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From Waste to Wealth: Developing a Restorative Business Model for Sustainable Re-Mining in Indonesia's Post-Tin Mining Management

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Abstract

Re-mining and reprocessing activities at post-mining tin sites on Belitung Island, Indonesia, present a strategic opportunity to recover non-metallic mineral resources, particularly silica, from legacy mining areas. Although PT Timah Tbk, Indonesia's state-owned tin mining company, has implemented environmental rehabilitation initiatives, field observations indicate that large portions of former mining landscapes remain degraded and underutilized. Notwithstanding these conditions, post-mining sites retain significant potential for sustainable resource management through the valorization of residual non-metallic materials. This study focuses on the sustainable utilization of mining waste by identifying, reprocessing, and integrating residual materials into environmentally responsible restoration practices, while simultaneously fostering the development of community-supported green industries. This article proposes a sustainable post-mining business model structured around three interrelated dimensions. From an ecological perspective, the model incorporates reclamation and revegetation value propositions, ecosystem restoration activities, green technology innovations for optimizing mining waste utilization, and alignment with regulatory and policy frameworks. From an economic perspective, the model emphasizes access to financing mechanisms, green investment instruments, and the circular utilization of mining residues to support long-term economic viability. From a social perspective, the model highlights stakeholder engagement through strategic partnerships with local communities and collaborative governance involving mining enterprises. Furthermore, the study advances a Restorative Business Model that integrates sustainability, circular economy principles, and land restoration into post-mining management. By promoting product diversification from mining waste, improving resource efficiency, generating local employment opportunities, and strengthening multi-stakeholder collaboration, the proposed model demonstrates the potential of post-mining landscapes to transition from environmental liabilities into regenerative socio-economic assets.

Keywords: *Post Mining Management, Sustainability, Restorative Business Model.*

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INTRODUCTION

The escalating global demand for mineral resources has intensified the environmental and social pressures associated with mining activities. Conventional mining practices have been widely documented to contribute to ecosystem degradation, manifested through deforestation, soil erosion, and contamination of water bodies (Ignatyeva et al., 2020). In response to these persistent challenges, the Restorative Business Model (RBM) has emerged as an alternative framework that redefines post-mining management by embedding ecological restoration within business operations. This article examines the core principles of the Restorative Business Model and evaluates its potential role in advancing sustainability-oriented practices in post-mining contexts.

Within contemporary sustainability discourse, the Restorative Business Model represents a paradigm shift from impact minimization toward active environmental regeneration. Rather than focusing solely on mitigating negative externalities, RBM emphasizes the deliberate restoration of degraded ecosystems as a strategic component of business value creation. This approach is particularly relevant for extractive industries, such as mining, which have historically generated substantial environmental disruption (Kretschmann, 2018).

This model is underpinned by the premise that business activities can be aligned with natural systems, fostering a mutually beneficial relationship between economic performance and environmental integrity (Ranta et al., 2018). By prioritizing restoration-oriented strategies, organizations are able to reconfigure their operational practices to simultaneously support ecosystem resilience, community well-being, and long-term economic feasibility. In this respect, the restorative business model departs from conventional extractive paradigms by embedding regenerative and sustainability principles into decision-making processes, thereby enabling the replenishment of natural resources and the revitalization of degraded ecosystems.

Beyond conventional sustainability frameworks, the restorative business model seeks to generate net-positive outcomes for both ecological systems and society by actively restoring and regenerating environmental and social capital (Kodir et al., 2017). Within the mining sector, this approach extends beyond impact mitigation to encompass post-mining environmental rehabilitation and the enhancement of local socio-economic conditions. By integrating sustainability objectives into the core business strategy, the restorative business model supports long-term value creation and strengthens competitive advantage through responsible and forward-looking practices (Pactwa et al., 2021).

Re-mining initiatives in Indonesia illustrate a pragmatic and sustainability-oriented approach to post-mining management, emphasizing land rehabilitation and the valorization of residual mining materials for environmentally friendly technologies (Lestari et al., 2018). By repurposing mining by-products within green technological applications, such initiatives not only facilitate ecosystem recovery but also contribute to the broader global transition toward clean energy

systems (Luthfiah et al., 2021). In this context, Sustainable Post-Mining Management (SPMM) has gained recognition as an integrative solution that mitigates the environmental externalities of mining activities while simultaneously stimulating innovation in green energy development (Kretschmann et al., 2017).

Sustainable post-mining management extends beyond the objective of minimizing environmental degradation during active mining operations (Kretschmann, 2020). Instead, it adopts a life-cycle perspective that encompasses pre-extraction planning, operational decision-making, and long-term post-closure strategies. Within this framework, the effective utilization of residual materials—such as silica sand generated from mining processes—can be strategically embedded into green business models through multiple valorization pathways, thereby enhancing both environmental and economic outcomes (Bazzi et al., 2023).

As mining activities reach completion, sustainability considerations become central to addressing the residual environmental and social legacies of extraction (Festin et al., 2019). Sustainable post-mining practices seek to ensure comprehensive land rehabilitation, the restoration of ecosystem functions, and the socio-economic resilience of affected communities. A restorative business model for sustainable post-mining management therefore requires a holistic and integrated approach, combining strategic sustainability governance, circular economy principles, inclusive stakeholder engagement, and robust monitoring and evaluation mechanisms to support long-term value creation and system regeneration.

LITERATURE REVIEW

Incorporating restorative practices into business strategies requires a paradigm shift. It involves rethinking profit models, supply chains, and stakeholder engagement to prioritize long-term ecological balance (Ahirwal et al., 2021). The shift from conventional methods to a restorative approach is not only about minimizing negative impacts but also about enhancing positive outcomes for the environment and society.

The Restorative Business Model is predicated on the principle that businesses should not only aim for profit but also contribute positively to the environment and society. The core philosophy of this model includes:

1. Restoration of Ecosystems, The RBM emphasizes the need to restore ecosystems affected by mining activities. This involves rehabilitating land, reforesting areas, and ensuring biodiversity is maintained or enhanced.
2. Local Community Engagement: Engaging with local communities is crucial for developing a restorative approach. Stakeholders, including indigenous populations, can provide valuable insights into the sustainable management of natural resources and can be involved in decision-making processes.

3. Circular Economy Principles: The model incorporates circular economy principles, emphasizing the reuse and recycling of materials. By minimizing waste and maximizing resource efficiency, companies can create a more sustainable system that benefits both the business and the environment.
4. Long-term Value Creation: Instead of focusing solely on short-term profits, the RBM seeks to create long-term value by investing in sustainable practices that enhance community resilience and environmental health.

The framework for a restorative business model in post-mining management can be structured around several key components (Hendrychová et al., 2020):

1. Strategic Sustainability Management trough Integration of Sustainability are Embedding sustainability into business operations is crucial. This involves setting strategic sustainability priorities and aligning corporate objectives with these priorities. And Sustainability Drivers is Identifying internal and external drivers that influence the incorporation of sustainability into business models is essential. These drivers can vary based on the extent to which sustainability is embedded in the business model (Deb et al., 2017).
2. Circular Economy Principles with Implementing the principles of reduce, reuse, and recycle (3R) can significantly improve the environmental and economic viability of mining projects. This approach helps in optimizing resource use and minimizing waste. And Dynamic Subsidence Reclamation (DSR), This involves proactive management of topsoil, subsoil, and water resources to enhance post-mining land use and socio-economic conditions. DSR has shown to improve farmland productivity and economic returns compared to traditional reclamation methods (Lewandowski, 2016).
3. Stakeholder Integration, trough Integrating stakeholders into the business model is vital for achieving sustainability objectives and gaining societal acceptance. This involves continuous communication, knowledge sharing, and improvement. And provide the Social License to Operate, its ensuring that mining operations meet the expectations of stakeholders and investors by adopting sustainable and restorative practices (Worden et al., 2024).
4. Sustainable Value Creation: Measuring sustainable value creation at the business model level is important. This includes assessing the impact on environmental, social, and economic dimensions. Beside that measuring Life-Cycle Data for Utilizing life-cycle data and standardized measures to align business and environmental objectives can help in the effective implementation of sustainable business models (Zhang, 2023).

To understand the framework of a restorative business model, we can draw insights from the broader discussions on sustainable and

regenerative business models, as well as general business model frameworks. This model focuses on creating value across multiple stakeholder levels, including nature, societies, suppliers, shareholders, and employees. It emphasizes interdependencies between humans and nature, providing a holistic approach centred on restoration rather than mere mitigation (D'Amato et al., 2021).

Restorative business models represent a significant shift from traditional models by embedding sustainability into their core operations. They prioritize the triple bottom line, adopt circular economy principles, and emphasize collaboration and long-term resilience (Geissdoerfer et al., 2017). This holistic approach contrasts with the profit-centric, linear, and short-term focus of traditional business models. To understand how a restorative business model differs from a traditional business model, it is essential to compare their core principles and objectives, see Table 1.

Table 1. Comparison Traditional Business Model and Restorative Business Model

Aspect	Traditional Business Model	Restorative Business Model
Primary Goal	Financial profitability	Economic, environmental, and social sustainability
Approach	Linear	Circular
Resource Utilization	Maximize scale and optimize material assets	Reduce, reuse, recycle
Collaboration	Independent value creation	Collaborative and networked value creation
Focus	Short-term financial gains	Long-term sustainability

The framework for a restorative business model can be informed by existing sustainable and regenerative business model frameworks: 1) Capability Categories and Management Practices: A comprehensive framework categorizes capabilities and management practices necessary for effective management, including phases like developing solutions, creating demand, selling solutions, and delivering solutions. 2) Value Triangle: This framework includes core elements such as society, the natural environment, and future generations, focusing on co-created and co-delivered value: public, partner, and customer. 3) Circular Business Models: These models aim to maintain resource value at its maximum for as long as feasible, eliminating or reducing resource leakage by closing, slowing, or narrowing resource flows. Here is a comparison of several business models that are relevant to the sustainable business models see Table 2.

Table 2. Characteristics Business Model Related with Post Mining Management

Model Type	Focus	Key Characteristics
Sustainable Models (Méndez-León et al., 2022)	Mitigation of negative impacts	Balancing economic, social, and environmental aspects
Regenerative Models (Konietzko et al., 2023)	Restoration and positive contributions	Emphasizing interdependencies and holistic restoration
Circular Models (Barros et al., 2021)	Resource efficiency and waste minimization	Closing, slowing, or narrowing resource flows

To develop a restorative business model for sustainable post-mining management, several key principles can be identified from the provided abstracts. These principles focus on integrating sustainability into business operations, stakeholder engagement, and adopting circular economy practices.

METHOD

This research employed an exploratory qualitative approach, focusing on the in-depth exploration of the post-tin mining phenomenon in Belitung Regency, Indonesia, with Tanjung Pandan as its capital. Ten (10) key informants were utilized in the exploratory process to understand the post-tin mining conditions. In addition to the informants, in-depth observations and document reviews were conducted, comprising relevant reports and previous studies.

In defining the concept of "Strategic Business Model for Sustainable Post-Mining Management Through the Optimization of Tin Mining Residual Utilization in Belitung Island," it is necessary to formulate appropriate strategic options that are desirable, viable, and feasible to implement. This process involves defining the Strategic Value, Strategic Objective, and Strategic Initiative, which are three key elements in strategic planning that are interrelated and hierarchical (Wunder, 2023).

This research will conduct Inter-Rater Reliability coding analysis using NVIVO 15 software, allowing researchers to code data independently and compare their results. A high level of consistency in coding outcomes from different researchers (e.g., similar coding results) indicates that the instruments and data analysis processes used are reliable (Alam, 2021).

RESULTS AND DISCUSSION

Transitioning from traditional mining practices to restorative approaches is a transformative process that requires careful planning and execution. Traditional mining operations typically focus on maximizing resource extraction with less regard for post-extraction consequences. In contrast, restorative approaches emphasize regeneration and sustainable resource management.

The diagram below (Figure 1) illustrates that the factors of governance, industry readiness, social and economic support, as well as technology and innovation are interconnected in facilitating successful post-mining restoration. Each identified relationship underscores the importance of a collaborative and innovative approach that involves all stakeholders to achieve sustainable restoration goals.

The following recommendations are proposed for the development of a restorative business model in sustainable post-mining management: 1) Enhance Government Engagement: Increase the involvement of government in oversight and regulation to ensure the quality of restoration efforts. 2) Develop Training Programs: Establish training programs to improve the adaptability skills of businesses within the

mining industry. 3) Strengthen Collaboration: Foster collaboration between the private sector, government, and communities to create inclusive and effective restoration plans. 4) Integrate Advanced Technologies: Incorporate the latest technologies in the management of mining waste to enhance efficiency and product innovation. By adopting this integrated approach, it is anticipated that better restoration outcomes will be achieved, providing direct economic benefits to communities while protecting and restoring the environment.

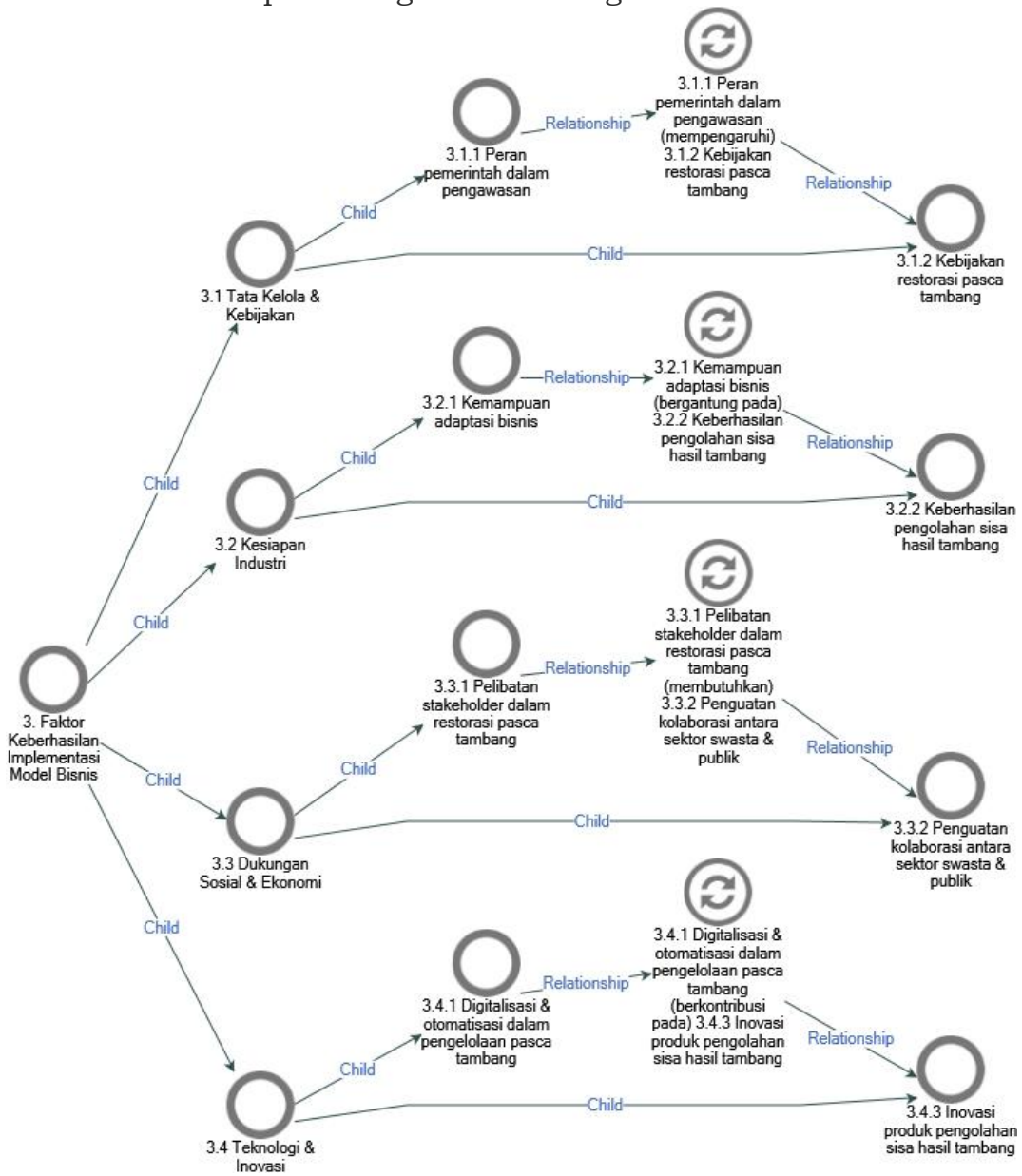

Figure 1. Diagram of the Relationship between Themes and Sub-themes of Successful Implementation of Restorative Business Models in Sustainable Post-Mining Management

The circular economy is a cornerstone of the restorative business model, offering principles that guide sustainable practices. Unlike the traditional linear economy, which follows a "take-make-dispose" model, the circular economy is designed to be regenerative by intention and design. It focuses on closing the loop of product lifecycles through greater

resource efficiency. Key Principles of a Restorative Business Model for Sustainable Post-Mining Management:

1. Integration of Sustainability into Business Operations
    a. Strategic Sustainability Management: Mining companies need to embed sustainability into their strategic management to achieve long-term value creation and competitive advantage. This involves setting strategic sustainability priorities and defining related corporate objectives.
    b. Corporate Commitment and Culture: A strong corporate commitment to sustainability, supported by a business culture that values sustainability, is essential. This includes integrating sustainability objectives through commitment rather than mere compliance.
2. Stakeholder Engagement
    a. Stakeholder Integration Model (SIM): Effective stakeholder engagement is crucial for achieving sustainability objectives and gaining societal acceptance. This involves identifying stakeholders, maintaining open communication, sharing knowledge, and continually improving practices to align with stakeholders' concerns.
    b. Social License to Operate: Mining companies must consider the needs of their stakeholders to secure their social license to operate. This includes addressing environmental, social, and governance (ESG) factors to build trust and strengthen stakeholder relationships.
3. Circular Economy Principles
    a. Closing Material Loops: Implementing circular economy principles such as waste valorisation, resource recovery from mine tailings, and water reuse can significantly reduce environmental harm and promote sustainable resource management.
    b. 3R Principles (Reduce, Reuse, Recycle): Applying the 3R principles in mining operations can lead to improved quality control, reduction of extractive waste, energy savings, and recycling of by-products, contributing to the overall economic viability and sustainability of mining projects.
4. Post-Closure Sustainability
    a. Human Welfare and Security: Post-closure sustainability must include considerations for human welfare, security, compliance with legal requirements, subsequent land use, and diversified employment opportunities 8.
    b. Land Reclamation and Habitat Enhancement: Successful land reclamation and habitat enhancement programs that go beyond regulatory requirements can serve as a foundation for sustainable post-mining management

By focusing on these principles, mining companies can develop a restorative business model that ensures sustainable post-mining management, balancing environmental, economic, and social

dimensions. Effective post-mining management is essential for achieving sustainability and mitigating the long-term impacts of mining activities. Several strategies can be employed to ensure successful restoration and rehabilitation of mined areas: 1) Integrated Land Use Planning: Developing comprehensive land use plans that consider ecological, social, and economic factors to guide post-mining land rehabilitation and future development. 2) Collaborative Stakeholder Engagement: Engaging with local communities, government agencies, and environmental organizations to align post-mining goals and foster partnerships for successful implementation. 3) Adaptive Management: Employing an adaptive management approach that allows for continuous monitoring and adjustment of restoration efforts based on new information and changing conditions.

The importance of sustainability in this context cannot be overstated. By adopting sustainable post-mining strategies, we can mitigate adverse effects such as soil erosion, water pollution, and habitat destruction. Furthermore, sustainable practices can foster economic opportunities for communities that have historically depended on mining, ensuring a smoother transition to new livelihoods.

Moreover, implementing sustainability in post-mining management is essential for compliance with increasingly stringent environmental regulations. These regulations demand that mining companies take responsibility for the long-term impacts of their activities. By integrating sustainability into their post-mining plans, these companies can not only fulfill regulatory requirements but also enhance their reputations as responsible corporate citizens committed to environmental stewardship.

With a central theme derived from the perspectives of informants, emphasizing the importance of collaboration among various stakeholders and innovative programs, this research aims to provide deep insights into the challenges and opportunities faced by mining companies in implementing restorative business models that leverage the principles of a circular economy.

This article will focus on analyzing how stakeholders collaborate to create sustainable value and manage resources effectively, as well as how cultural changes and managerial commitment can strengthen the transition toward a circular economy. By identifying regulatory barriers, financial challenges, and the importance of educating local communities, this research seeks to offer strategic recommendations for responsible and sustainable mining practices. Ultimately, the article will evaluate the sustainability impact of post-mining management that adopts restorative business models and provide an overview of how this approach can holistically benefit the environment, society, and the economy. In-detail see Figure 2.

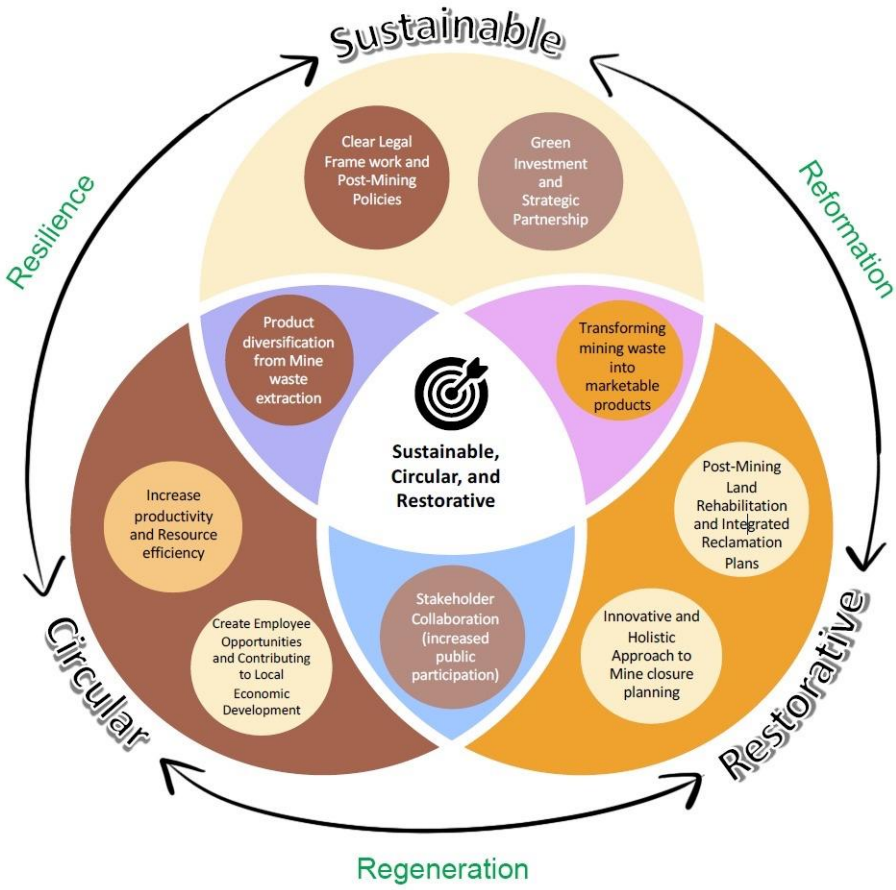

Figure 2. Restorative Business Model for Sustainable Post Mining Management

The Figure 1 above is a business model that emphasizes the importance of integrating sustainability, circularity, and restoration in the mining industry. To achieve this goal, clear policies, strategic investments, product innovations, and active collaboration with various stakeholders are needed in the concept of "Sustainable, Circular, and Restorative" within the context of mining. The following is an detail overview of the restorative business model:

1. Ecological Perspective: The sustainable post-mining business model highlights the importance of integrating key factors for sustainability in the mining industry. A strong Value Proposition through reclamation and revegetation programs enhances company competitiveness while providing significant environmental and community benefits. Key Activities should focus on ecosystem restoration and optimizing the use of mining waste materials. Green technology innovations, such as converting tin waste into high-value commodities like silica sand for solar panels, are essential. Recycling and utilizing mining waste is an ideal strategy that minimizes environmental burden. Supportive regulations, such as Law No. 03 of 2020 and Minister of Energy and Mineral Resources Regulation No. 25 of 2018, create a robust legal framework for effective and sustainable restoration and waste utilization.

2. Economic Perspective: The success of post-mining management is heavily influenced by the availability of Funding and Green Investments. These enable companies to implement environmentally friendly initiatives and create new economic opportunities through the utilization of mining waste materials. Efficient technologies, like turning silica sand into silica powder for solar panels, can add value and attract investments with favorable internal rates of return (IRR). Revenue generated from diversifying processed mining waste enhances the company's position in the circular economy, reducing environmental impact and increasing income streams. Sustainable incentives and funding support the transition to a circular economy-based business model, enhancing business resilience to market fluctuations.
3. Social Perspective: Strategic partnerships with local communities and stakeholders are crucial for creating mutually beneficial relationships. Involving the community in decision-making processes helps companies understand their needs and expectations, potentially reducing social conflicts and building trust. Collaboration with local communities fosters empowerment through skills development, training, and job creation, benefiting both the community and the sustainability of projects. Empowering local communities can improve livelihoods, create new jobs, and reduce unemployment, making strong relationships between mining companies and local communities key to achieving sustainable social and economic goals.
4. Restorative Business Model: This model emphasizes the integration of sustainability, circularity, and restoration in mining practices. It promotes the utilization of mining waste through product diversification, enhanced resource efficiency, and job creation to support local economic development. Collaborative stakeholder engagement ensures greater public participation, leading to better policies and innovative post-mining rehabilitation practices. This approach contributes to a healthier environment and generates new market opportunities by transforming waste into marketable products, thereby fostering a resilient and sustainable economic cycle. The restorative business model can create significant positive impacts for both communities and ecosystems.

In summary, a restorative business model is an advanced approach that integrates ecological and societal restoration into its core operations, requiring systemic understanding, cross-functional alignment, and strong management support for effective implementation. By focusing on these components, mining companies can not only mitigate their environmental impact but also contribute to ecological restoration and socio-economic development for sustainable post-mining management.

CONCLUSION

As we look to the future of post-mining management, the integration of sustainability practices becomes increasingly vital. The

restorative business model offers a promising framework for achieving this integration, promoting ecological health, community resilience, and economic sustainability. By embracing restorative approaches, we can transform the legacy of mining from one of environmental degradation to one of regeneration and renewal. The journey towards sustainable post-mining management is not without challenges, but it presents an opportunity for innovation, collaboration, and positive change. By leveraging tools, resources, and strategic partnerships, we can overcome these challenges and create a future where the benefits of mining are balanced with the needs of people and the planet.

Sustainable restoration techniques are frequently hampered by local governments' regulatory and supervision shortcomings. Other obstacles to local community participation in decision-making include a lack of knowledge and understanding about the advantages of using mining waste, which might weaken social support. Furthermore, the development of value-added products is hampered by inadequate infrastructure and restricted access to suitable processing technology.

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