

# Abandoned mines: turning problems into benefits

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## Abstract

*The abandonment of mining ventures impacts not only the environment, but also the relationship between the mining sector and the population. In the state of Minas Gerais, Brazil, there are more than 500 abandoned mines without adequate closure and recovery. In most cases, the holders of the mineral rights where the abandoned ventures are located do not have the financial means to close the mine or address situations of illegal mining being conducted without the authorisation of the union (the federal government) and in which the offenders are not even identified. In addition, the federal government does not have the budget to implement closure measures for the abandoned mines, making this liability difficult to deal with. Due to this context it is necessary to search for mechanisms that encourage the adequate closure of mines as well as the recovery of abandoned enterprises. An example is the carbon credit market whereby companies that reduce their CO<sub>2</sub> emissions generate carbon credits that can be negotiated between companies and governments. This paper looks at the possibility of using a similar strategy to boost the recovery of abandoned mines. The entrepreneur who implements all the necessary recovery measures and completes the proper closure of an abandoned mine will generate 'REMIN credits', Mine Recovery Credits (Recuperação de Minas – REMIN) that can be exchanged for benefits in all their enterprises, namely: (i) prioritisation in analysis of environmental licensing processes; (ii) exemption from payment or a discount on fees for environmental licensing processes; and (iii) reduction of the percentage paid of financial compensation for the mineral exploration in other mines. The entrepreneur will be able to choose the most attractive benefit. This way, it is expected that entrepreneurs with more capital will be interested in closing abandoned mines for the sake of benefits and the company's image improvement in the eyes of society.*

**Keywords:** abandoned mines, mining areas recovery, mine recovery credits

## 1 Introduction

Mining is an essential activity for economic development, providing raw materials that are indispensable for various industries. However, mineral exploration also generates significant environmental impacts, especially when mining areas are abandoned without proper rehabilitation. These environmental liabilities pose a challenge to sustainability and the preservation of ecosystems.

Proper closure consists of a planned and systematic process of ceasing mining operations with the objectives of ensuring the physical and chemical safety of the site, minimising environmental and social impacts, and enabling the land to be used safely and sustainably in the future. As it is a complex process it requires significant costs for its implementation. The lack of financial capacity on the part of the operator is one of the reasons for the abandonment of mines without providing for their proper rehabilitation.

Brazil faces a significant challenge with abandoned mine sites, with an estimated 3,943 mines – approximately 11% of the country's authorised mining operations – showing signs of abandonment (as paralysed mines, activities were temporarily halted). This alarming figure comes from a recent study by the Instituto Escolhas, a Brazilian research institute focused on public policy and sustainability, which highlighted that many of these sites are left without proper rehabilitation, posing serious environmental and social risks. Despite Brazil's established regulatory framework, including the National Mining Agency, enforcement remains inadequate,

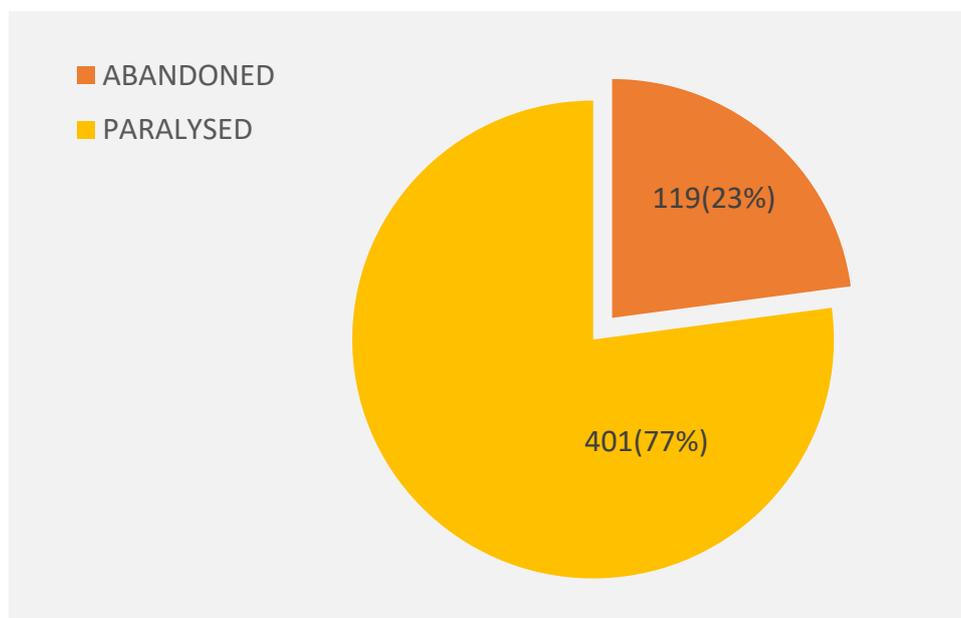
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with around only 100 inspectors for the entire country. This resource constraint prevents effective monitoring and compliance, allowing for the deterioration of mining sites and posing risks such as water contamination, soil degradation and public safety hazards.

The risks associated with abandoned mines in Brazil are multifaceted. Environmental risks include contamination of water sources from untreated tailings, soil erosion and deforestation. Social risks are also severe, particularly in areas where local communities are left to deal with the aftermath of mining operations. The absence of rehabilitation has led to increased poverty, displacement and health hazards for nearby populations.

According to a survey conducted by the State Foundation for the Environment (Fundação Estadual do Meio Ambiente [FEAM]) in 2022, the Brazilian state of Minas Gerais has 520 abandoned and paralysed mines, with 401 classified as paralysed and 119 as abandoned, within its territory (Figure 1).



**Figure 1 Total number of paralysed and abandoned mining operations in the state of Minas Gerais, as per 2022. Source: State Foundation for the Environment (Fundação Estadual do Meio Ambiente 2022)**

According to the definition used in the FEAM study (FEAM 2022), mines were classified as “paralysed” when mineral extraction activities were temporarily halted but with plans to resume production and with environmental control and monitoring measures in place. In contrast, “abandoned” mines were defined as those with inactive mineral extraction activities, no plans to resume operations and no environmental control or monitoring measures, and where the mine closure process is either incomplete or entirely absent.

The causes of mine abandonment can stem from failures in mine closure planning during the operation of the activity, including factors such as unrealistic goals, the inability of regulatory bodies to require progressive recovery actions, economic issues such as falling prices for mineral raw materials and loss of market, underestimation of closure costs and timelines, lack of provision for closure stages, and an inadequate legal and institutional framework to ensure the implementation of closure actions (Fernandes 2021).

From another perspective, greenhouse gas (GHG) emissions also create a significant environmental liability that affects the entire world. These emissions, primarily from the burning of fossil fuels, deforestation and industrial activities, significantly contribute to global warming and climate change. In addition to environmental impacts, there are also the associated economic costs, such as damage to infrastructure, reduced agricultural productivity and increased public health expenditures (Guitarrara 2025). Therefore, it is crucial to adopt measures to mitigate these emissions and promote the transition to a low-carbon economy.

In this sense, carbon credits (which represent the non-emission or removal of greenhouse gases from the atmosphere) emerged, based on the Kyoto Protocol, to help developed countries meet their targets.

In comparison to carbon credits, a similar proposal could be adopted in the context of environmental liabilities generated by abandoned mine activities. The idea is that companies dedicating their efforts to the recovery of these areas could earn credits which could be converted into specific benefits. This article suggests that the creation of 'REMIN credits', Mine Recovery Credits (Recuperação de Minas - REMIN) would be beneficial.

## 2 Carbon credits

Carbon credits, formerly known as certified emission reductions, are certificates that attest to the reduction of GHG emissions through projects designed to curb the volume of pollutants released into the atmosphere as a way of mitigating global warming. They serve as a mechanism for companies to offset their GHG emissions and can be traded with countries or companies aiming to compensate for their own emissions. These credits are part of the Clean Development Mechanism which came into force with the Kyoto Protocol in 2005.

In 2024 during COP29, Article 6.4 of the Paris Agreement was approved with the aim of regulating the international carbon market and expanding bilateral cooperation among countries to reduce GHG emissions. In Brazil, the carbon market began to be regulated by the Brazilian Emissions Trading System following the enactment of Law No. 15,042 in December 2024.

Carbon credits are generated through sustainable projects designed to lower GHG emissions, including reforestation efforts, renewable energy production, changes in agricultural practices and carbon capture initiatives. All projects active in the carbon market must meet a series of criteria established by the UN and undergo monitoring and verification processes before credits can be issued. These credits can then be sold to companies, industries or countries that fail to meet their own CO<sub>2</sub> emission targets (Guitarrara 2025).

One carbon credit is issued for every metric tonne of CO<sub>2</sub> equivalent that is either reduced or removed from the atmosphere. The value of a credit varies not only by country, but also by the nature of the project behind it. Projects that actually remove carbon from the atmosphere tend to command higher prices than those that merely reduce emissions.

Purchasing credits can serve to offset emissions that have already occurred or to provide a margin for future emissions. For instance, a developed country with high annual emissions can buy credits from another country to compensate for its environmental impact. Similarly, a company might purchase credits from domestic or international projects in order to be allowed to emit more greenhouse gases in its operations.

In conclusion, carbon credits are a powerful incentive for sustainability. They encourage the adoption of environmentally responsible practices, contribute to environmental protection and play a meaningful role in reducing long-term environmental liabilities.

## 3 Environmental recovery incentive

Environmental recovery incentives represent an essential strategy employed by public authorities to promote sustainable initiatives aimed at reducing environmental liabilities. Beyond carbon credits, numerous innovative programs have emerged globally.

In the Philippines, the Coal to Clean Credit Initiative, backed by The Rockefeller Foundation and ACEN Corporation, presents a distinctive yet complementary approach. This initiative facilitates the early decommissioning of coal-fired power plants and supports their replacement with renewable energy sources. It introduces "transition credits", a new category of carbon credit designed to finance emission reductions during energy sector transitions (Department of Environment and Natural Resources 2024).

In Australia, one notable initiative in the context of carbon credits in mining was led by BHP at its Nickel West operations in Western Australia, where the company has been testing mineral carbonation as a method to

sequester atmospheric CO<sub>2</sub> within mine tailings. This process accelerates the natural conversion of CO<sub>2</sub> into stable mineral forms, effectively capturing carbon while contributing to the rehabilitation of mining areas. The project has the potential to generate Australian Carbon Credit Units under the national carbon market framework, thereby offering a dual benefit: environmental recovery and financial return. While regulatory endorsement for credit issuance is still under development, the initiative represents a promising step toward integrating carbon finance into mine closure strategies (Commonwealth of Australia 2011).

In Brazil, one of the key efforts is the Environmental Regularization Program, which enables landowners and rural occupiers to bring their properties into compliance with environmental laws after the illegal clearing of native vegetation. Participants may benefit from suspended penalties, provided they engage in environmental recovery efforts (Instituto Federal de Florestas [Federal Institute of Forests] 2025).

Another noteworthy initiative is Law No. 25,144 of 2025, enacted in the state of Minas Gerais. This legislation allows environmental fines to be converted into services that support environmental conservation, recovery and enhancement. By offering reduced penalty values, the law encourages voluntary settlement of infractions and accelerates the remediation of environmental damage. It channels funds directly into tangible recovery efforts, such as the rehabilitation of degraded ecosystems and the advancement of sustainable land use practices, thereby contributing to real environmental improvements and the safeguarding of natural resources (Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável (State Secretariat for Environment and Sustainable Development) 2025).

Within the mining sector, however, initiatives aimed at encouraging environmental recovery remain limited. There is a clear need for collaboration between environmental and regulatory agencies to develop joint programs that actively incentivise mining companies to implement forward-looking strategies for the recovery of degraded areas.

## 4 Mine recovery credit

Given the environmental liabilities resulting from abandoned mining operations where proper mine closure procedures were not carried out, in this paper the authors propose a new approach with a creative incentive to promote environmental recovery – introducing a new concept of credits which may be referred to as REMIN credits.

REMIN credits would function similarly to environmental credits and could be generated by companies engaged in the recovery of abandoned mining sites. These credits could then be converted into specific incentives, attracting companies with available capital and an interest in both environmental recovery and reputational gains. By contributing to the rehabilitation of third-party environmental liabilities, these companies would also enhance their public image and social licence to operate.

To implement the REMIN credit system a foundational step is required: identifying and registering the environmental liabilities linked to abandoned mines in need of recovery as mine hazards from abandoned sites like foundations, old shafts etc. This registry would need to be established and maintained by competent environmental authorities to ensure transparency and the accuracy of information.

In Minas Gerais, the FEAM began such a process in 2014, launching a diagnosis to better understand the dynamics of the local mining sector and to assess the effectiveness of regulations governing mine closure. This effort resulted in the publication of the I Cadastro de Minas Paralisadas e Abandonadas no Estado de Minas Gerais (First Database of Inactive and Abandoned Mines in Minas Gerais) in 2016, which was updated in 2022. This registry has become a valuable management tool for FEAM, supporting the enforcement of environmental oversight and facilitating the regularisation of non-compliant sites.

Following the example of Minas Gerais, it is recommended that similar diagnostics and registries be carried out nationwide. A unified national database would lay the groundwork for the broad application of the REMIN credit system throughout Brazil.

Once the registry of abandoned mines and their associated environmental liabilities is in place, the REMIN system would operate through three key stages: certification of environmental recovery efforts, issuance of REMIN credits and conversion of those credits into tangible benefits (see Figure 2).



**Figure 2 Key phases in the operation of REMIN**

#### 4.1 Environmental recovery certification

Companies interested in this initiative will be able to choose the most attractive mines for recovery from the areas available in the register of abandoned mines. These companies must submit an environmental recovery project for the chosen area, which may include plans, best practices and deliverables for actions such as revegetation, erosion control, waste treatment and habitat recovery. The project must include a detailed schedule of actions to be taken, necessary resources and an exact calculation of the area recovered. This calculation is essential as it is suggested that one REMIN credit unit be issued per hectare recovered.

The criteria for the recovery of abandoned mines should be jointly defined by the environmental and mining authorities, establishing the necessary metrics to determine when a previously degraded area can be considered effectively recovered.

If more than one company is interested in recovering the same area, the environmental agency will be responsible for evaluating the recovery projects submitted by both and, based on technical criteria, deciding which is the best project from an environmental perspective. The company that submits the best project will have the right to recover the area.

The recovery actions can only be initiated after the environmental agency approves the recovery project and the companies must implement the actions according to the approved plan. During the execution phase, continuous monitoring will be essential to ensure that the activities are being carried out according to the established guidelines. It is also recommended that the companies submit periodic reports to the regulatory bodies, detailing the progress of the recovery actions and any necessary adjustments.

After completing the activities, the recovery must be certified by independent auditors to ensure the reliability of the process. The auditors will conduct a detailed evaluation of the area, including onsite inspections and analysis of environmental data, to verify whether the recovery objectives have been achieved, considering the recovery criteria previously defined by the environmental and mining authorities.

#### 4.2 Issuance of REMIN credits

With the certification of recovery, the company receives REMIN credits proportional to the positive impact generated by the recovery of the degraded area. This calculation must be carried out for each rehabilitated site and considers factors such as the extent of the area recovered, improvements in soil and water quality, and the recovery of biodiversity. As a suggestion, one REMIN credit unit could be equivalent to one hectare recovered, multiplied by weighting factors that would consider the environmental relevance criteria of the area and the actions implemented, such as:

- recovered biome (e.g. the Atlantic Forest would have a higher weight)
- improvement percentages in soil quality
- improvement percentages in water quality
- the biodiversity restoration index

- the complexity of undertaken recovery actions
- the cost of undertaken recovery actions, assigning a higher weight to actions that required greater investment.

These credits could be registered in a national REMIN credit system, created to ensure the traceability and integrity of the process.

### 4.3 Conversion of REMIN credits into benefits

The REMIN credits can be converted into various benefits for companies, encouraging active participation in the recovery of environmental liabilities. Considering the regulatory context and the current state of mining activity in Brazil, the following are suggestions of potential benefits that could be adopted:

- Reduction of environmental licensing fees: companies generating REMIN credits can obtain discounts on licensing fees for new projects, reducing operational costs and encouraging sustainable practices.
- Priority in environmental process analysis: companies with REMIN credits can be given priority in the analysis of environmental processes for their projects, accelerating project approval and licence issuance, and facilitating the expansion of their activities.
- Reduction of the financial compensation rate for mineral exploration (CFEM): companies that accumulate REMIN credits may benefit from a reduction in the CFEM rate for their mining operations for a specified period. This will reduce the financial costs associated with mineral exploration and, consequently, improve the profitability of their ventures.
- To calculate the specific value of REMIN credits required for each type of benefit it is essential that an approach based on objective and measurable criteria is adopted, with the following proposed suggestions
  - Reduction of environmental licensing fees: establish a progressive discount table for environmental licensing fees where each discount percentage corresponds to a specific number of REMIN credits.
  - Priority in environmental process analysis: define a points system for priority analysis where each priority level, weighted by the complexity factor, requires a specific number of REMIN credits. The complexity factor is the component that considers the complexity of the environmental process being analysed. The calculation formula would be

$$\text{Necessary credits} = \text{priority tier} \times \text{complexity factor} \quad (1)$$

- Reduction of the financial compensation rate for mineral exploration (CFEM): create a scale for reducing the CFEM rate, where each percentage reduction corresponds to a specific number of REMIN credits. The reduction would be applied to the CFEM for a period of five years. If the company wishes to extend the reduction period, additional REMIN credits must be presented. For example, if 500 REMIN credits are needed to achieve a 10% reduction in the CFEM for five years, then 1,000 REMIN credits will be required to apply the reduction for the full 10-year period.

This approach ensures that REMIN credits are calculated fairly and proportionally to the desired benefit, encouraging companies to invest in the recovery of environmental liabilities.

## 5 Conclusion

The implementation of the REMIN credit system for the recovery of abandoned mining liabilities represents an innovative and effective solution to promote sustainability in the mining industry. This system not only encourages the rehabilitation of degraded areas but also offers tangible benefits for companies, fostering responsible practices and contributing to environmental preservation.

By establishing a clear and transparent mechanism for issuing REMIN credits, it is possible to ensure that recovery actions are carried out efficiently and in a verifiable manner. Independent certification of recovery activities ensures the integrity of the process, while the conversion of credits into specific benefits, such as reduced environmental licensing fees, priority in process analysis and reduced CFEM rates, creates a significant economic incentive for companies.

Moreover, the proposed approach ensures that REMIN credits are calculated fairly and proportionally to the positive impact generated by the recovery. This ensures that companies' efforts are appropriately rewarded, encouraging active participation in the recovery of environmental liabilities.

The adoption of this REMIN credit system can transform environmental challenges into opportunities for sustainable development, promoting a more responsible mining industry that aligns with environmental preservation goals.

This new concept of REMIN credits requires further detailing of the proposed methodology before implementation so that all parameters are assessed and clear guidelines for the process are defined. Additionally, a robust system needs to be created to host the database of abandoned mines and manage the credits earned by companies.

Furthermore, collaboration between environmental agencies and mining regulators will be essential to define the entire procedure, granulate the parameters for credit calculation and establish specific regulations, including provision of a thorough impact analysis to assess the benefits and challenges of implementing this project.

Implementing the REMIN credit system is a significant challenge that requires joint action to establish specific regulations and create an innovative system that will promote mining sector sustainability, benefiting both the economy and the environment.

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