

## USE OF AI IN THE DESIGN OF MINING SITES RECLAMATION. A CASE STUDY FOR JIU VALLEY, ROMANIA

Andreea Gabriela ȘFABU<sup>1</sup>, Izabela-Maria APOSTU<sup>2\*</sup>,  
Maria LAZAR<sup>3</sup>, Florin FAUR<sup>4</sup>

<sup>1</sup>University of Petroșani, Faculty of Mining, Petroșani, Romania, sfabua1@gmail.com

<sup>2</sup>University of Petroșani, Faculty of Mining, Department of Environmental Engineering and Geology, Petroșani, Romania, izabelaapostu@upet.ro

<sup>3</sup>University of Petroșani, Faculty of Mining, Department of Environmental Engineering and Geology, Petroșani, Romania, marialazar@upet.ro

<sup>4</sup>University of Petroșani, Faculty of Mining, Department of Environmental Engineering and Geology, Petroșani, Romania, faurfloring@yahoo.com

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**Abstract:** *The Jiu Valley bears the marks of mining, an industry that has shaped the destiny of the region for over a century and a half. The exploitation of coal deposits experienced a significant expansion in the 20th century, transforming the Jiu Valley into a vibrant industrial center. Generations of people have been linked to this industry, building their lives and identities around this mining area. However, after a period of glory, the mining industry in the Jiu Valley entered a decline determined by a series of interconnected factors, such as resource depletion, decreased demand, lack of investment, and strict European regulations, ultimately leading to the gradual closure of the mines (the last mines being scheduled for closure in 2032). In this context, the sustainable development and just transition of the region are important concepts, of present interest. In the Jiu Valley, the just transition aims to diversify the economy and create new employment opportunities in sustainable sectors, thus reducing the negative impact on communities dependent on mining, while improving environmental quality. The purpose of this paper is to analyze and provide optimal solutions for the ecological rehabilitation of land affected by mining in the Livezeni mining perimeter and support the transition to a sustainable economic model. Achieving the proposed objectives involved the use of a current tool for rehabilitation design, namely the ChatGPT software Version 4.0/2024, based on artificial intelligence (AI).*

**Keywords:** *Coal, mine, reclamation, design, artificial intelligence, Jiu Valley, Livezeni perimeter*

### 1. Introduction

The decline of the mining industry in the Jiu Valley was determined by a series of factors, such as: the long-term exploitation of deposits that led to the depletion of economically exploitable coal reserves; the transition to a green economy that significantly reduced the demand for coal on the domestic and international market; the implementation of European environmental protection standards that imposed significant additional costs for the mines in the Jiu Valley; the lack of investment in the modernization and in “green” solutions for mining operations, which affected the competitiveness of the industry.

Given the significant negative impact that coal mining has had on the environment for more than 150 year (soil, air, and water pollution, deforestation, land occupation and degradation, microclimatic changes, landscape modification, damage to the ecological balance, biodiversity, worsening of population health, etc.), but also the downward trajectory of mining in the Jiu Valley, the transition to sustainable economic activities and improving environmental quality are essential objectives for the revitalization of the area [1–5]. The Jiu Valley was an important coal mining center. Currently, within the Jiu Valley Energy Complex (CEVJ) there are 4 active mines: E.M. Lonea, E.M. Livezeni, E.M. Vulcan, and E.M. Lupeni. Over time, 3 mines (E.M. Petrila, E.M. Paroșeni, E.M. Uricani) and one coal preparation (E.P.C. Coroești) have been closed (fig. 1).

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\* Corresponding author: Izabela-Maria Apostu, Lect.dr.eng., University of Petroșani, Faculty of Mining, Department of Environmental Engineering and Geology, Petroșani, Romania, University Street no. 20, izabelaapostu@upet.ro

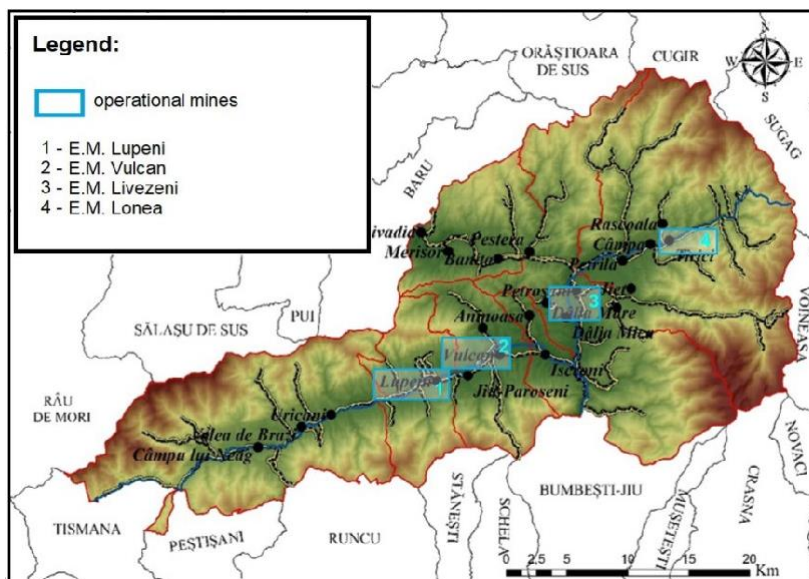


Fig. 1. The Jiu Valley coal basin and its division into mining fields; modified after [6]

Taking into account the necessity to implement the Mine Closure Plan for the period 2023-2032, the European Commission has authorized support measures for the decarbonization of the energy sector and the closure of coal-based energy capacities by 31 December 2032. Thus, the Romanian Government has implemented a phased plan for the closure and ecological reconstruction of mining perimeters with different deadlines (31 of December 2026 for Lupeni and Lonea mines, respectively 31 December 2032 for Livezeni and Vulcan mines) [7].

The Livezeni mining area is therefore preparing for a new phase, leaving behind a legacy of mining activity. The authorities have approved a reconversion plan that will guide the transformation of the area into a green and sustainable space. This process will be gradual, focusing on the rehabilitation of affected lands and the greening of degraded areas with local species.

The current state of the Livezeni mining area highlights a period of significant transformation, with government initiatives aimed to the mine closure, the decarbonization of the energy sector, the economic restructuring of the area, the adoption of renewable technologies, and the diversification of the CEVJ energy portfolio, including the construction of infrastructures for the production of solar, hydroelectric and gas energy with carbon capture according to Emergency Ordinance no. 108/2022 on the decarbonization of the energy sector in Romania [7, 8].

However, the authors of this paper believe that the solution proposed by the authorities is justified, but not sufficient. The solution for the revitalization of the Jiu Valley is found in the transition from mining to tourism, the area being well known for its mountainous and valley landscapes and the various activities that can be carried out here, from visits to museums, caves, mountain hikes to paragliding, skiing, snowboarding, mountain biking, etc.

The proposed ecological reconstruction solution of degraded lands will be transposed through a series of actions, the most important being the elimination of pollution sources, the improvement of environmental quality, the remediation of lands (shaping and arrangement), and repurposing of the existing building in accordance with the new type of use. At the same time, solutions for the production of energy from renewable sources can also be integrated.

Professional retraining, the maintenance and creation of jobs protect the rights of workers and ensure the well-being of the affected communities.

## 2. Description of the Livezeni mining perimeter and the environment

The Livezeni mining perimeter is located in Hunedoara County, Petroșani Municipality, in the eastern area of the Jiu Valley coal basin, on the banks of the Jiu River.

Access to the region is provided by the electrified railway line Filiași – Livezeni – Simeria and the national road Tg. Jiu – Petroșani – Hațeg.

Mining in the Livezeni perimeter (fig. 2) began in the 18th century using artisanal methods. The 19th century saw the introduction of the underground method, which led to a significant development of mining. The peak was reached in the 20th century, when annual production exceeded 1 million tons.



Fig.2. Livezeni Mining Exploitation (left – [9])

The existing mining infrastructure on the main enclosure consists of two extraction shafts with a depth of 300 meters, a network of underground galleries with a total length of 50 kilometers, a coal preparation facility and a coal transport railway.

Mining has generated a significant impact on the environment, materialized through deforestation and modification of the relief, air pollution with dust and gases, soil damage, occupation of land surfaces by industrial buildings, dumps, etc. [10, 11].

The Livezeni active dump (located on the right bank of the East Jiu River) is an example of the negative impact that mining can have on a territory (landscape) (fig. 3).



Fig.3. U.P. Livezeni waste dump (left [9])

The Livezeni dump is going through monitoring and stabilization procedures. The sterile rocks are stored in conditions that prevent landslides, essential for maintaining long-term stability.

The perimeter is located in a hilly area with terraces that decrease from north to south. The vegetation is mostly formed by pastures, with forests covering large areas only on the surrounding hills and mountains. The flora and fauna of the Jiu Valley present elements that make it a center of tourist attraction. In the mountains, coniferous forests predominate (spruce, pine, juniper, yew, etc.). The oak and beech forests are also hospitable; they shelter numerous species of birds and provide habitat for animals such as: rabbit, wolf, fox, wild boar, deer, bear, chamois, etc.

From a hydrographic point of view, the Livezeni mining perimeter is furrowed by numerous springs and streams, tributaries of the East Jiu River.

From a climatic point of view, the mining basin presents an alpine microclimate, humid and cool, with significant precipitation in terms of quantity, in the form of rain and snow. The average annual precipitation has values between 700 - 800 mm [12].

The number of days with high cloudiness reaches over 200 per year. Because of the atmospheric pollution, dust and smoke particles act as condensation nuclei, so fog and drizzle are particularly frequent in autumn.

The elongated shape of the Jiu Valley and its isolation by high mountains have a great influence on climatic aspects, because the circulation of air masses is from north to south, through the Bănița - Merișor and Surduc - Lainici transverse gaps.

An interesting thermal phenomenon occurs in the valley, that of thermal inversion. This process can be described as stagnation and cooling of the air sliding from the heights of the mountains towards the cities. Under the influence of these stagnations and cooling, frosts are stronger in the valley than on the surrounding heights.

### 3. Mining degraded land reclamation

In the long term, ecological rehabilitation plans and integration of the mining area into the natural and social landscape of the region are of major importance. Ecological reconstruction projects aim to transform this degraded area into a space that supports biodiversity and provides benefits to the local community. Such initiatives are essential for remedying the negative effects of decades of mining and for promoting a sustainable future for the Jiu Valley.

#### 3.1. Field studies

The surface area of the main enclosure of Livezeni mining perimeter, located on the left bank of the East Jiu River, is of, approximately, 19 hectares (fig. 4). The main buildings identified as having major potential for future uses are summarized in tab. 1 and fig. 4.

Table 1. Data on the main buildings/premises in the mining area

| Building | Perimeter, [m] | Building footprint, [m <sup>2</sup> ] |
|----------|----------------|---------------------------------------|
| A        | ≈ 530          | ≈ 4800                                |
| B        | ≈ 130          | ≈ 960                                 |
| C        | ≈ 115          | ≈ 600                                 |
| D        | ≈ 106          | ≈ 600                                 |
| E        | ≈ 105          | ≈ 680                                 |
| F        | ≈ 135          | ≈ 1000                                |
| G        | ≈ 205          | ≈ 2200                                |
| H        | ≈ 53           | 175                                   |

The Livezeni active dump includes a heterogeneous mixture of waste rocks (clays, marls, sandstones, shales with coal fragments, etc.) from coal mining and sorting. This non-uniform composition, with grains of varying sizes, requires careful monitoring for stabilization, drainage and the risk of self-ignition of coal fragments [13].

The base terrain on which the dump is built plays a role in ensuring its stability, the shape of the land being a favorable one from this point of view. The land surface is relatively flat, and the general shape of the area is trapezoidal, with the large base facing south. The area was previously occupied by hayfields, agricultural fields and even some marshy areas. No significant land development works were required before the construction of the dump. Atmospheric precipitation, in the form of rain and snow, are the only sources of water in the area that can influence the stability of the dump.

The waste dump covers an area of approximately 3.75 ha and stores a volume of rock of approximately 600,000 m<sup>3</sup> [14]. The main geometric characteristics of the dump are the slope height and slope angle, which vary 9.2 – 20.1 m in height, respectively 25 – 43.5° inclination [15].

Under the influence of pore water pressure, the stability reserve may decrease by approximately 25-30%, and in some areas, the stability could reach the equilibrium-disequilibrium limit. In this context, the following measures were recommended to ensure the stability of the dump [15, 16]:

- Ensuring slope angles of maximum 34-37°;
  - Construction of an intermediate berm on the western boundary of the dump with a width of 10 m, to reduce the height of the slope by creating sub-steps of max. 15 m height;
  - Leveling and compacting the dumped rocks;
  - Creation of a platform of the dump slightly inclined towards the marginal slopes, to facilitate the drainage of water outside the slopes;
- Construction of a drainage system at the western boundary of the dump;
- Continuous monitoring of the stability of the dump over time;
  - Afforestation and grassing of the permanently arranged areas to consolidate the slopes and prevent erosion;
  - Strict compliance with the technical regulations regarding the design, construction, and conservation of the dumps, including periodic measurements and stability studies.

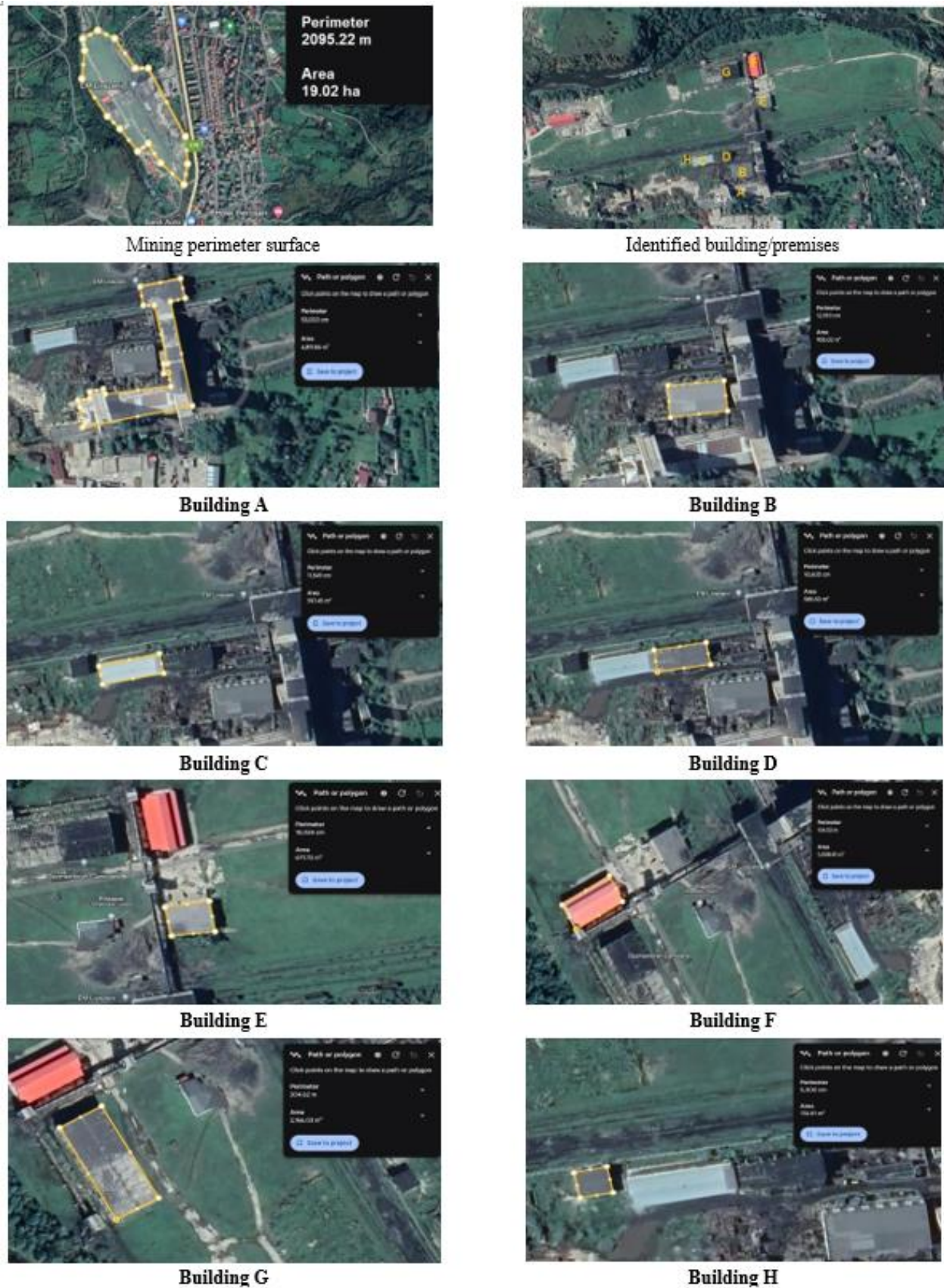


Fig. 4. Livezeni mining perimeter and buildings that may enter the rehabilitation process [9]

In the area of the dump outbuildings are illegally built, and access is sporadic. The dump is used to store waste resulting from landscaping and tree trimming. Even so, considering the classification of rock deposits according to the nature of the objectives in the area of influence and their technical condition, due to the fact that the dump presents conditions of high stability, it falls into the very low vulnerability class [17].

### 3.2. Rehabilitation and reconstruction plan of the Livezeni mining area

According to [18, 19], rehabilitation and reconstruction strategies must be adaptable to be consistent with socio-economic and environmental changes. Plans must include proactive measures to protect and restore ecosystems affected by new developments, providing solutions that reduce human impact and promote natural land regeneration.

Figure 5 shows the proposed plan for the rehabilitation and reconstruction of the Livezeni mining area.

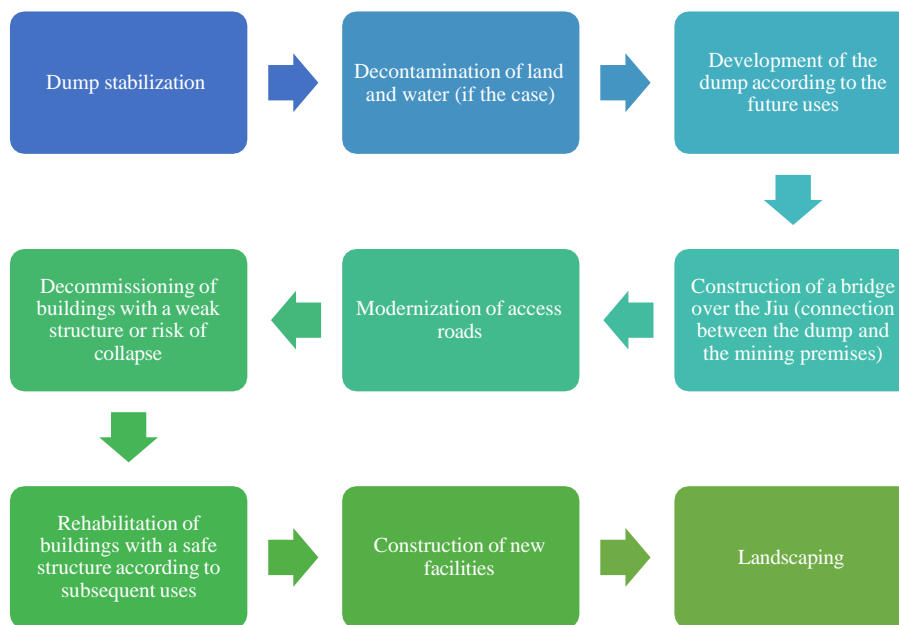


Fig. 5. Ecological restoring plan

It is important to develop rehabilitation projects through collaboration between all stakeholders, including mining companies, local authorities, communities, and other interested groups. This involves establishing a consensus on the final objectives of the rehabilitated areas, as well as on integrated planning that takes into account both the economic and ecological needs of the area [13].

By continuously adapting to dynamically changing conditions and involving the local community, the rehabilitation plan will ensure environmental protection, public safety in the area, and economic development. These measures are necessary to maintain ecological integrity and prevent any future incidents that may result from current land use changes.

The rehabilitation of buildings A-H in the Livezeni mining area is considered, as these are the largest structures in the area, have potential and offer a generous space for the development of various tourist facilities. In addition, the resistance structure is solid and allows for renovation and adaptation to new functions without requiring investments for reconstruction.

At present, there are other industrial buildings that have a rather negative visual impact (as they are located in the immediate vicinity of inhabited areas, having as a background natural terrains) and, some of them (the abandoned ones), pose a real risk for workers and general population (because of the constructive elements that detach and fall, but also because of the accumulation of various waste inside them) [20].

At the same time, these buildings are also the most representative for the mining area and, by restoration, may have a strong positive visual impact, as well as a significant patrimonial value. Therefore, their renovation will contribute to the preservation and valorization of the industrial heritage of Livezeni perimeter.

The other option, reconstructing the entire area from scratch, would require considerable financial and time resources, which would make the project unrealistic at this time.

### 3.3. Designing the rehabilitation plan for the Livezeni mining area using artificial intelligence

After establishing the foundations through specific research, previously summarized in the paper, it was concluded that the rehabilitation of the area must essentially include projects for restoring biodiversity, creating diverse habitats, shaping the land, rehabilitating buildings, creating new facilities, and landscaping the area.

The spaces dedicated to recreational and educational activities can include hiking and cycling trails, picnic areas, observation platforms, environment education laboratories, museum of mining history. Facilities for various sports can be integrated, from football and golf fields to areas for extreme sports such as ziplining, bungee jumping, or treetop adventure trails. These activities not only provide entertainment, but also education and interaction with nature, attract a wide range of visitors, and increase the economic value of the area. Also, a route for children to ride mine cars (mine wagons) and more can be created on the railway in the mining perimeter (long of about half a kilometer), which will represent a considerable attraction (fig. 6–9).

The design of the rehabilitation works was carried out using the ChatGPT 4.0 software [21] which is based on artificial intelligence. The ChatGPT 4.0 software is an increasingly used tool, and to obtain satisfactory results, the input data must be described correctly, in detail, and clearly. In order to generate images that would reflect as realistically as possible the authors' vision regarding the rehabilitation of the Livezeni mining area, such descriptions were necessary for each individual objective.

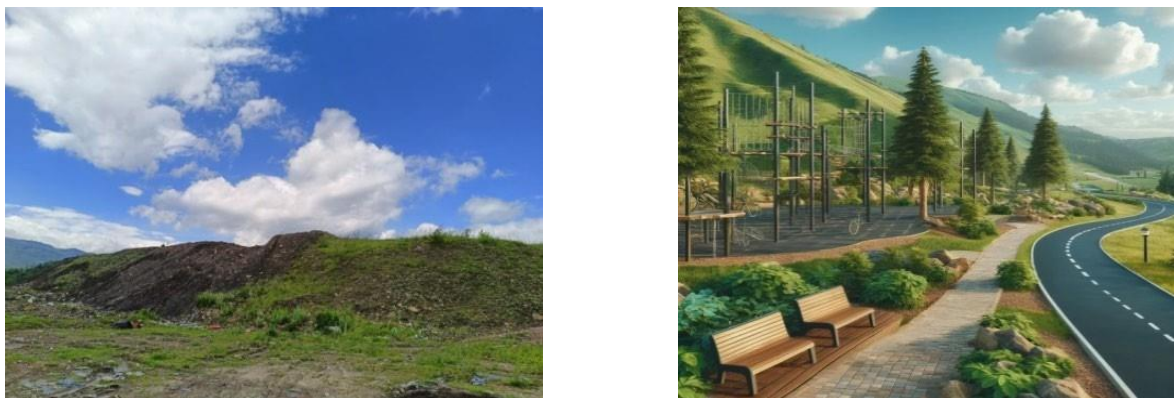


Fig. 6. Sketch of the dump area; right – [21]



Fig. 7. Sketch of sports fields and relaxation areas (including the modernization and extension of Lunca Street, parallel to DN66); right – [21]



Fig. 8. Sketch of bungee jumping tower; right – [21]

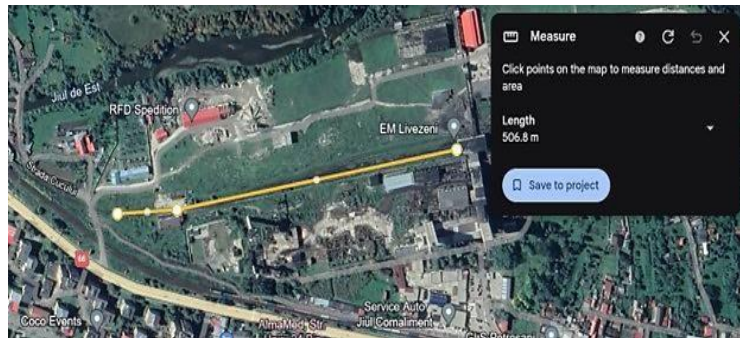


Fig. 9. Railway route, 0.5 km; modified after [9]

In all phases of development and planning of the Livezeni perimeter, sustainable solutions can be implemented to reduce the negative impact on the environment to ensure the long-term sustainability of the project. These include the use of environmentally friendly construction materials, efficient water management systems for human consumption and other activities, and the integration of renewable energy sources, such as solar panels, to power local infrastructure and beyond. Green infrastructure, such as green roofs and green walls on newly constructed buildings, can be integrated to reduce the ecological footprint of the development. These technologies not only improve aesthetics, but also contribute to the thermal efficiency of buildings, reducing the energy requirements for air conditioning and heating. Furthermore, they increase the water retention capacity of the region, reduce the impact of surface runoff, and enrich urban biodiversity.

Through these measures, the rehabilitation project focuses on transforming a once degraded area into a successful example of regeneration and sustainable land use, providing added value to the local community and visitors. This integrated approach ensures that the area will not only be rehabilitated, but will also become a point of interest for ecological and educational tourism.

In addition to recreational and ecological areas, the perimeter will also include spaces dedicated to education and research (fig. 10, buildings E and F can take on this function as follows: building F becomes a research laboratory center, and building E is transformed into lecture and seminar rooms; their location, on the banks of the Jiu River and the availability of large areas of land, will ensure the smooth conduct of research activities). These spaces will host educational programs for schools and universities, ecological awareness workshops for the general public, and research facilities for the study of ecological conservation and restoration techniques.



Fig. 10. Sketch for educational spaces - building E (left and middle) and research - building F (right) [21]

A central element in the rehabilitation and reconstruction of the mining area is the development of a tourist resort, which will reflect the notes of the mining industry, integrating modernity with the cultural and industrial heritage of the region.

The resort will include a hotel (building A), restaurants (buildings A, B), event hall (building C), bar and terrace (buildings D and H), and an interactive museum (building G) dedicated to the history of mining (fig. 11–17). The latter will offer visitors an educational vision of the evolution of mining in the area, using advanced multimedia technologies to create immersive experiences.

To maximize the attractiveness of the resort, extensive wellness and relaxation areas will be created, including spas, nature meditation areas, and therapeutic gardens. These spaces will provide an oasis of tranquility and restoration for visitors, thus promoting health and well-being through closeness to nature.



Fig.11. Sketch of the tourist resort, buildings A and B; right – [21]



Fig.12. Sketch of the event hall, building C [21]



Fig.13. Sketch of the bar and terrace area, buildings D and H [21]



Fig.14. Sketch of the train station of the E.M. Livezeni tourist resort; right – [21]



Fig. 15. Room sketch of the E.M. Livezeni tourist complex; right – [21]



Fig. 16. Sketch of the reception of the E.M. Livezeni tourist resort; right – [21]



Fig. 17. Sketch of the E.M. Livezeni museum; right – [21]

These investments could not only diversify the tourist offer of the resort, but would also contribute to attracting a wide range of visitors, generating significant income for the municipality. The implementation of these facilities must be planned in such a way as to minimize the impact on the environment, using sustainable materials and integrating ecological solutions into their design.

The resort can become an example of good practice in integrating industrial elements into a natural setting, demonstrating deep respect for the history of the place and commitment to a sustainable future. This project of reconstruction of a mining area into a tourist resort not only redefines the landscape, but also offers a new economic and social beginning for the local community, making tourism and environmental conservation central pillars of sustainable development.

### 3.4. Economic aspects foreseen

The reconstruction of the Livezeni perimeter and its transformation into a tourist resort involves a series of costs that must be managed with caution to ensure that the project is economically viable. Thus, the evaluation of the initial costs represents the financial foundation of this transformation process.

The project is designed to attract significant investment, create jobs, and stimulate the local economy by attracting tourists and organizing events. The financial sustainability of the project is closely linked to the ability to balance the initial costs with the incomes generated on medium and long term. An important part is represented by the identification and access to multiple sources of financing. Several financing possibilities have been identified for the proposed rehabilitation and redevelopment project such as:

- ❖ European and National Funds: European Structural and Investment Funds (ESI), European Regional Development Fund (ERDF) and Cohesion Fund are the main sources of European funding for infrastructure and regional development projects. The Large Infrastructure Operational Programme (LIOP) finances infrastructure projects in areas such as transport, energy, and environmental protection. The rehabilitation and modernization of infrastructure in the mining area can fall within the objectives of the LIOP, thus providing a significant source of funding for the project.

- ❖ The Just Transition Fund (JTF) is intended to support regions and communities affected by the transition to a green economy. The funds can be used for economic reconversion, the rehabilitation of degraded land, and support for employees affected by mine closures. The project aims at the JTF objectives, thus having real chances of funding.

- ❖ The LIFE Programme, which supports environmental projects, nature conservation, and climate action.

- ❖ National Funds: The Environment Fund which supports development projects, including the rehabilitation and modernization of infrastructure in different areas or other State Aid schemes through which the Romanian Government offers various support for investments in infrastructure, tourism, and the environment.

According to an economic estimation performed by the authors, the costs for implementing the project for the rehabilitation of the Livezeni mining area after the definitive closure of the mining activity amounts to approximately 120-130 million euros. The approximate amounts that can be allocated by accessing the types of funds would be of hundreds of thousands of euros to hundreds of millions of euros. Also, funds for this bold project can be obtained from national and foreign investors, public or private institutions, fundraising, donations etc.

### **3.5. Short and long term gains, opportunities and benefits**

The Livezeni perimeter reconstruction project aims not only to ecologically rehabilitation, but also to economically revitalization of the area.

In the short term, hundreds of direct jobs will be created in construction, project management, and ecological consulting, contributing to reducing unemployment and stimulating the local economy.

In the long term, the project will generate profits from tourism activities and improve the quality of life for residents through modernized infrastructure and expanded public services. Local businesses, such as restaurants and hotels, will benefit from the influx of workers and visitors, with sales expected to increase.

Infrastructure development, including roads and utility networks, will facilitate the project and attract new businesses to the area. As the area becomes attractive, interest in real estate investments will increase. The project thus demonstrates a positive and sustainable economic impact, justifying the strategic investment in the rehabilitation of a degraded area.

The use of existing infrastructure demonstrates how available resources can be optimized for sustainable development, providing a replicable model for other regions and contributing to the economic and social transformation of the Jiu Valley.

The transition from mining to tourism offers the opportunity for professional reconversion of former miners. Given that retired miners are relatively young, with the retirement age of 45 years, professional reconversion ensures an active future for those who wish to continue their activity in one form or another. If the implementation of renewable energy production technologies is pursued, retraining programs, developed in collaboration with educational institutions, private institutions, and non-profit organizations, will help workers with relevant skills.

Through strategic investments in training, the community will be prepared to actively participate in redefining the economic landscape, open up new opportunities for personal and professional development, and strengthen the foundation for a diversified and resilient local economy.

## **4. Conclusions**

Due to the fact that Petroșani municipality, as well as the entire Jiu Valley, offers all that is necessary for the development of tourism, a promising field in the long and very long term, in this paper the authors came up with the proposal to design the rehabilitation of a mining perimeter in this direction.

The Livezeni perimeter has extraordinary potential to become a model of ecological rehabilitation and sustainable use of post-industrial lands, exemplifying how modern technology and the commitment of local authorities and communities can transform a degraded area into a valuable resource.

It is important that the emphasis be placed on creating a dynamic environment, which is not just a holiday destination, but a symbol of revitalization and revalorization of a territory, offering valuable lessons about the harmony between man, industry, and nature.

The project aims to become a pilot model in transforming post-industrial areas into multifunctional spaces that capitalize on historical and natural heritage, while providing economic and recreational opportunities for the local community and tourists.

Access to new types of programs based on artificial intelligence offers unlimited possibilities for application in any field. However, it is very important that they are used by people capable of evaluating and validating the results obtained. In this paper, the Chat GPT 4.0 software was used to design the rehabilitation works of the Livezeni mining area. The authors introduced detailed requirements in the program regarding the vision of the land after rehabilitation, returned with clarifications and corrections whenever necessary and presented the results, respectively the design works, in the form of images.

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