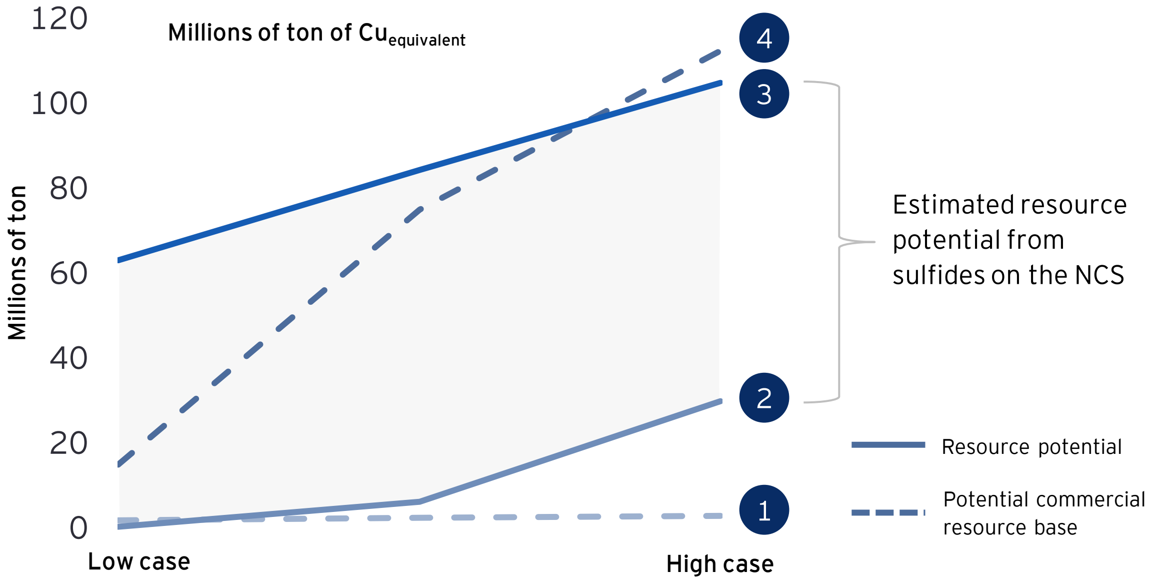
3. The importance of a holistic value chain for deep sea mining and cases

The cases presented here are not exhaustive, and many other organizations and facilities could be included. Most of the cases and companies mentioned as examples are not engaged in the activity of deep-sea mining. Rather, they serve to showcase the technological capabilities within their respective technology and value chains.

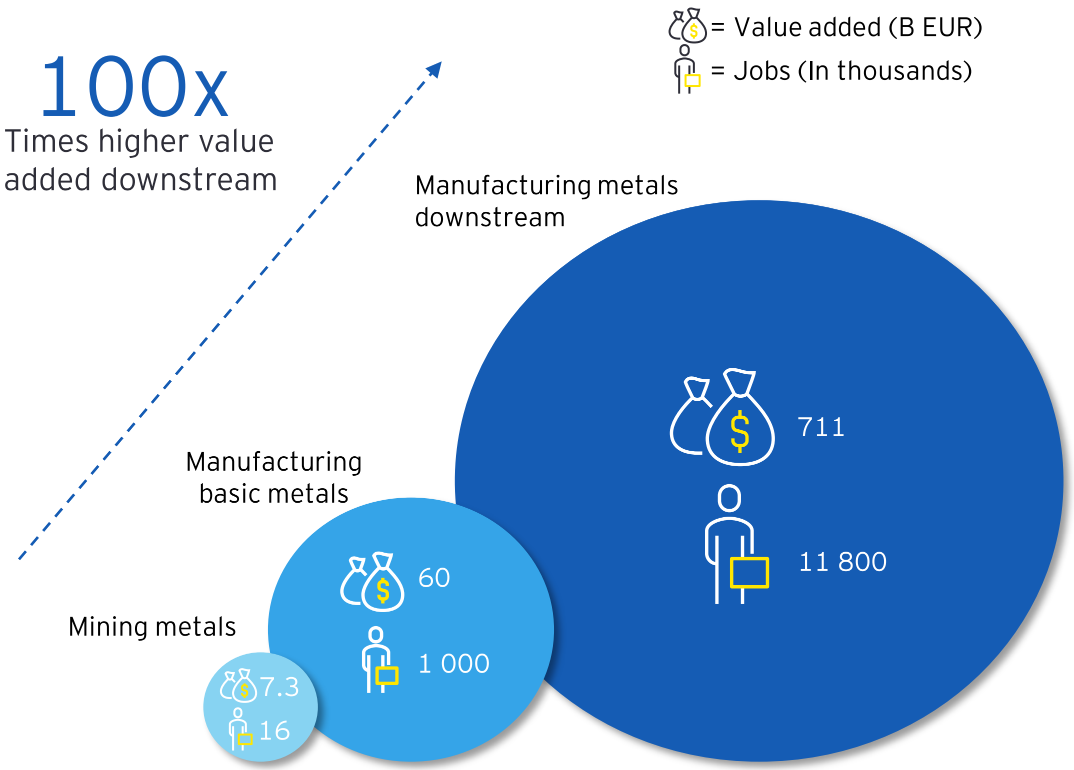
Successfully capitalizing on the potential of seafloor mining on the NCS requires capturing the value created throughout the downstream value chain

Seafloor mining of sulfides on the Norwegian Continental Shelf may not be economically viable on its own

The potential economic value of mineral extraction may vary significantly depending on factors such as the number and size of discoveries, their proximity, and the concentration of metals. Several different scenarios for the resource potential and potential commercial resource base on the NCS have been presented indicating a wide range of possible outcomes:



However, each job in the mining industry may lead to ~500-1000 jobs downstream the value chain[5]



Source: 1) Perspectives on exploration and extraction of seafloor massive sulfide deposits in Norwegian waters. 2) Ellefmo, S. L., Søreide, F., Cherkashov, G., Juliani, C., Panthi, K. K., Petukhov, S., ... & Snook, B. (2019). Quantifying the unknown. Nordic Open Access Scholarly Publishing. Values are from the aggregated F95, F50, and F5. 3) NPD (2023) Ressursvurdering havbunnsmineraler. The values are from P95, P50 and P05. 4) Rystad (2020) Marine minerals Norwegian value creation potential. 5) Within the EU, 12 million jobs depend on the extraction of metals. European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, (2021). 3rd Raw Materials Scoreboard : European innovation partnership on raw materials.

Simplified value chain

Extraction › Processing › Refine › Recycling

Case 1 - Developing technology for extraction of nodules

Developing the world's largest estimated source of battery metals, including nickel, copper, cobalt, and manganese

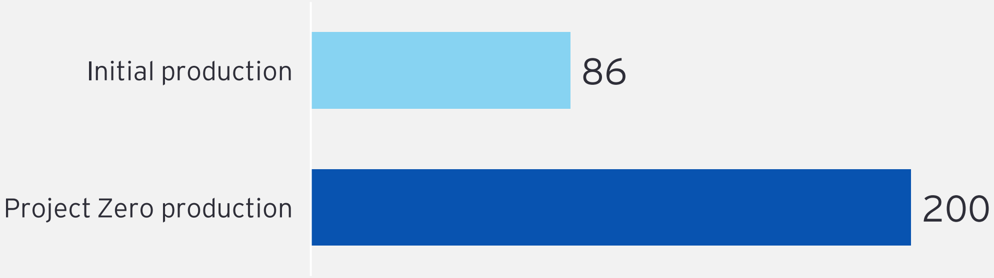
The Metals Company have successfully completed the first integrated system test for collecting polymetallic nodules from the seafloor in the Clarion Clipperton Zone of the Pacific Ocean.

Approximately 4,500 tons of nodules were collected during the test, with over 3,000 tons brought to the surface via a 4.3 km riser system[1]. The fully operational riser system is expected to use 18 MW under normal operations.

They achieved a sustained production rate of 86.4 tons per hour. This is expected to be scaled up for NORI's Project Zero, which aims for a production rate of over 200 tons per hour (equivalent to about 133 small cars per hour).

The test also included environmental impact monitoring, using remotely operated and autonomous underwater vehicles to survey the sediment plumes and noise generated by the nodule collection operations.

The production rate (tons of nodules per hour) is set to more than double yielding a yearly extraction of 11.2 Mt nodules (wet)[2]



Source: 1) The Metals Company (2022) NORI and Allseas Lift Over 3,000 Tonnes of Polymetallic Nodules to Surface from Planet's Largest Deposit of Battery Metals, as Leading Scientists and Marine Experts Continue Gathering Environmental Data. 2) The Metals Company Timeline

Simplified value chain

Extraction | **Processing** | Refine | Recycling

Case 2 - Processing of metals - manganese

Photo: Eramet

Eramet has invested in environmentally-friendly technology, making it a leader in sustainable manganese production

Eramet Norway is owned by the French mining and metallurgy group, Eramet. They focus on environmentally friendly practices and has made investments in environmental filters, a cleansing facility for heavy metals, energy recycling, and a water purification facility[1].

The advanced refining process is monitored closely using a control system to ensure sustainable processing and high-quality output.

The world's most environmentally friendly manganese production for use in steel

Eramet Norway has a long history in the production of manganese alloys and is a leader in the smelting and refining of these alloys. They operate three processing plants in Norway – in Porsgrunn, Kvinesdal and Sauda – and is a part of Eramet's Manganese Alloys Activity which also includes plants in France, USA and Gabon. Eramet Group owns the major part in Comilog's world-leading (volume) mine in Gabon

The facility in Sauda has two 40 MW furnaces and a refining facility and is one of the largest in the world. The main raw materials are manganese ore, reducing agents (coke) and Si-sources, mainly coming from foreign/global suppliers (except Si-sources).

The company uses clean, renewable hydroelectric power and is the world's most environmentally friendly manganese producer. They have an ambitious climate roadmap and is already actively working on projects to replace fossil reductants (coke) with biocarbon and to run a pilot on CO_2 capture to prepare a future CCS facility to be installed before 2030.

Source: 1) Eramet sustainability.

Simplified value chain

Extraction → **Processing** → Refine → Recycling

Case 3 - Processing of metals - sulfides

NIKKELVERK
A GLENCORE COMPANY

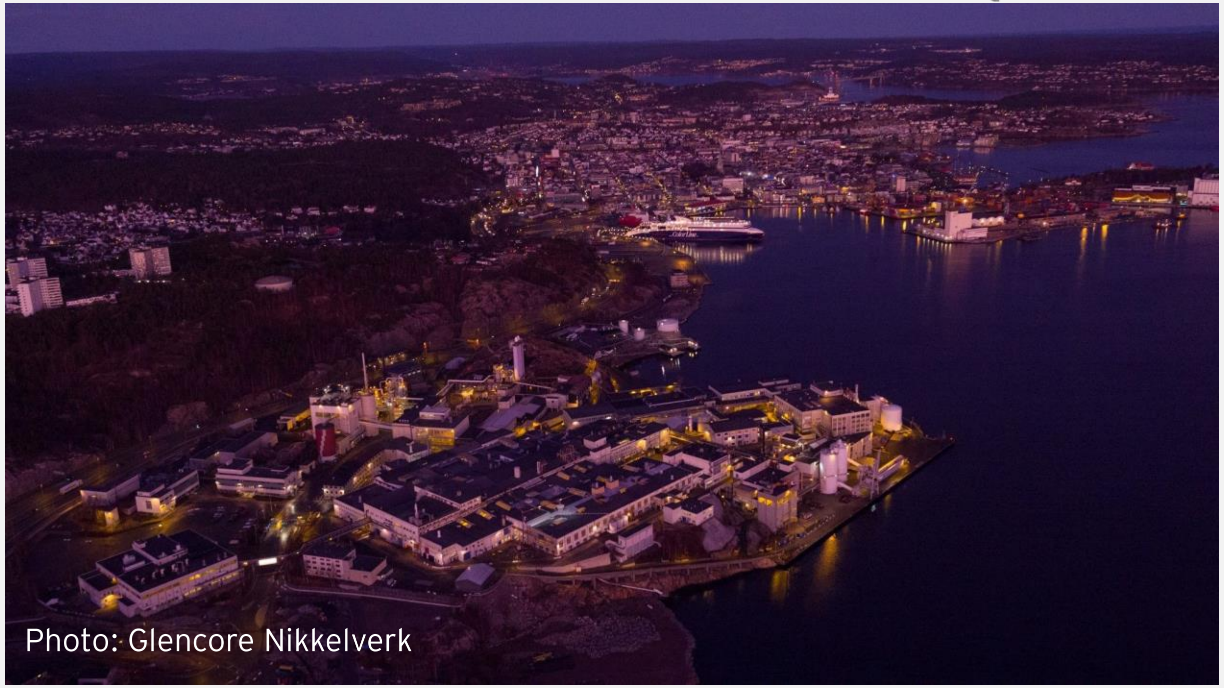


Photo: Glencore Nikkelverk

In 2019, Nikkelverk had a yearly capacity of 39 000 metric tons of copper and 5 000 metric tons of cobalt.

Glencore Nikkelverk produces high purity nickel, copper, and cobalt from sulfide material.

Nikkelverk is a highly technological company and the environmental, energy, and process technologies used makes it one of the most effective and technologically advanced refineries in the world.

The Glencore Nikkelverk facility in Kristiansand is currently developing new methods of electrolysis to produce nickel, cobalt, and copper. The new process is heavily automated, which helps to reduces the energy consumption. Additionally, the resulting products will be more fitting for use in battery production[1].

Production capacity 2019

NICKEL **92 000** MT	COBALT **5 000** MT
COPPER **39 000** MT	SULPHURIC ACID **115 000** MT

Source: 1) Forskningsrådet (2022) HIPP - Hyperspectral Imaging for product and process control.

Simplified value chain

Extraction | **Processing** | Refine | Recycling

Case 4 – Processing of REE metals in Norway

Processing of rare earth elements within the Herøya Industrial Park

REEtec is a technology company that has successfully scaled its technology from the laboratory to industrial production. In 2019, they started operating an industrial scale demonstration unit at Herøya Industrial Park.

The technology they use has a high efficiency and a competitive cost structure. Because they are able to recover and reuse most of the consumables in the production process at a low energy demand it is also an environmentally friendly approach.

Photo: REEtec

Sustainable production of high-purity rare earth elements (REEs) has the potential to help reduce Europe's dependance on imports of REE and significantly reduce CO_2-emissions associated with the production

REEtec has raised EUR 115 million to build the first full-scale production plant for separating rare earth elements in Herøya, Porsgrunn[1]. The plant will produce three main products – neodymium-praseodymium oxide (NdPr oxide), terbium oxide (Tb oxide), and dysprosium oxide (Dy oxide), which are used in, amongst others, the manufacturing of electric motors, wind turbines, robots, and pumps.

They will be able to recycle mixed rare earth elements from end-of-life magnets and turn these into pure virgin elements.

REEtec's process can reduce Europe's dependency on imports of REEs and create a complete value chain for REEs and magnets. The proprietary technology has the potential to reduce CO_2 emissions significantly compared to other leading suppliers

Source: 1) REEtec (2022) REEtec raises NOK 1200 million for first industrial plant.

Simplified value chain

Extraction → Processing → Refine → Recycling

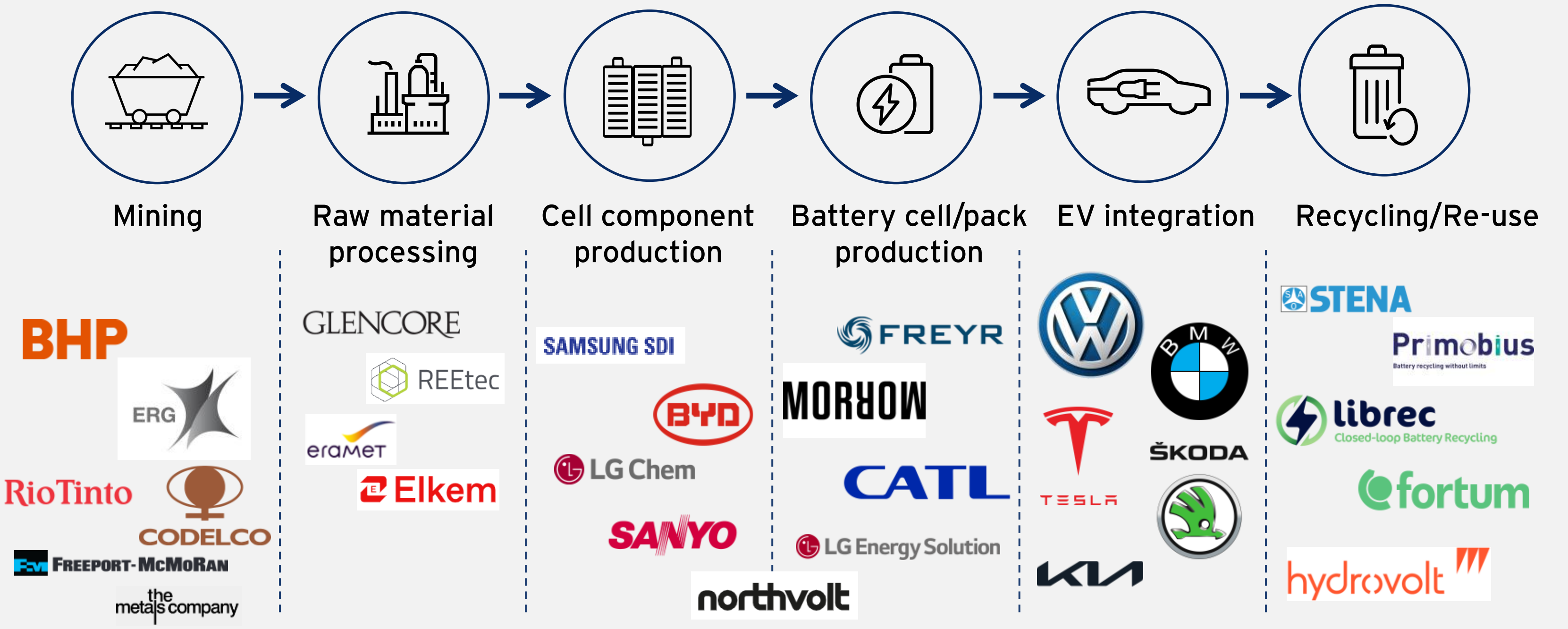
Case 5 - the EV battery value chain

The value chain of EV battery production*

The core of the EV battery value chain is a reliable supply of raw materials

The Nordic Battery Belt[1] is emerging as a cross-border Nordic battery cluster fueled by locally sourced raw materials. The region is expected to attract massive investments in the coming years, as companies and governments seek to capitalize on the region's strengths in battery production.

Ensuring a steady supply of the required metals and materials, however, is critical for the growth of the industry.



Percentage of value added[2]	25-30%	70-75%

*The overview is not an exhaustive list, but shows selected examples

Source: 1) Okonkwo, E. (2022) An overview of the Nordic Battery Belt: an emerging network for cooperation within the Nordic battery cluster. Fennia 200(1) 52-67. 2) Schade, W., & Mader, S. (2016). Analysis of the battery value chains with regard to the German industry and the global context.

EY

4. Roadmap, critical success factors, and infrastructure needs

What are the next steps for seabed mining on NCS?

The seabed mining process from 2019 to 2023 by the Oil and energy department marks the beginning of a potential new industrialization in Norway.

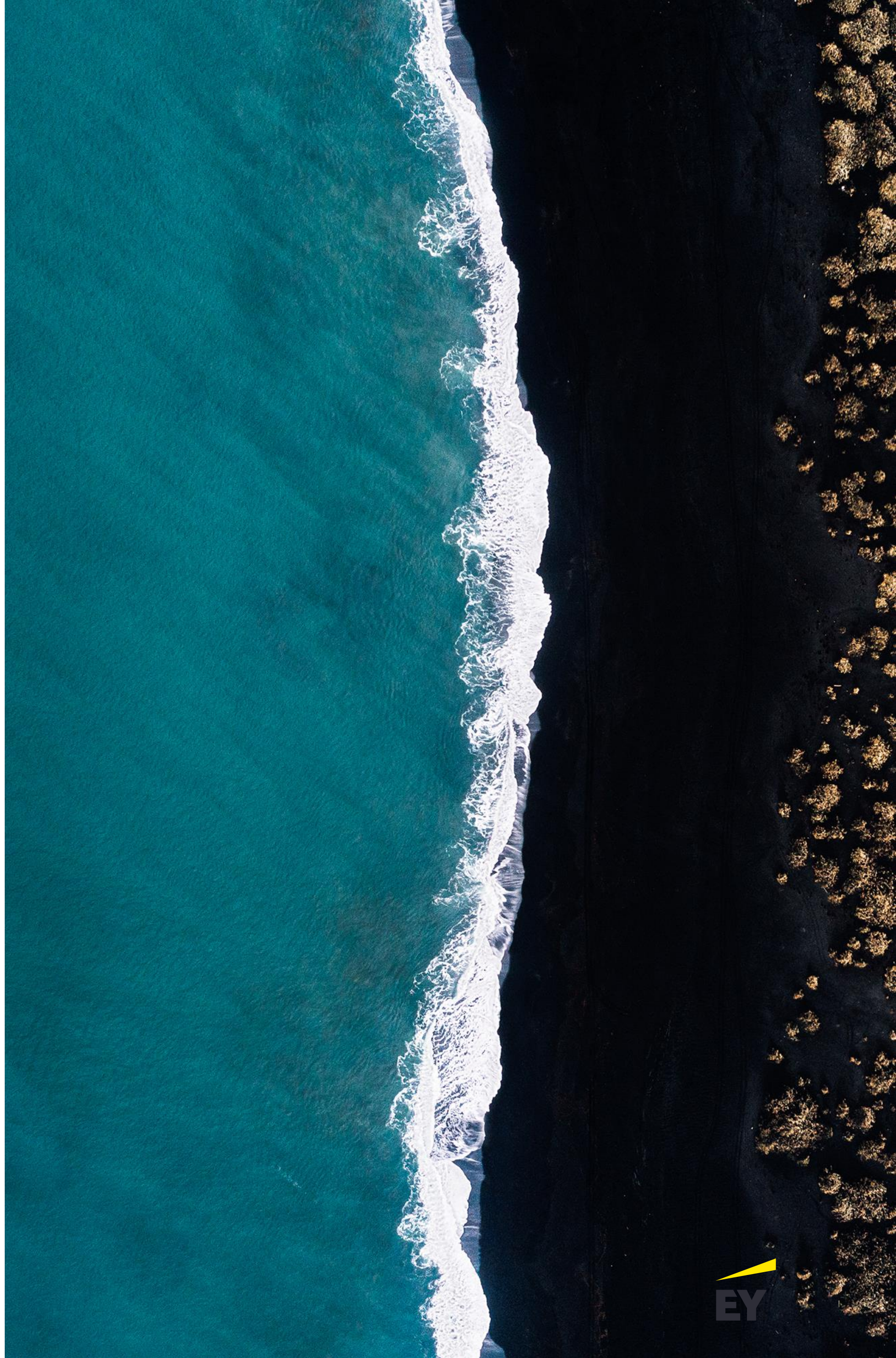
In the next five years, there is a global ambition to greatly increase the deployment of renewable energy sources. This electrification drive will require a significant amount of metals, such as copper, cobalt, and rare earth elements, to support the infrastructure and technology needed to generate and distribute clean energy.

Some of the things that will characterize the coming years:

Land-based mining operations are likely to face increasing stakeholder pressure related to environmental, social, and governance (ESG) issues, land use, and biodiversity loss[1,2].

The current supply of metals is not enough to drive and support the ambitious decarbonization and electrification of our society[3].

As the need to secure access to key resources becomes more pressing, the issue of deglobalization is likely to rise on the political agenda. The global geopolitical landscape is expected to remain volatile, with the current disruptions having long-lasting impacts.



Source: 1) Owen, J. R., Kemp, D., Lechner, A. M., Harris, J., Zhang, R., & Lèbre, É. (2022). Energy transition minerals. Nature Sustainability, 1-9. 2) Cabernard, L., & Pfister, S. (2022). Hotspots of Mining-Related Biodiversity Loss in Global Supply Chains and the Potential for Reduction through Renewable Electricity. Environmental Science & Technology. 3) The drive for decarbonization, Wood Mackenzie

We see exploration, extraction and value chain capabilities as key factors for succeeding with marine minerals on the NCS

According to our scenario analysis, there are three key criteria that must be met for a new industry based on seafloor minerals to be successful. These criteria include effective exploration and resource identification, efficient and sustainable extraction methods, and a holistic value chain that capitalize on the value of the minerals.

Resources and development

The ability to locate and identify deposits that are large enough and of sufficient ore grade to be economically viable. This involves both geological and geophysical surveys, as well as ground truthing activities, sampling and coring.

- Size and concentration
- Number and distribution of deposits
- Technology for exploration
- Human capital

Extraction concepts

The development of methods for extracting minerals that are efficient and sustainable. This means finding ways to minimize the environmental impact such as reducing the sediment plumes and minimizing the potential for destruction of habitat. It also involves developing cost-effective techniques for extracting the minerals and transporting them to the surface.

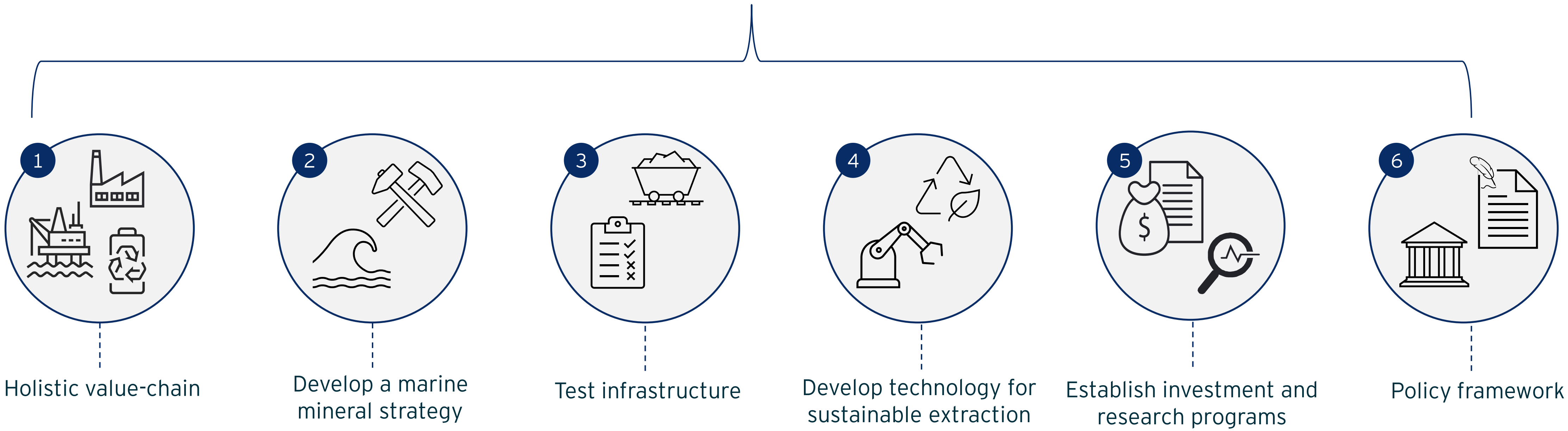
- Cost-effective and sustainable operations
- Handling of ore and waste materials
- New cost-effective technology

Processing and value chain capabilities

The downstream value chain activities for marine minerals includes processing and turning the metals into new usable products. To be successful, we must ensure that all these activities are integrated and optimized to maximize the value capture.

- Efficient and effective processing techniques
- Holistic value chain
- Metal prices key for profitability

Six critical success factors for accelerating the development a new deep sea mineral industry on the NCS



A successful industry based on seafloor minerals requires a holistic value chain, a clear marine mineral strategy, supportive test infrastructure, technology for sustainable extraction, research and investment programs, and an enabling policy framework. By addressing all the critical success factors and focusing on applying the sustainability principles and precautionary approach, we expect a more rapid industrialization.

We expect investments on the scale of > 10 000 m NOK to reach commercialization of the new industry in Norway

Deep sea mining on the Norwegian Continental Shelf will be a highly capital-intensive industry

Significant upfront investment costs are required to develop the necessary technology and infrastructure. Cost drivers are related to the development of specialized mining equipment as well as the construction of onshore processing facilities.

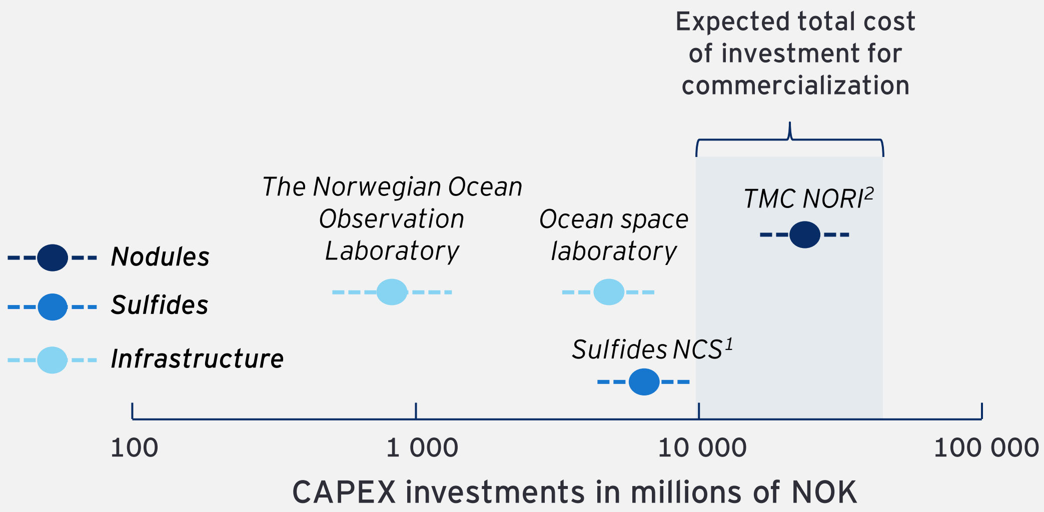
The high investment costs associated with deep sea mining are a significant challenge for development and commercialization. In addition, the risks and uncertainties associated with deep-sea mining can make it challenging for companies to secure the funding needed to support these operations.

Collaboration and alliances will likely be key to the successful development of a new seafloor mining industry. The complex and technologically advanced industry requires a range of expertise and resources that may be accelerated through partnerships and collaborations and public-private initiatives.

The development of the new seafloor mining industry will require a collaborative approach that brings together a diverse range of expertise and resources to explore, extract, and maximize the value of these valuable resources while minimizing the environmental impact.

Example of investments (expected and realized) in nodules, sulfides, and infrastructure relevant to the deep sea mining industry in Norway

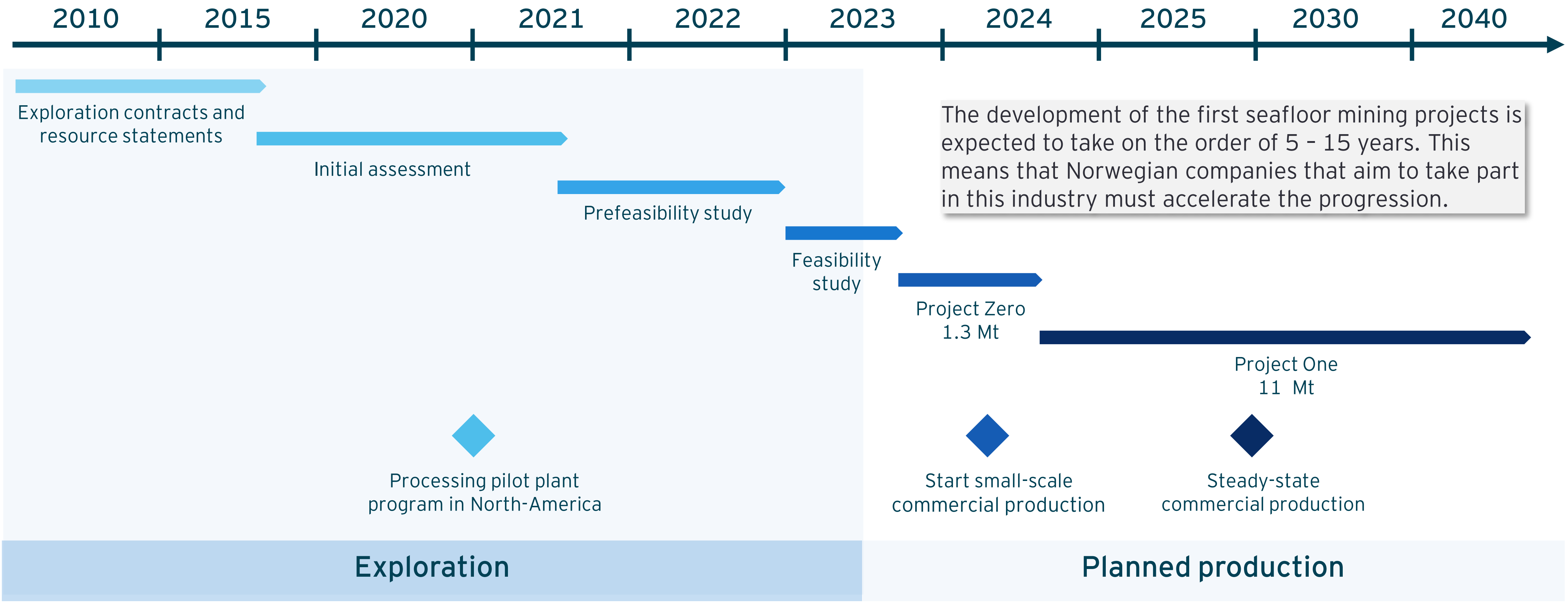
The exact costs of deep-sea mining will depend on a variety of factors



 Source: 1) Rystad (2020) Marine minerals: Norwegian value creation potential 2) The Metals Company (2021) Annual report.

Seafloor mining is characterized by long development times which means that there is an urgent need to begin exploration and development

The timeline is an example for the development of mining of nodules by The Metals Company[1]



To successfully establish a seafloor mining industry in Norway, time is of the essence. The first projects will have a longer development timeframe than later projects due to building of knowledge and experience. Although some companies have already begun to build expertise, there is still room for Norwegian companies to build on existing offshore technologies and competencies to gain a competitive advantage. Seizing these advantages may be key for Norwegian companies to capture market shares. If the opportunity is not taken advantage of, international competition is highly likely to capture that role.

Source: 1) The Metals Company Timeline.

Shared infrastructure can potentially help the industry develop concepts to locate and extract seafloor minerals while reducing the environmental impact

Considering the challenges, the limited knowledge about the resource potential, the harsh operational environment, and the high cost of exploration, there is an open space for innovation and technological improvement that can help accelerate the development of the industry such as geophysical methods, remotely operated- and autonomous technology.

Challenges for development of the industry on the NCS that could be improved through shared infrastructure:

- Limited knowledge about the resources and environment
- High cost of exploration
- Considerable lag between initial exploration and minerals being landed onshore
- Responsible and cost-efficient production and processing with minimal environmental impact

The different properties of SMS deposits and ferromanganese crusts, means that the two categories of deposits will likely require somewhat different technology for exploration, extraction, and processing.

Test facilities can provide the enabling tools, resources, and access for businesses to develop new technologies and methodologies relevant for marine minerals. Such expensive and advanced facilities may also serve as a meeting place for companies, entrepreneurs and researchers looking to conduct development and testing.

For questions about the report

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