An investigation of the relationship between regional sustainable development and depletion of surface coal mines

C. Roumpos[1], F. Pavloudakis[2], and Z. Agioutantis[3]

[1]Public Power Corporation of Greece, Greece
[2]University of Western Macedonia, Greece,
[3]University of Kentucky, USA

INTRODUCTION

The concept of sustainable development has become one of the most challenging issues for the mining industry. According to a basic definition[1], sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It is a critical goal for large-scale surface mining projects with a long-life span, such as coal extraction by continuous surface mining. The sustainability evaluation of surface coal mines includes multiple factors. They may refer to sustainable exploitation of mineral and natural resources, mining operations, environmental management and, ultimately, sustainable socio-economic development. This effort involves studies of the quality of soils or waters[2], the determination of geotechnical parameters[3], as well as the assessment of the socio-economic effect of mining activities through sustainable development indicators (SDI)[4] or by using spatiotemporal patterns of the surface coal mining areas[5]. From the perspective of mining exploration and exploitation, correlations with human well-being have been combined with SDI[6].

In this frame, mine closure, including decommissioning of retired facilities, has been rated among the top five operating risks in mining[7] and are differentiated into progressive and final mine closure. Therefore, both aspects must be incorporated into the strategic planning of surface mining projects for total mining sustainability.

[1] Brundtland Report. (1987). Our Common Future, Report of the World Commission on Environment and Development United Nations.

[2] Park J, Kwon E, Chung E, Kim H, Battogtokh B, Woo NC. (2020). Environmental Sustainability of Open-Pit Coal Mining Practices at Baganuur, Mongolia. *Sustainability*, 12(1):248. https://doi.org/10.3390/su12010248

[3] Roumpos, C. & Papacosta, E. (2013). Strategic mine planning of surface mining projects incorporating sustainability concepts. Proceedings, 6th International Conference on Sustainable Development in the Minerals Industry (SDIMI 2013), 30 June – 3 July 2013, Milos Island, Greece: 645–651.

[4] Que CT, Nevskaya M, Marinina O. (2021). Coal Mines in Vietnam: Geological Conditions and their Influence on Production Sustainability Indicators. *Sustainability*, 13(21):11800. https://doi.org/10.3390/su132111800

[5] Zeng X, Liu Z, He C, Ma Q, Wu J. (2018). Quantifying Surface Coal-Mining Patterns to Promote Regional Sustainability in Ordos, Inner Mongolia. *Sustainability*, 10(4):1135. https://doi.org/10.3390/su10041135

[6] Mohsin M, Zhu Q, Naseem S, Sarfraz M, Ivascu L. (2021). Mining Industry Impact on Environmental Sustainability, Economic Growth, Social Interaction, and Public Health: An Application of Semi-Quantitative Mathematical Approach. *Processes*, 9(6):972. https://doi.org/10.3390/pr9060972

[7] World Risk Report 2018

In this context, the sustainability of mine closure is achieved by considering depletion components[8]. Key performance areas (KPAs) and key performance indicators (KPIs) are some of the tools used to establish the mine closure with principles[9].

Considering the transition to an electricity generation sector that will be based on renewable energy sources, investigating the relationship between the depletion time of surface coal mines and the long-term prosperity of the local and regional economies is an important research issue regarding the sustainable use of mineral resources. The contribution of mining activities to the viability of these economies may relate directly to economic development and indirectly to a suitable social environment. These relationships allow utilisation of the available land and other resources to be effective in the post-mining period.

METHODS

This paper investigates regional sustainable development concerning long-term surface coal mining operations for electricity generation. The main research question refers to the impacts of mining activities and their implications for sustainable development goals considering the related indicators. As a case study, the lignite production in the region of Western Macedonia, Greece, is examined by a combination of continuous and non-continuous surface mining. The broader study area of Western Macedonia is presented in Figure 1. In this context, related sustainable development indicators are analysed, based on a mining life- cycle model. The main parameters investigated include (i) the lignite production and earthmoving works, (ii) the regional gross domestic product (GDP), (iii) the employment, (iv) the investment in exploration, (v) the environmental reclamation of the mining areas, (vi) the thermal energy provided to the cities in close vicinity to the mines and power plants, (vii) the economic sources for archaeological excavation in the mining areas, (viii) the utilisation of by-products, (ix) the use of pumping water for irrigation since the beginning of mining operations.

The mine life cycle approach is combined with circular economy principles, while the statistical correlation analysis was employed using the data obtained from the Hellenic Statistical Authority.

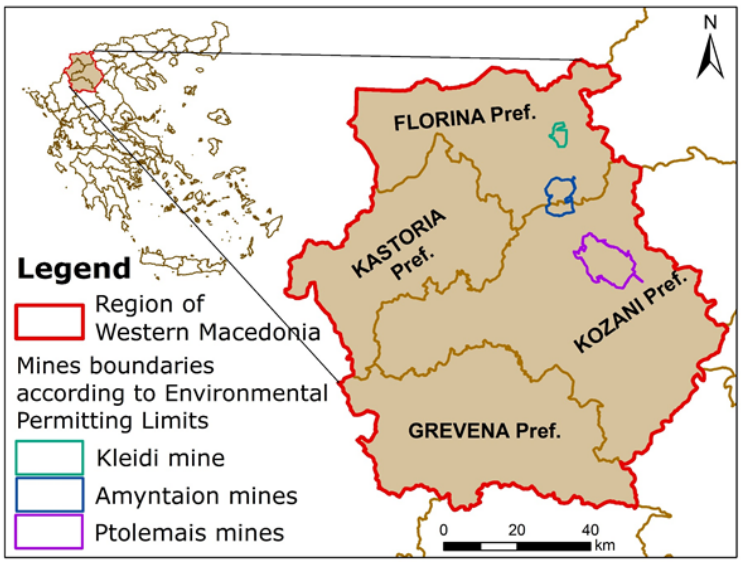

Figure 1. Western Macedonia region and surface lignite mines boundaries.

[8] Central Mine Planning and Design Institute (CMPDI) - Ministry of Coal/Sustainable Development Cell. (June 2021) Report. Status of Environmental Sustainability in Coal Mines 2019-2020.
[9] International Council of mining and metals, 2019

The analysis of the lignite production through time is based on a logistic sigmoid function in the form of Equation 1:

$$L = \frac{a}{1+(\frac{a-m}{m})e^{-bt}} \quad (1)$$

where L is the lignite production, t is the year from the beginning of the production, and a, m and b constants.

RESULTS AND DISCUSSION

Figure 2 shows the GDP change in Greece and the Western Macedonia regions from 2000 to 2019. In the crucial period 2008-2013, the country's economic crisis did not affect Western Macedonia.

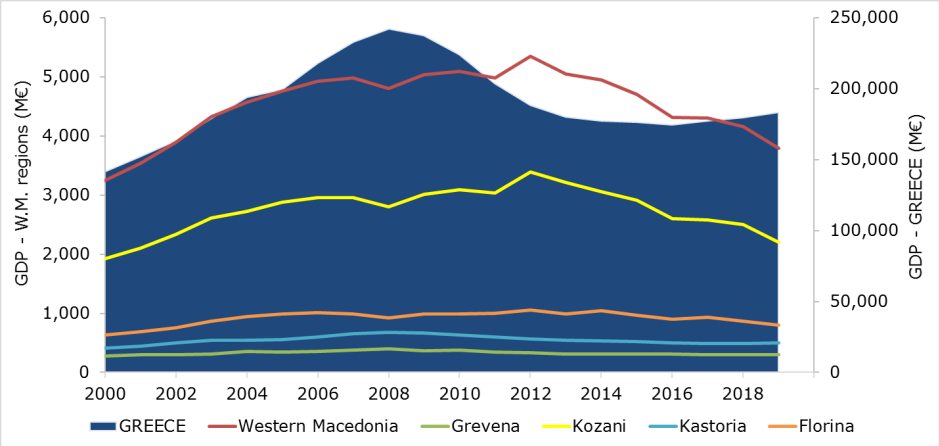

Figure 2. GDP change in Greece and the Western Macedonia regions (2000-2019).

In 2010 the country's GDP began to decrease, while the GDP of Western Macedonia continued to increase until 2012. Furthermore, the rapid decrease in GDP of Western Macedonia and mainly of Kozani Prefecture began with the decrease in lignite production. However, manufacturing (including mining) employment did not show the same trend as the GDP, as most of the job positions had been lost until 2013, and after a period of minor fluctuations, they started to increase after 2018 (Figure 3a). This counterbalancing trend could be interpreted because the new job positions are not as well paid as the ones lost in the mining sector (Figure 3b).

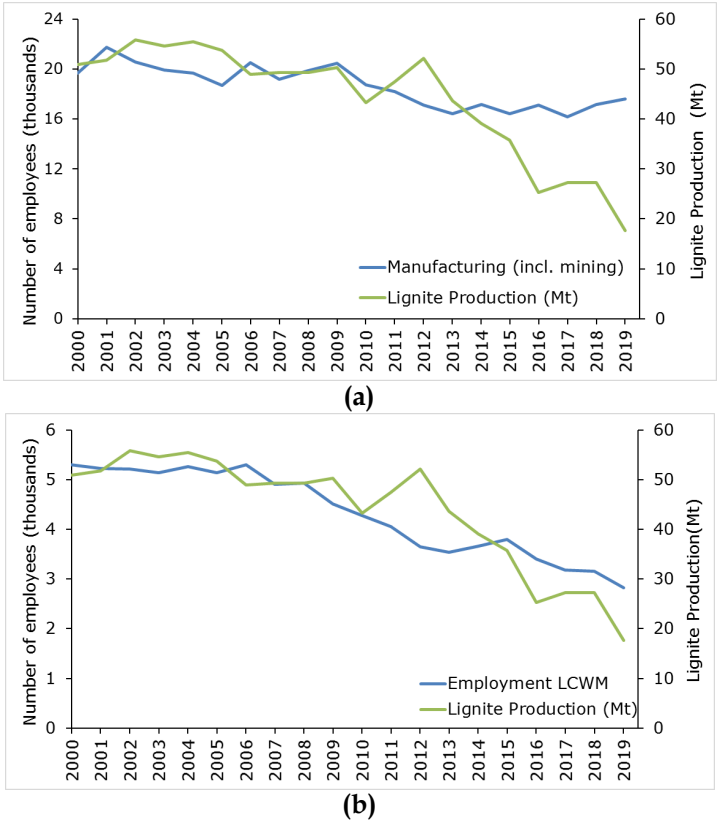

Figure 3. (a) Employment in the manufacturing sector (including mining) and lignite production through time (b) Employment in the Lignite Centre of Western Macedonia (LCWM) and lignite production through time.

From the correlation analysis of Figure 4, it is concluded that employment in the manufacturing sector, as an intermediate category, has a strong correlation with both total employment and employment in lignite mines. However, the loss of jobs in lignite mines exhibits a much weaker correlation with total employment. Nevertheless, the loss of more than 15,000 jobs between 2009 and 2013 is evidence that the global financial crisis of 2007-2008 shrank the regional economy considerably due to the austerity measures that forced the Greek government to cut spending and increase taxes.

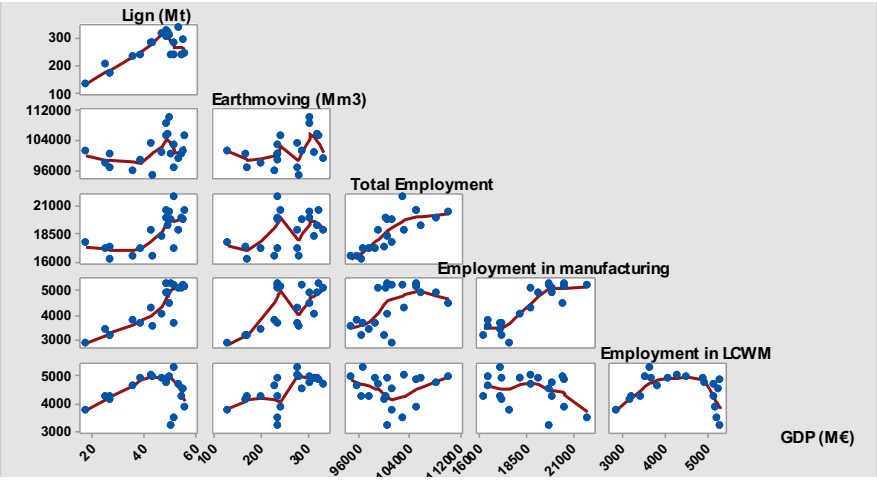

Figure 4. Matrix plot of indicative correlations of production and employment parameters.

CONCLUSIONS

The depletion of coal surface mines due to the energy transition policies adopted by many countries worldwide makes it difficult to achieve sustainable development goals at a regional level, at least in the short to medium term. Moreover, delays in implementing certain site-specific measures to support the emergence of new productive activities and maintain social cohesion lead local economies to a lower level of balance, this being restored through the migration of scientists, reducing wages, etc. On the contrary, a suitable planning of a mine closure, following the principles of sustainable development and circular economy as well as incorporating material, energy and and other indicators flow analysis, is expected to absorb most of the adverse socio-economic impacts.

Christos Roumpos

Director of Mining Engineering and Closure Planning Department
Public Power Corporation of Greece

Dr. Christos Roumpos is a Mining Engineer with an MSc in Energy and Environmental Management and a PhD in mining engineering. Since 1991 he has been working for the Public Power Corporation of Greece in many engineering, environmental, and energy economics fields and research projects. For about 20 years, he has taught mining engineering, mineral economics, and project management courses at universities. He is the author or co-author of more than 130 papers in scientific journals and international conferences.