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Economic drivers of seabed mining

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Abstract

Introduction. *Seabed mining is attracting increasing attention as a potential source of precious minerals and metals to meet growing global demand. The vast and largely unexplored seabed mineral deposits present a unique opportunity to access valuable resources that are essential for various industries, including advanced technologies. However, the pursuit of seabed mining is not solely driven by resource availability. Economic drivers play a decisive role in shaping the process of prospecting and further development of a deposit.*

Research objective *is to study various economic drivers determining the feasibility of seabed mining and highlight their impact on the industry.*

Results. *Economic drivers that provide impulses for seabed mining were outlined, namely resource scarcity and growing demand for critical minerals, market fluctuations and technological advances, as well as the state's independence from raw material import and possibility to generate employment. All of those are clear economic drivers of prospecting and seabed deposits development with an untapped potential to meet global demand. The study presents major economic drivers of seabed mining and their detailed analysis.*

Conclusions. *Prospecting and seabed mining project development offer a potentiality to meet the growing global demand for minerals and metals, especially for critical elements required for various industries. It should be noted that seabed mining economic drivers understanding and optimization is vital for all parties concerned: subsoil users, politicians and prospectors. By applying methods of sustainable development, environmental management, and international cooperation, it is possible to maximize benefits while mitigating potential environmental risks. The paper sets a vector for further in-depth study of the economic drivers discussed.*

Keywords: *seabed mining; economic drivers; resource scarcity; mineral costs; technological advances; economic development.*

Introduction. Prospecting for mineral resources and their extraction from the seabed, known as seabed mining, has attracted much attention in recent years [1–5]. With depleting mineral reserves [6, 7], seabed mining is a promising opportunity to meet the growing demand for metals and minerals [8–10]. However, the economic viability of seabed mining projects largely depends on various factors, in particular the effective economic drivers (Figure 1).

The paper presents the main factors that increase economic feasibility and profitability of seabed mining. Through a more detailed research into the role of the major economic drivers, it will be possible to understand their impact on the development, sustainability and future prospects of the seabed mining industry.

The present research is focused on the analysis of major economic drivers (Figure 1) and detailed factors, which determine and generate the feasibility of seabed mining. Their impact on the economic viability and further success of both leading enterprises and those just planning to start sea bed mining, has been assessed.

Methods of research. This paper uses a systems approach to collecting and analyzing information on economic drivers of seabed mining. Based on a literature review and data analysis, a conceptual flow chart has been developed to illustrate the relationship between

various economic drivers of seabed mining (Figure 1). The concept helps understanding the key factors affecting economic viability and ways of enhancing the economic drivers in the industry.

Review of economic drivers of seabed mining. Seabed mining represents a potential opportunity to meet the growing global demand for minerals and metals. This section provides a description of major economic drivers of the development of both prospecting and seabed mining.

1. Resource scarcity and demand. Global demand for minerals and metals is growing steadily, driven by key factors: rapid population growth and urbanization; development of infrastructure and various industries; transition to environmentally friendly energy sources, etc. At the same time, as existing deposits are exploited, they are depleted. Seabed mining therefore opens up opportunities to develop new mineral reserves and meet growing demand.

Figure 1. A classification of major economic drivers of seabed mining
Рисунок 1. Укрупненная классификация экономических стимулов для развития подводной добычи полезных ископаемых

2. Cost of minerals and market prices. One of the main factors driving interest in seabed mining is the presence of high concentrations of economically valuable resources such as polymetallic nodules and cobalt-rich ferromanganese crusts. Moreover, market prices for many minerals and metals that are mined underwater have been on a steady upward trajectory in recent years. This is due to a number of factors, including growing global demand, geopolitical tension affecting traditional supply chains, and developments in technologies that require the use of specific minerals.

3. Technological advancements. Technological advancements and cost reduction strategies in seabed mining can significantly impact the economic viability of such enterprises. Advanced extraction technologies, automation, data analytics and energy efficiency measures can help reduce operating costs, improve productive capacity and profitability [11–14].

Table 1. Clarification of factors affecting major economic drivers of seabed mining development
Таблица 1. Уточнение факторов, влияющих на укрупненные экономические стимулы для развития подводной добычи

Major economic drivers	Detailed factors
1. Resource scarcity and demand	*Depletion of the onshore mineral resource base*. Annual increase in mining extent (according to statistics, over the past 20 years the growth rate has been almost 50%) [15, 16]. *Increased demand for certain types of mineral raw materials*. Growing demand for specific minerals reflects the changing needs of modern society and the transformative power of developing technologies.
2. Cost of minerals and market prices	*Dynamics of supply and demand*. If demand for a particular mineral exceeds available supply, prices tend to rise. When supply outstrips demand, price acts in the opposite way. *Market conditions*. Global economic cycles, investor sentiment, currency exchange rates and geopolitical factors can influence mineral prices. *Quality of raw materials*. This factor includes the chemical composition, the content of commercial components in the ore and other geological factors that ultimately determine the qualitative characteristics of the raw material
3. Technological advancements	*Prospecting and resource valuation*. The significance of technological advancements in prospecting and valuation is to improve accuracy and efficiency and reduce costs in the early stages of mining. *Extraction and production*. Modern mining and processing technologies make a significant contribution to improving efficiency, reducing costs and minimizing environmental impact. *Data analytics and automation*. Data analytics and automation have become powerful tools for increasing operational efficiency, reducing costs and improving decision making.
4. Strategic resource independence	*Diversification of supply sources*. Countries are seeking to establish partnerships with other resource-rich nations, fostering long-term trade relationships and reducing dependence on a single supplier. This approach helps reduce supply risks and improve the stability of mineral supply chains. In addition, countries can invest in strategic stocks or reserves of critical minerals to ensure their availability during periods of shortages or disruptions
5. Job creation and economic development	*Direct employment in the mining sector*. It involves hiring skilled and semiskilled workers, as well as supporting personnel employed directly at mining enterprises. *Indirect employment*. Forming an economic link with other industries (engineering firms, consulting services, research institutes, local regional enterprises, etc.)

4. Strategic resource independence. Strategic resource independence means reducing dependence on imported minerals due to the domestic market. Seabed mining can help achieve strategic resource independence through access to mineral deposits within an exclusive economic zone or territorial waters of a country. This reduces dependence on foreign suppliers and enhances national security and economic stability.

5. Job creation and economic development. Seabed mining has the potential to create direct and indirect employment opportunities, stimulating economic development in coastal regions. The establishment of mining companies, support services and related

industries can generate employment, lead to increase in income and economic growth, benefiting local communities and contributing to wider economic development.

Results and discussion. It should be noted that understanding the major economic drivers of seabed mining gives an idea of the potential benefits and challenges of this developing industry.

Table 1 reveals the main detailed factors that are part of the major economic drivers under consideration.

The analysis reflects the complex and versatile nature of the economic drivers of seabed mining as they reflect a combination of growing demand for minerals and metals, resource depletion, increasing costs of onshore mining, technological advancements and other important issues. These factors collectively provide a strong drive for mining companies to explore and exploit the potential of seabed mining as a way to develop a new source of valuable resources.

Conclusions. Addressing resource scarcity, tracking market dynamics, introducing technological innovation, ensuring strategic resource independence and promoting rational mining practices, seabed mining can contribute to global resource security, economic development and the transition to a more sustainable future. Careful planning, stakeholder engagement and effective management are critical to mitigating potential risks and ensuring responsible development of seabed mining projects.

Thus, the development of deposits located in the seas and oceans is not just a solution to economic problems for mining companies or states, but a multifaceted activity of global significance.

Seabed mining allows to solve problems associated with onshore mineral reserves depletion and meet demand for them without exacerbating environmental degradation.

The development of seabed mining can help increase international cooperation and diplomacy. It also has a potential to stimulate economic growth in the regions where mining occurs since these regions benefit from job creation, infrastructure development and increased economic activity.

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Экономические стимулы для развития подводной добычи полезных ископаемых

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Реферат

Введение. *Подводная добыча привлекает все больше внимания как потенциальный источник ценных минералов и металлов для удовлетворения растущего мирового спроса. Обширные и практически неизученные подводные месторождения полезных ископаемых представляют собой уникальную возможность получить доступ к ценным ресурсам, которые необходимы для различных отраслей промышленности, включая передовые технологии. Однако стремление горнодобывающих компаний к подводной добыче обусловлено не только наличием ресурсов – экономические стимулы играют решающую роль в формировании процесса разведки и дальнейшего освоения месторождения.*

Цель работы *– всестороннее изучение разнообразных экономических стимулов, определяющих целесообразность применения подводной добычи. Ставится задача обеспечить комплексное понимание их влияния на отрасль.*

Результаты. *Перечислены экономические стимулы, связанные с подводной добычей полезных ископаемых. Например, нехватка ресурсов и растущий спрос на важнейшие минералы, колебания конъюнктуры рынка и технологические достижения, а также возможность для государства не зависеть от поставок сырья из других стран и попутно создавать дополнительные рабочие места – явные экономические стимулы для разведки и разработки подводных месторождений полезных ископаемых, обладающих*

неиспользованным потенциалом для удовлетворения глобального спроса. В исследовании представлены как укрупненные экономические стимулы для развития подводной добычи, так и их детализированный разбор.

Выводы. *Разведка проектов подводной добычи и их разработка предлагают миру потенциальную возможность удовлетворения растущего мирового спроса на минералы и металлы, особенно на критически важные элементы, необходимые для разных отраслей промышленности. Следует отметить, что понимание и оптимизация экономических стимулов, связанных с подводной добычей, чрезвычайно важны для всех заинтересованных сторон: недропользователей, политиков и исследователей. Применяя методы устойчивого развития, рационального природопользования и международного сотрудничества, можно максимизировать выгоды, одновременно снижая потенциальные экологические риски. В работе задан вектор проведения будущих работ в направлении более углубленного изучения рассмотренных экономических стимулов.*

Ключевые слова: *подводная добыча; экономические стимулы; дефицит ресурсов; стоимость минералов; технологические достижения; экономическое развитие.*

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