

Problems and Countermeasures in the Development of China's Rare Earth Industry

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Abstract. China is the biggest, rare-earth reserve-producing country and supply country in the world and most of rare earth resources in China are located in Baiyunbo in Inner Mongolia and ion-type deposits in the south China, which includes 17 elements and has extremely high application value. China rare earth industry is strategic resource of the country, which plays an important role in national industrial security. However, China rare earth is also facing several challenges, including environmental pressure, imbalance in the industrial chain structure, and global competition. This research shows that these challenges can be solved by promoting green technology, upgrading the industrial chains, and establishing internationalized supply chain layout. These methods can make China rare earth industry more sustainable, efficient, and competitive. This research can provide instruction and reference for policy makers and industry participants, which has significant application value for protecting China national resource security and promoting the sustainable development of China rare earth industries.

Keywords: China, Rare earth, Sustainable development

1. Introduction

Rare earth is a fundamental element for modern industry. These elements are used in permanent magnetic materials, catalytic converters, precision polishing, hydrogen storage alloys, and fluorescent materials. These industry raw materials are essential to modern industry as this industry raw material is widely used in fields such as new energy vehicles, wind power generation, aerospace, information technology, and national defense, and military industries. Therefore, rare earth has already become key mineral resources that major powers in the world are competing for, which relate to national industrial security and technological competitiveness.

The development of China's rare earth industry has significantly influenced the global rare earth landscape. In the early ages, China became the largest producer and exporter in the world by taking the advantage of resources, but because China didn't have core technology of exploit and extract of rare earth during this period, China was mainly served as a place for low-end processing or raw material supplier, and profit was comparatively low. Through total extraction control, industry consolidation and reorganization, and promoting environmental protection upgrades and technological research and development, China successfully shifted its rare earth industry from resource export to technology export in smelting processes. Now a day, China not only supplies for

approximately 60% - 70% of the global rare earth raw materials but also hold over 85% of the rare earth smelting and separation production capacity, which take place as an irreplaceable core position in global rare earth industry.

This article focuses on three core challenges behind the prosperous of China rare earth industry. These three main challenges are environmental sustainability pressure, imbalance in industrial structure, global competition and supply chain risks. Focus on these three challenges, this article mentions the establishment of a "green, high-end, and internationalized" model for China's rare earth industry. For example, mandatory implementation of green mining technologies, establishment of a resource recycling system, extension of the industrial chain to downstream high-value-added sectors, and deepening international cooperation through technology transfer. This article focused on set of action guidelines for policy makers and companies, which holds significant reference value for ensuring national resource security and improving the international competitiveness of industries.

2. Problems

2.1. Environmental and resource sustainability

The process of exploiting, smelting, and separating rare earth has significant impact on environment, which has become one of the severe challenges to the rare earth industry. The traditional method of exploiting rare earth, especially Heap leaching and pond leaching processes for ionic rare earth ores will produce enormous wastewater containing ammonia nitrogen and heavy metals. This wastewater has destructive effects on the ecosystem of water body in digging. The smelting and separation process involves a large amount of acid and base reagents. It will produce radioactive waste and wastewater, if these wastes are not managed properly, they will cause long-term pollution to the soil and groundwater [1]. Although the new technology has been spread, the cost of reaching green production is extremely high. Therefore, the profits of companies will decrease, so most of them are not willing to implement green production.

In addition, the high intensity of resource extraction will lead to pressure for long-term exploit. Indeed, China have huge amount of rare earth reserves, but the long period of high intensity exploit increases pressure for resource guarantee.

2.2. Structural industry composition and technological innovation

Nowadays, China has a significant advantage in the upstream mining and smelting, most of capacity for smelting and separation is concentrated in China. However, on some high value-added and high-tech content processed products domain, such as some high-performance rare-earth permanent magnetic materials and terminal components, the industrial competitiveness still has room for improvement. According to "China's Rare Earth Industry in 2025: Market Dynamics and Future Prospects under Strategic Resource Regulation", the proportion of China rare earth deep-processing increase from 35% in 2020 to 58% in 2025 [2]. It true that this proportion increases rapidly, it also reveals that there still in negligible part of the industrial value has not been fully competed within China.

Technological innovation challenges is also an important challenge for China rare earth industry. Facing the radical international competition for rare earth market, it is important and essential for making breakthroughs in technologies. For example, in the fields of high-purity separation of rare earth elements, preparation of new permanent magnetic materials, and efficient recovery of waste

materials, there still requires continuous efforts. Although some companies make development through research, they like increasing the secondary utilization rate of rare earth in the waste magnet recycling system to 92%.

2.3. Global competition and supply chain security risks

Nowadays, most of countries are reducing their dependency on China rare earth considering security of their supply chain. These countries actively promote the diversification of domestic mining and supply of rare earth resources. For example, Australia and Canada accelerate the expansion of their national rare earth industry. Although these countries are promoting their rare earth industry and aimed for approach self-sufficiency for rare earth, the overseas rare earth production capacity in 2025 is expected to only be able to meet 28% of the global demand and facing lots of technical bottlenecks and pressure from environmental protection organization [3]. It is true that foreign rare earth industry cannot shift the domain of China rare earth in global market, but when these countries have technically innovation or increase output in the future because the government support, China rare earth industry will face severe challenge.

Moreover, there are technological substitutions and uncertainty brought by trade policy for rare earth. Lots of countries are actively researching on substitution of rare earth to reduce the dependency on China rare earth. For example, Tesla has begun to develop motors without rare earth elements [4]. Dadio Steel also exploring the technology for replacing neodymium with cerium elements. If this technology gain breakthrough in the future, it will decrease the demand of rare earth in global market, which may have a long-term impact on the export of China rare earth. In addition, international trade environment, geopolitics factors, such as increase of tariff and war, will also bring dramatic influence on the develop of China rare earth industry.

3. Solutions

3.1. Green mining, recycling systems, and control systems

Government should implement mandatory implementers of green mining and smelting technologies to reduce environmental issues. For ionic-type rare earth minerals, government should prohibit lagging processes such as heap leaching and pond leaching, and promote in-situ leaching, an alternative to traditional U milling, which produces no tailings at the surface and pumps extractant solutions into the ore body in place [5]. Also, research and application of efficient and environmentally friendly leaching agents, reduce ammonia nitrogen pollution from the source. For fluor cerium ore and other light rare earths, researchers should research and promote superconducting magnetic separation, a method of mineral processing that separates magnetic materials from non-magnetic ones by using strong magnetic fields produced by superconducting magnets. This method can decrease the number of ore entering the smelting process, which reduces energy consumption and waste generation.

In addition, government should establish a full life cycle resource recycling and utilization system, which can use the recourse more efficiently and avoid waste. Government can establish a complete network for the recycling of secondary rare earth resources. To achieve this, Chinese rare earth industry should focus on breakthrough in key technologies for efficient recovery of rare earths from waste neodymium-iron-boron magnets, waste phosphors, and waste catalysts. Also, establish standard recycling production lines aim at increasing the proportion of renewable resources in rare earth raw materials in the future. To make more companies join the recycle program, government

can implement the "Producer Responsibility Extension System", which requires downstream application enterprises such as rare earth permanent magnets to participate and be responsible for recycling [6].

Moreover, government should implement more scientific and precise control of total amount of resources being exploited. When implementing the police, government should not simply limit the total amount of recourse that has been exploited but based on element. For elements such as cerium and lanthanum that are in excessive supply, the extraction volume should be strictly controlled. For supply of rare elements in short supply such as neodymium, praseodymium, dysprosium and terbium, government can be adjusted the amount of exploit according to market demand to ensure the raw material security of downstream industries. With this method, government can limit both the amount of rare earth been exploited to avoid excessive exploitation and sufficiency in the demand of market.

3.2. Reorganization of rare earth enterprises and decrease dependency on foreign countries

Chinese government should promote strategic reorganization of rare earth enterprises. By support the leading enterprise such as China Rare Earth Group, government can reduce the disordered competition inside China and integrate recourses inside country. With more resources, these leading companies can purchase or jointly establish high-end magnetic materials, motor, sensor and other processing and application enterprises, which can build a giant that crosses the entire industrial chain [7]. Also, with more resources, these leading companies can implement more recourses on innovation, which focus on overcoming techniques like highly abundant rare earth (cerium, lanthanum) balanced utilization technologies, ultra-high performance neodymium iron boron, and new rare earth catalytic materials, and rare earth alloy materials.

Moreover, government should also focus on decreasing the dependency of high-end equipment from foreign countries and industries. According to "The new quality productive forces empower the high-quality development of the rare earth industry the actual problems, internal mechanisms and practical paths", in the downstream technology industry, the layout is highly valued in countries like the United States [8]. For instance, Hitachi is the only corporation in Japan with more than 600 patents in the application industry [9]. Therefore, it is essential to promote the research on downstream equipment to reduce the dependency of downstream on western countries and protect the security of China rare earth industry. Intelligent the rare earth industry is also important, it can decrease the need for labor and increase the efficient of rare earth production, which will increase the competitive of Chinese rare earth dramatically in global market. Therefore, domestication and Intelligence are two important domain China rare earth industry need to focus to.

3.3. Diversify supply chain, upgrade industries, and deepen internationalization cooperation

China needs to maintain its superiority in the technology of rare earth smelting and separation as well as the supply of high-purity products, which make it as an irreplaceable role in global rare earth market. Also, China must promote domestic enterprises to invest out sea. Use its technique and Capital invest in over sea rare earth project, such as mines in Australia, Canada and Africa, participate in up-stream exploitation, to achieve diversity of supply of rare earth recourses, which can increase the ability of facing geopolitical risk.

Moreover, China should actively respond to technological substitution, not passive defense, but actively lead the market. Chinese companies or government need to establish a special project and closely monitor news innovation about substitute of rare earth, such as Tesla's rare-earth-free motor,

Japan's reduced-rare-earth technology. To test the feasibility of this research and substitute technics for rare earth to face future competition. Also, China can focus on how to use the advantage of rare earth and maximize its benefits. By research on developing the new generation of rare earth technology that performance far exceeding alternative solutions, such as permanent magnetic materials with higher magnetic energy products and higher working temperature, new substitutes like Tesla's rare-earth-free motor will lose its advantage.

Furthermore, China can deepen international cooperation, shifting from resource export to technology export. China can export its advanced technique and experience on exploiting rare earth to those countries just started to develop rare earth industry, such as Vietnam and Myanmar. By transform green mining and smelting technologies, standards, equipment, and management experience to these countries, China can increase and strengthen the cooperation with these countries in rare earth industry [10]. Therefore, China will have more allies on rare earth industry in global market and will not be affected to much by the sanction from western countries like United States, which protect the security of Chinese rare earth market.

4. Conclusion

This research elaborates on the significant position of China's rare earth industry in terms of strategic Key Areas, its development process, and multiple challenges it is facing, including environmental, structural and international competition. To solve these challenges, this article points out our three solutions, the development of greenness, high-end reform, and internationalization, also providing specific implementation strategies.

However, this study still has some limitations, mainly because data and policy documents cited have limited timeliness, have not included latest industry developments in 2024 and 2025. Also, some of policies mentioned in the text are still necessary to further refine during real implementation and verify by considering local practices and industry differences because of a lack of deep analysis of the regional obstacles that may occur during the implementation of the policies.

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