

# Prospects of Nuclear Power-Based Industry As A Replacement For Depleting Tin Resources In Bangka Belitung

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**Abstrak** Menipisnya sumber daya timah di Bangka Belitung menimbulkan tantangan yang signifikan bagi keberlanjutan ekonomi dan ketahanan energi daerah. Studi ini mengeksplorasi prospek pembentukan industri berbasis tenaga nuklir sebagai pengganti menipisnya sumber daya timah. Penelitian ini menggunakan metodologi komprehensif yang mencakup tinjauan literatur, pengumpulan data, penilaian potensi, analisis keberlanjutan, analisis implikasi ekonomi, studi kasus, analisis skenario, dan rekomendasi kebijakan. Studi ini dimulai dengan tinjauan literatur, yang memberikan dasar pengetahuan tentang teknologi tenaga nuklir, sumber daya timah, dan industri masing-masing. Pengumpulan data kemudian dilakukan untuk mengumpulkan informasi yang relevan tentang tren produksi dan konsumsi timah saat ini di Bangka Belitung, serta data tentang teknologi tenaga nuklir, potensi implementasinya, dan implikasi ekonomi dan lingkungannya. Temuan penelitian ini menunjukkan bahwa industri berbasis tenaga nuklir menjanjikan sebagai alternatif yang layak untuk mengatasi menipisnya sumber daya timah di Bangka Belitung. Penilaian potensial menunjukkan kelayakan penerapan teknologi tenaga nuklir, sementara analisis keberlanjutan menyoroti pentingnya mengatasi masalah lingkungan dan sosial. Analisis implikasi ekonomi mengungkapkan manfaat ekonomi potensial dan studi kasus memberikan wawasan tentang skenario yang mungkin. Rekomendasi kebijakan menawarkan panduan untuk pembangunan berkelanjutan dan keterlibatan pemangku kepentingan yang efektif.

**Kata kunci:** Kata kunci: tenaga nuklir; sumber daya alam; pertambangan timah; industri

**Abstract** The depletion of tin resources in Bangka Belitung poses a significant challenge for the region's economic sustainability and energy security. This study explores the prospects of establishing a nuclear power-based industry as a replacement for depleting tin resources. The research employs a comprehensive methodology that includes a literature review, data collection, potential assessment, sustainability analysis, economic implications analysis, case study, scenario analysis, and policy recommendations. The study begins with a literature review, which provides a foundation of knowledge on nuclear power technology, tin resources, and their respective industries. Data collection is then conducted to gather relevant information on the current tin production and consumption trends in Bangka Belitung, as well as data on nuclear power technology, its potential implementation, and its economic and environmental implications. The findings of this research suggest that a nuclear power-based industry holds promise as a viable alternative to address the depletion of tin resources in Bangka Belitung. The potential assessment demonstrates the feasibility of implementing nuclear power technology, while the sustainability analysis highlights the importance of addressing environmental and social concerns. The economic implications analysis reveals potential economic benefits and the case studies provide insights into possible scenarios. The policy recommendations offer guidance for sustainable development and effective stakeholder engagement.

**Keywords:** nuclear power; natural resources; tin mining; industry

## INTRODUCTION

Indonesia is one of the most mineral-rich countries in the world and heavily relies on extractive mining industries, such as nickel, copper, natural gas, gold, and tin. Its geographical location along the Southeast Asia Tin Belt, alongside Myanmar, Thailand, and Malaysia, makes it the second-largest tin producer globally, contributing approximately 26% of the total global tin production after China (Aleva dkk., 1973). Tin sediments are widely distributed across the western islands of Indonesia, including Bangka, Belitung, Singkep, and Karimun Kundur, which are collectively known as "The Indonesian Tin Belt." The regulation and management of mining policies are crucial aspects in ensuring economic sustainability and environmental resilience (Rosyida dkk., 2019). Moreover, the mining sector poses various risks often associated with the "resource curse," a phenomenon characterized by degradation and systemic losses resulting from improper resource management.

Essentially, the resource curse leads to latent problems in the environmental, economic, and social domains, particularly in major mining regions (Ross, 1999). This condition is evident in the complexity and latent issues faced by Bangka Belitung, the second-largest tin-producing archipelago in the world. Currently, Indonesia is the world's second-largest tin exporter, with 98% of its total production being exported to other countries, while only 2% is used for domestic industrial needs (Erwana dkk., 2015). With a total production of 76,400 tons in 2017 and an average of 60,000 tons over the past decade, 99% of Indonesia's tin is produced in Bangka Belitung (Yanto dkk., 2023). Since the colonial era, tin exploitation has been conducted on a massive scale, leading to the growth of mining towns such as Muntok, Sungailiat, Pangkalpinang, Toboali, and Koba. The tin mining sector in Indonesia has undergone different governance approaches over the years since the end of colonialism. The three tin mining companies owned by the Netherlands were nationalized and merged in 1958, forming the Tin Mining State Company in 1968. For the next 31 years, the Indonesian government fully controlled and regulated tin mining as a strategic mineral resource (Susilo & Maemunah, 2009).

Bangka Belitung, is not only renowned for its tin resources but also holds a hidden treasure in the form of rare earth elements (REEs) (Asof dkk., 2022). With vast reserves of over 350,000 tons of REEs, including monazite, xenotime, and thorium, the province possesses tremendous economic potential. Bangka Belitung's geological landscape harbors substantial deposits of rare earth elements. (Diana dkk., 2021) Monazite, xenotime, and thorium are rich in REEs such as cerium, neodymium, and lanthanum, which are critical components in the production of advanced technologies, including electronics, renewable energy systems, and high-performance magnets. (Harjanto dkk., 2013) The abundance of these rare earth minerals positions Bangka Belitung as a significant player in the global rare earth market.

The demand for rare earth elements has witnessed remarkable growth due to their indispensability in various industries. Electric vehicles, wind turbines, and smart devices rely heavily on REEs for their functionality and efficiency (Priyagus, 2023). As global interest in sustainable technologies continues to surge, the demand for REEs is expected to rise exponentially. Bangka Belitung can seize this opportunity to meet the increasing demand and become a key supplier in the international market. Namun, belum tersedianya teknologi yang dimiliki Indonesia untuk melakukan pengelolaan REEs menyebabkan keseluruhan potensi tersebut belum dapat digunakan.

The industrial prospects and economic substitution have emerged as fundamental and crucial issues for Bangka Belitung. The potential of tin, which has served as the backbone of the economy for the past 350 years, necessitates the

initiation of diversification before tin mining is completely depleted by 2040-2050. Presently, Bangka Belitung possesses 14% of the world's tin reserves, totaling approximately 800,000 tons. However, with an average mining rate of 70,000 tons per year, this potential will be exhausted in less than 20 years.(Yanto dkk., 2023) With the discovery of new reserves and advanced processing methods, the economic potential of tin could be extended for up to 30 years. Nonetheless, this does not diminish the urgency of economic diversification and the exploration of alternative resources to replace tin in the future. One crucial strategy is the utilization of nuclear power plants to support the industrial sector.

## **METHOD**

This research aims to assess the prospects of establishing a nuclear power-based industry as an alternative to address the depleting tin resources in Bangka Belitung. The study employs a comprehensive research method that combines literature review, data collection, potential assessment, sustainability analysis, economic implications analysis, and policy recommendations.(Hamzah, 2021) To begin, a thorough literature review is conducted to gather existing knowledge on nuclear power technology, tin resources, and their respective industries. This provides a solid foundation for understanding the current state of nuclear power technology, the depletion of tin resources in Bangka Belitung, and any previous research conducted in this area.

Data collection involves gathering relevant information on the current production and consumption trends of tin in Bangka Belitung. Additionally, data is collected on nuclear power technology, its potential implementation in the region, and its economic and environmental implications. Reliable sources such as government reports, industry publications, and academic studies are utilized to gather accurate and up-to-date data. The research proceeds with a potential assessment, which evaluates the feasibility and potential of establishing a nuclear power-based industry. Furthermore, a sustainability analysis is conducted to evaluate the environmental, social, and economic sustainability implications of adopting nuclear power in Bangka Belitung.

## **RESULTS AND DISCUSSION**

### **Economic Dependencies and Environmental Degradation of the Tin era**

The government's policy to maintain the centralization of tin mining faced challenges with the declining market prices in the 1980s (Adikara & Munandar, 2021). Efforts to stabilize the global tin price through the International Tin Agreement and the International Tin Council failed to yield positive surpluses. The failure of the 6th ITA agreement, the accumulation of ITC debt, the discovery of substitute materials, and post-consumer tin recycling disrupted global tin prices and had far-reaching impacts on Indonesia. Although tin production figures remained consistent on average, the state's revenue sharply declined over the following 10 years (Erman, 2022). This directly contributed to the decrease in state income, the decline in living standards, scarcity of necessities and food, inflation, and widespread political unrest until 1998.

The government initiated a restructuring of tin mining in 1999, declaring tin as an export commodity no longer regulated and supervised by the central government (Rahayu, 2016). Law Number 22 of 1999 on Regional Governments shifted the responsibility to regional governments for regulating and managing mining in their respective areas. This provision was part of the regional autonomy project. The decentralization policy introduced by the government in the early reform era aimed to reduce the centralized authority that had been constraining during the New Order era,

while providing opportunities for regions to independently develop their economic potential (Jati, 2016).

The economic decentralization and the removal of tin as a strategic mineral in 2002 resulted in the phenomenon of the "Illegal Mining Boom," characterized by direct community involvement in tin mining. However, weak mining management led to uncontrolled artisanal mining practices, resulting in systemic losses. Although it generated economic surpluses that improved community welfare, illegal tin exploitation contributed significantly to environmental damage (Ibrahim, Haryadi, dkk., 2019).

There is no exact data on the number of illegal miners in Bangka Belitung. The Association of Artisanal Tin Mines (ASTIRA) recorded 13,345 small-scale (non-conventional) mines in 2006. According to provincial government data in 2018, this number increased to 18,000 units. PT Timah Tbk released findings in March 2012 indicating the presence of 6,230 illegal suction dredges scattered in the waters of Bangka. Wahana Lingkungan Hidup (Walhi) recorded that from 2004 to 2013, there were 81,000 illegal mining units scattered in Bangka Belitung (Yanto dkk., 2023). Although there is no updated data until 2023, it is certain that the number of illegal miners has not decreased since before 2013, as evidenced by the increase in annual average environmental damage caused by illegal mining.

In a study conducted by Ibrahim et al. in 2019, a comprehensive examination of the history, socio-economic aspects, and income contributions concluded that the people of Bangka Belitung have a high dependency on tin. Ibrahim explicitly states that "selling activities in primary markets available in Bangka Belitung Islands Province were greatly depended on tin mining results." This dependency is not only seen in the significant contribution of tin to the Regional Original Income (PAD), which fluctuates above 50% since the beginning of the reform era, but also in the income received by the community. Comprehensive data indicates that the value of tin sales also influences the fluctuation of prices for basic necessities in the market. Quantitative data from the study showed that 84.5% of respondents agreed that there was an increase in the prices of basic necessities that correlated linearly with tin (Ibrahim, Haryadi, dkk., 2019). This direct dependency has caused various enduring problems that are difficult to overcome, even until today. Tin mining has contributed to a high rate of school dropouts and child labor. In 2015, there were 3,337 child workers under the age of 17 involved in the mining sector (Rosyida dkk., 2019). The involvement of children in illegal mining activities is a form of marginalization and is in conflict with labor laws in Indonesia, the basic principles of the International Labor Organization, and human rights.

The exploitation of tin mines has left extensive environmental damage in Bangka Belitung. Environmental damage data inventory released by the Provincial Environmental Agency of Bangka Belitung in 2014 reported that out of a total land area of 1,675,240.51 hectares, there were critical land areas covering 15.15%, potentially critical land areas of 37.28%, moderately critical land areas of 44.54%, and only 10.79% remaining as non-critical land areas. Furthermore, a survey conducted by the Wahana Lingkungan Hidup (Walhi) of the Bangka Belitung Islands Province in 2020 showed that the critical land areas had expanded to 1,053,253.19 hectares, or 64.12% of the total land area. Over the past decade, Bangka Belitung has also lost 320,000 hectares of productive land due to mining activities (Ibrahim dkk., 2018).

Environmental damage caused by tin mining is directly associated with the dredging and separation of tin ore from the soil and seabed. According to data released by PT Timah, the average tin ore content in Bangka Belitung is 0.32-0.43 kilograms per cubic meter. With a total production of 82,820 tons in 2018, it requires the removal of approximately 18.6 million cubic meters of soil in just one year (Susilo & Maemunah, 2009). Over a five-year period, from 2017 to 2021, the total tin

production in Bangka Belitung was 291,590 tons, resulting in the excavation of 65.8 million cubic meters of soil. The remaining land from tin mining cannot be utilized for productive purposes and is often used as small-scale mining areas by the community. Unlike large-scale mining areas, which are required to undergo reclamation, illegal small-scale mining leaves behind holes and contamination without any remediation. Data from the Environmental Agency in 2021 shows that 75% of the 67 rivers flowing in Bangka Belitung have been polluted due to illegal mining. Additionally, seven rivers that hold the largest freshwater reserves in Bangka, including the Mabet, Kayubesi, Limbung, Baturusa, Selindung, Pangkalbalam, and Rangkui rivers, are categorized as heavily polluted with chemical compounds exceeding water quality standards based on Government Regulation No. 82 of 2011 (Mentari dkk., 2017).

Environmental degradation systematically transforming the landscape of Bangka Belitung into 'Dead Islands' is expected to continue for several decades (Yanto dkk., 2023). As of 2020, the total known tin reserves worldwide amount to 4,741,000 tons, with 800,000 tons (17%) located in Indonesia. With an average mining rate of 70,000 tons per year, Bangka Belitung will continue to be mined at least until 2035. However, ongoing exploration activities over time are likely to result in the discovery of new reserves, thus extending the lifespan of tin exploitation on the island.

While tin mining has brought economic benefits to Bangka Belitung, the province's heavy reliance on this sector poses challenges and risks. The fluctuating global tin prices can impact the province's revenue and profitability, leading to economic instability (Panjaitan & Himlawan, 2023). Environmental concerns arising from unsustainable mining practices and the potential exhaustion of tin reserves pose long-term risks. Moreover, the concentration of economic activity in a single sector leaves the province vulnerable to external shocks and market fluctuations.

### **Post-Tin Economy and the Limitations of Potential Due to Mining Damage**

Tin is not available indefinitely. The estimate of 25-35 years remaining of tin reserves highlights the recurring question that has emerged since the reform era, "What economic sectors can be relied upon after tin in Bangka Belitung?" As of 2023, agriculture, tourism, and micro, small, and medium enterprises (MSMEs), which have been promoted through government programs, have not demonstrated a dominant contribution to the regional revenue graph. Bangka Belitung has yet to identify the answer (Gunawan & Somantri, 2023).

Since 2019, the industry has shown more promising potential, with projects such as palm oil plantations dominating large areas of land, although they provide insufficient employment opportunities and wealth distribution to the local community. (Faculty of Law, University of Bangka Belitung, Bangka, Indonesia dkk., 2022) The shrimp farming industry, which was once popular and quickly proliferated in several areas, has high projections. Additionally, the development of industrial zones, such as the Sadai Integrated Industrial and Port and the Tanjung Kelayang Special Economic Zone, opens alternative opportunities for investment and promising industrial development in Bangka Belitung to reduce and eliminate dependency on tin.

However, the progressive development of industries is encountering a (too) rapid slowdown. The shrimp farming industry faces electricity supply constraints, as do several industrial development plans. In 2020, the peak load capacity of electricity in Bangka Belitung was 186.77 MW, with the peak load used by the community amounting to 154.57 MW. Mathematically, this condition results in a surplus of at least 32.2 MW. However, power plants are not always operated at their peak load and often limit the power generated for efficient utilization. From an industrial development perspective, this condition is not ideal and poses high risks, especially for shrimp farming. The interconnection disruptions that occurred in 2021, 2022, and 2023

indicate that Bangka Belitung is experiencing an "energy stability crisis," a condition that needs to be eliminated to ensure the implementation of development in the region.

On the other hand, the economic transition to curb environmental degradation and stabilize industrial projections requires a substantial supply of energy. The government's plan to undertake tin downstreaming as part of economic development and value addition also necessitates a large and stable energy supply. Therefore, interconnection solutions through the Sumatra transmission network are not reliable long-term solutions to support industrial development projections in Bangka Belitung. For an archipelagic province, energy self-reliance and resilience are fundamental requirements for development in Bangka Belitung. This condition hinders the potential development of the shrimp farming industry in Bangka Belitung.

In addition, the tin mining industry in Bangka Belitung has had far-reaching consequences, leading to significant environmental degradation and negatively impacting key sectors such as agriculture, tourism, and fishing (Ibrahim dkk., 2018). Tin mining has caused severe damage to agricultural land in Bangka Belitung. The extensive extraction activities have resulted in deforestation, land degradation, and soil erosion (Yunianto, 2009). The clearing of vegetation and disruption of natural water systems have adversely affected the fertility and productivity of agricultural areas. Farmers struggle to cultivate crops in the aftermath of tin mining, leading to reduced yields and economic hardship (Mentari dkk., 2017). Restoring agricultural land and implementing sustainable farming practices will be crucial for revitalizing the agricultural sector in the region.

The environmental degradation caused by tin mining has also taken a toll on the tourism industry in Bangka Belitung. The once-pristine natural landscapes and coastal areas have been marred by mining activities, leaving behind scars of desolation (Ibrahim, Zuhri, dkk., 2019). The destruction of coral reefs and marine ecosystems has impacted the region's potential for diving and snorkeling tourism. Furthermore, the loss of biodiversity and deforestation have diminished the appeal of eco-tourism. Rehabilitating the environment, investing in ecological restoration, and promoting sustainable tourism practices are essential for reinvigorating the tourism sector and attracting visitors to the region (Haryadi dkk., 2023).

Shore mining activities, which involve extracting tin from coastal areas, have disrupted the marine ecosystem and fish habitats. The sediments and pollutants discharged during mining operations have affected water quality, reducing fish populations and biodiversity. Fishermen struggle to make ends meet as their catch declines, leading to economic hardship in coastal communities. Implementing measures to restore coastal habitats, enforcing sustainable fishing practices, and promoting aquaculture initiatives can help revive the fishing industry and secure livelihoods for fishermen (Rosyida dkk., 2019). The degradation caused by tin mining poses significant challenges for finding viable economic substitutes. Reversing the environmental damage and rebuilding the affected sectors requires substantial investment, long-term planning, and collaborative efforts from various stakeholders.

### **Nuclear Powerplant Based-Industry Potential**

The development plan for a Thorium-based Nuclear Power Plant (NPP) brings a breath of fresh air to long-term development plans in Bangka Belitung. It presents a solution to the dualism of urgent needs, addressing the energy requirements for industry while promoting green and emission-free energy use, all within a new and pioneering concept in Indonesia: the Thorium-based NPP. A comprehensive study conducted by PT Surveyor Indonesia during a three-year Feasibility Study from 2011 to 2013 demonstrated the viability of Bangka Belitung as a site for the construction of an NPP with a power capacity of up to 10,000 MW. Assuming a development of 50%

of this potential capacity, or 5,000 MW, Bangka Belitung would not only be able to meet domestic energy demands but also distribute energy sources to all provinces in Sumatra. This would have positive impacts on industries, development, and the economy. Downstreaming tin to obtain added value by optimizing the remaining reserves can also be carried out with the support of Thorium-based NPPs (Yanto, 2022).

The feasibility study assessed various factors such as geology, geotechnical conditions, seismicity, hydrology, and site suitability, indicating that Bangka Belitung possesses the necessary characteristics for the construction and operation of an NPP. The study also considered the regulatory and licensing requirements, safety considerations, waste management, and public acceptance. The results provide a strong foundation for the potential establishment of a Thorium-based NPP in Bangka Belitung (Rayhan dkk., 2022). With the depletion of tin mining reserves on the horizon, Bangka Belitung, an Indonesian province, faces the challenge of transitioning its economy towards sustainable and diversified sources. The Indonesian government's plan to establish a Nuclear Power Plant (NPP) in Bangka Belitung offers significant economic benefits. This essay explores the potential advantages of an NPP in driving economic growth and prosperity in the province after tin mining depletion.

The establishment of an NPP in Bangka Belitung would enhance energy security by providing a stable and reliable source of electricity. As tin mining depletes, the province may face uncertainties in its energy supply. A nuclear power plant, with its capacity to generate up to 10,000 MW, can meet the growing energy demands of industries, commercial sectors, and households, ensuring uninterrupted power supply and reducing reliance on imported energy sources. Moreover, the construction and operation of an NPP also would generate a significant number of employment opportunities in Bangka Belitung. Skilled workers would be required for various stages, including engineering, construction, maintenance, and operation. The establishment of training programs and vocational institutes would further enhance local skills development, creating a highly skilled workforce that can contribute not only to the NPP but also to other sectors in the province.

The NPP provide a much-needed catalyst for economic diversification in Bangka Belitung. With the decline of tin mining, the province has an opportunity to attract investments in industries related to the nuclear power sector, such as nuclear research, technology development, and manufacturing of equipment and components. This diversification would reduce the province's dependence on a single industry and contribute to a more resilient and balanced economy. The establishment of an NPP in Bangka Belitung create an attraction for significant foreign direct investment (FDI) to the region. International companies specializing in nuclear power technologies and services would seek partnerships and investment opportunities. This FDI influx would not only bring capital but also foster knowledge transfer, technology advancement, and expertise development. Additionally, Bangka Belitung could potentially export surplus electricity to neighboring regions, generating additional revenue and strengthening its position as an energy hub.

A nuclear power plant-based industry can facilitate the development of value-added REE products in Bangka Belitung. With a stable energy supply, the province can attract investments in REE downstream industries, such as the production of magnets, catalysts, and advanced materials. By moving up the value chain, Bangka Belitung can capture a larger share of the global REE market, create higher-value products, and generate increased revenue and employment opportunities.

As a clean and low-carbon energy source, nuclear power can help mitigate environmental challenges in Bangka Belitung. By reducing reliance on fossil fuels for electricity generation, the NPP would contribute to the province's efforts in combating climate change and improving air quality. The transition to nuclear power would also

align with global sustainability goals and enhance Bangka Belitung's environmental credentials, attracting environmentally conscious investors and tourists. The establishment of a Nuclear Power Plant in Bangka Belitung after tin mining depletion offers numerous economic benefits. Energy security, job creation, economic diversification, foreign direct investment, and environmental advantages are among the key advantages that an NPP would bring to the province. The government's comprehensive study by Badan Tenaga Atom Nasional (BATAN) in 2011 confirming the suitability of Bangka Belitung for an NPP further strengthens the case. By embracing nuclear power, Bangka Belitung can position itself as a sustainable energy leader, driving economic growth, and ensuring a prosperous future for its inhabitants.

## CONCLUSION

Bangka Belitung's economic dependency that relies on the tin extractive sector is not sustainable. The remaining potential tin reserves provide an economic transition time for Bangka Belitung in less than 30 years. Currently, Indonesia is still the largest tin exporter in the world, with exploitation that leaves a number of problems, both social and environmental. As a consequence, a number of economic potentials are threatened with not being able to develop due to the impact of tin exploitation, including agriculture, tourism, and capture fisheries. Mining is shutting down alternative economic sources in Bangka Belitung. One important economic resource that has not been developed extensively, but has high potentiality is industry. Bangka Belitung can transition into an industrial center province with the support of thorium-based nuclear technology. The content of Rare Earth Elements (REEs) in tin tailings can be produced through a purification process with the support of abundant energy availability. The existence of NPP will contribute highly to the economic development of the people of Bangka Belitung after tin can no longer be relied on as the main source of income in the future.

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