ENERGY TRANSITION AND THE FUTURE OF LIGNITE MINING IN THE REGION OF WESTERN MACEDONIA, GREECE

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ENERGY TRANSITION AND THE FUTURE OF LIGNITE MINING IN THE REGION OF WESTERN MACEDONIA, GREECE

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Abstract

The transition to a zero-carbon economy can be decoupled from the closure of lignite mines. Lignite will continue to be used in a wide range of applications critical to key industrial sectors and to maintaining the living standards of modern society. Throughout the lignite phase-out effort, a central priority is to ensure a socially just development of the lignite mining areas, based on three pillars: employment, compensation of the socio-economic impacts and secure energy supply in lignite producing regions and the country at large. In this context, the present work focuses on the advantages of coal co-combustion with other solid fuels in small-scale decentralized units and, at the same time, points out the need to develop different land uses in the reclaimed coal mining areas, which satisfy a series of socio-economic and environmental objectives associated with the just transition to a new, sustainable, productive model.

Keywords: Coal, lignite, surface mines, energy transition, just transition

1. Introduction

In September 2019, during the United Nations Climate Action Summit in New York, the Greek Prime Minister pledged to phase-out all lignite-powered electricity production by 2028 (CORDIS, 2020). The above announcement was captured in the new National Plan for Energy and Climate (NPEC), presented in December 2019 following a public consultation and a debate in the Greek Parliament (The Hellenic Republic, 2019). The NPEC is an ambitious plan, in accordance with the UN Agenda 2030 and its 17 global Sustainable Development Goals, as well as with the recently adopted European Green Deal, setting, in some cases, even higher goals at the national level (UN, 2015; European Council, 2019).

The NPEC comprises a series of policy axes, which aim at: (i) the phase-out all lignite-fired electricity production by 2028, with the majority of coal fired power plants, representing over 80% of current installed capacity, being withdrawn by 2023, (ii) further development of Renewable Energy Sources (RES), which are projected to reach the 65% of electricity production in 2030, (iii) decrease of natural gas share in the national energy mix in 2030 compared to 2020, (iv) concerning climate change issues, 42% and 56% reduction of greenhouse gas emissions over 1990 and 2005 emissions, respectively, and (v) concerning energy-saving initiatives, a realization of a program for the energy renovation of public buildings, industrial facilities and residences.

The NPEC envisages investments worth 43.8 billion euros in RES, natural gas and electricity transport and distribution networks, financial incentives for purchasing electric cars, and energy-saving by 2030. National financial resources and European funding deriving in particular by the Just Energy Transition Fund, a new EU financial instrument enhancing an energy transition that is just and socially fair, will be used.

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In addition to the NPEC, National Strategies for Circular Economy and Climate Change have been developed to optimise the use of resources (energy, water, raw material) and biodiversity conservation, adequate water resources management and forest management, respectively (The Hellenic Republic, 2018 and 2016).

In this frame, the present study addresses the energy transition problem in Western Macedonia, where large-scale lignite mining and power generation activities were developed for more than 70 years. The study focuses particularly on the future of the lignite mines, taking into account the abundance of their remaining exploitable lignite reserves and the need to support the social and economic development of the region in the short- to medium-term based on the know-how and the skills of the local workforce.

2. Energy transition in Greece

A basic characteristic of the Greek energy system is its dependency on crude oil and natural gas imports. This is due to the decreasing consumption of domestic lignite for electricity generation. Lignite was strategically chosen as the basic indigineous fuel for electricity production in the decade of 1950 and was supported by all Greek governments over the years. Up to now, 1.7 billion tons of lignite have been produced. However, over the last ten years, increasing use of natural gas for electricity generation was occurred. Although natural gas still represents a small share of total consumption in Greece and falls short the European average, after introducing the CO_2 emissions trading scheme, it represents a significant share in electricity production, which is steadily growing over the years.

Specifically, after the peak in 2005, when lignite-fired power plants generated more than 35 TWh of electricity, lignite production in Greece cumulatively decreased by ca. 56.5% from 2008 to 2019. According to this development, the cumulative reduction of GHG emissions in Greece from 2007 to 2017 stood at -31%, the 3rd largest in the EU-28, after Sweden (-66%) and Finland (-39%). In the same period, power generation from RES almost doubled. As a result, currently, there is no dominant fuel in the generation mix. Figure 1 presents the substantial progress made in Greece regarding the diversification of the electricity fuel mix, especially in the deployment of various RES. In 2014 the lignite-fired power plants still met 45% of the country’s electricity demand. From 2014 to 2018, the share of lignite in power generation decreased by 35%, while the shares of natural gas and RES (including hydro power) increased by 115% and 20%, respectively. The year 2018 exhibited the most balanced contribution between lignite, natural gas and RES (including large Hydro) power, with their shares being 29%, 28% and 31%, respectively. In the next two years, the lignite share was decreased dramatically to 11% and natural gas, and RES shares were increased to 36% and 35%, respectively.

These developments positively impacted Greece's environmental indicators, primarily in terms of carbon dioxide (CO_2) emissions, as quantified in Figure 2.

Another basic characteristic of the Greek energy sector is its higher contribution to Gross Value Added (GVA) and employment than most EU countries. In this transitional period, this contribution is poised to grow significantly in the coming years, driven by several factors:

- the optimization of the energy mix, which consists of the reduction of fossil-fuel generated electricity and increased contribution from RES,
- the liberalization of the electricity and natural gas markets,
- the further separation of power production and supply businesses from the management of electricity transmission networks,
- the potential for Greece to become a European gateway for natural gas, electricity and oil resources through mega-infrastructure projects such as the TAP-IGB-EastMed gas pipelines, EuroAsia Interconnector or gas and oil exploration and production,
- the enhanced energy efficiency and reduction of cost-driven by smart technologies such as smart metering, smart grid technologies, LED lighting, energy efficiency in buildings, etc.,
- the development of major infrastructure such as the interconnection of the Greek islands with the main electricity grid, and
- the establishment of the Hellenic Energy Exchange according to the electricity Target Model supports the development of the Single Energy market in Europe.

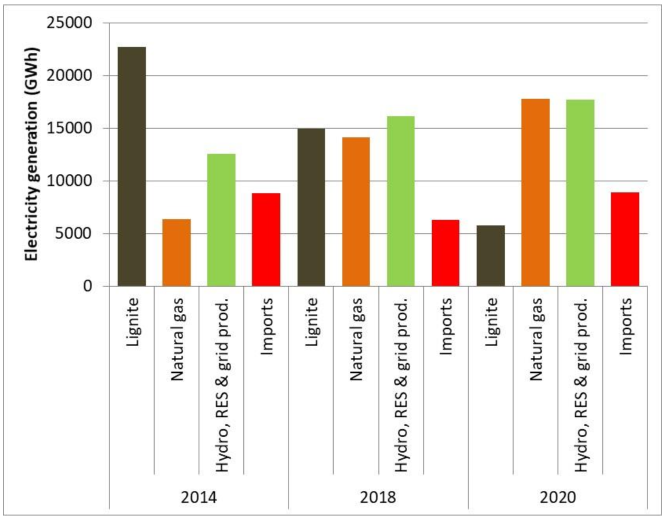

Figure 1: Fuel mix used for power production purposes in Greece

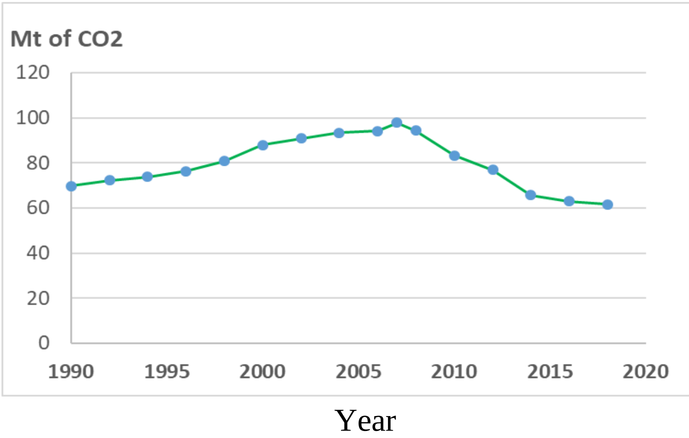

Figure 2: Total CO_2 emissions in Greece (IEA)

3. The just regional development transition plan

The exploitation of the lignite deposits of the Western Macedonia region started at the end of the 19th century. Since 1956, lignite production was launched at an intensive pace with the involvement of Public Power Cooperation (PPC SA), with the peak of production in the period 2001-2004 (Figure 3).

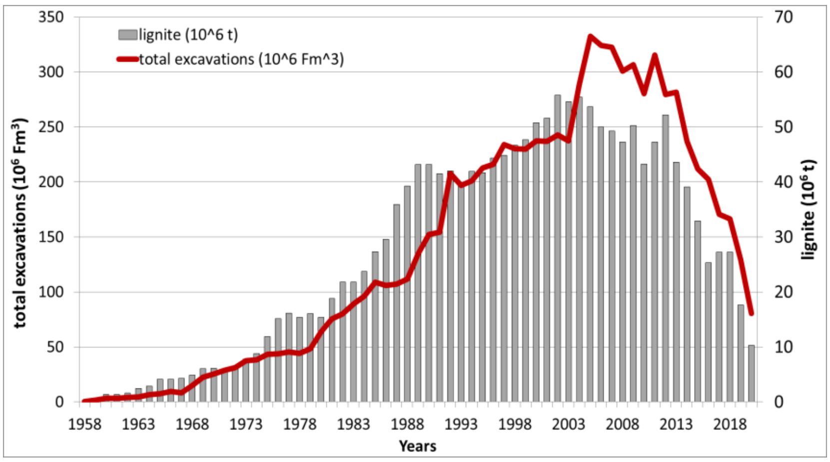

Figure 3: Lignite production in the Mines of PPC SA in the region of Western Macedonia (1956-2020)

Since 2004, the lignite industry in the Western Macedonia region has entered a recession period. However, due to the size of the lignite industry and the inherent inertia that accompanies it, the impacts began to be experienced in the local community in the decade of 2010. After 2019, these impacts were triggered by: (i) the increased CO_2 prices determined by the Emissions Trading System (ETS), which in turn increased the operating costs of lignite-fired power plants, (ii) the policies that promote the use of renewable energy and natural gas and (iii) the technological improvements in RES, which resulted to a significant reduction of installation costs.

In this development, energy transition in Western Macedonia will require considerable investment and a decisive policy response at all levels. Although all regions will need funding, the transition will pose a significant challenge to some of them, which have to adopt radical restructuring of their economies, changes in business models, and the development of new skills. Regions highly dependent on lignite utilization for electricity generation purposes will need to ensure that new economic activities can maintain social cohesion and provide an adequate number of new jobs.

Nevertheless, energy transition relies not only on selecting the best technical solutions but also on human potential and behaviours. This applies especially for Western Macedonia, where energy transition's success demands for a generalized productive reconstruction. Consequently, participatory decision-making, transparency of political commitment and building trust are crucial parameters of the energy transition governance.

3.1 The Governance of lignite phase-out

According to Act 52 of the Council of Ministers of 23-12-2019, a *Governmental Committee* was established, and Just Development Transition to the post-lignite era of the Region of Western Macedonia and the Municipality of Megalopolis in the Peloponnese Region is formed. The main task of the Committee is the approval and monitoring of the implementation of the Just Development Transition Plan (JDTP), which addresses all issues arising from the strategic decision of the Government to withdraw all lignite-fired plants of the country by 2028.

In order to address the economic and social repercussions, the Greek Government announced a Master Plan for the Just Development Transition and set up a *Steering Committee* to coordinate the preparation of the plan. After a draft was presented in September 2020, it underwent to a public consultation in October-November 2020. The revised JDTP was discussed at government level and in the Parliament and was presented to the public, on 9 December 2020.

Following a systematic collaboration with the World Bank, the European Commission-funded study entitled "A road map for a managed transition of coal dependent regions" was completed and utilized in the same period.

From May 2020, a *Technical Committee* has been established, with the main task of the preliminary evaluation of investment proposals and formulating a scientifically substantiated opinion. In July 2020, an open invitation was published to submit non-binding investment proposals and development plans by non-public sector bodies.

Furthermore, the Government Committee approved a Special Interim Fair Transition Program (2020-2023) and is being prepared for the lignite areas, which will be financed mainly by the NSRF 2014-2020, the Green Fund and the Recovery Fund. In September 2020, an invitation has been published to Public Sector bodies that are based/active in the lignite areas, for the submission of proposals concerning the financing of projects and actions, within the framework of the interim program.

The required investment in Western Macedonia will be funded from European funds mainly from the EU Just Transition Fund (JTF) and national sources, low-interest public loans from European sources and other financial instruments, commercial loans and private investment.

3.2 The vision of the transition process for Western Macedonia

The Master Plan of the energy transition of Western Macedonia Region is governed by five basic principles: (i) development of employment opportunities in local communities, (ii) utilization of the inherent advantages of the affected areas, (iii) priority to quick-wins projects, (iv) promotion of sustainable development projects, and (v) integration of modern technology and promotion of innovation. Based on the above principles, the vision for the "next day" regarding energy transition in Western Macedonia will be based on the following five pillars of development:

- Clean energy
- Industry, small industry and trade
- Smart agricultural production
- Sustainable tourism
- Technology and education

In order to initiate the transition process locally, the following indicative measures within the Just Transition Development Plan are in the start-up or implementation phase:

- Installation of photovoltaic parks
- Re-construction of district heating systems based on alternative fuels after the shut-down of lignite-fired units
- Spatial planning of lignite areas, including the development of fast permitting processes
- The total amount of €130 million stemming from the special levy on electricity consumers for the support of lignite regions
- €60 million of financing towards lignite areas from auctioning of CO_2 allowances (Green Fund)
- Further development of solid waste management facilities
- Promotion of the role of the University of Western Macedonia for the regional development
- Request to the European Commission to declare lignite areas as special tax zones.

3.3 Public acceptance at a regional level

Overall, the interventions of local stakeholders so far show a widespread reluctance to accept an accelerated process towards decarbonisation and lignite phase-out. Besides, almost all local stakeholders agree on the following (Ziouzios et al., 2021):

- No alternative economic activity could unequivocally replace the jobs and wealth offered for decades by the local lignite industry. This practically means that the new development model of Western Macedonia must be based on a strongly differentiated production level in terms of complementarity.
- Given that from the primary sector and manufacturing to electrification and hydrogen technology, new productive activities will not be labour-intensive but knowledge-intensive, investing in Research and Innovation is a critical success factor.
- There must be a balance between external direct investment and the development of an intra-regional production capacity to avoid future mono-dependencies.
- The rehabilitation of depleted lignite mines, spatial planning, the promotion of licensing simplification and the launch of infrastructure projects are recorded as necessary prerequisites by the stakeholders.

4. The prospects of lignite mines and reclaimed mining land

Based on the analysis mentioned above, it is clear that the transition to a green economy relies to a large extent on the phase-out of lignite-fired power plants. As a result, lignite mines are facing shut down long before the depletion of their exploitable reserves. In the Region of Western Macedonia, these remaining exploitable reserves in the lignite fields under exploitation by Public Power Corporation SA are estimated to be 820 million tons, while private mines reserves are 120 million tons. In addition, Public Power Corporation SA also has the right to exploit 460 million tons of lignite located in areas where mining activities have not been developed so far.

Nevertheless, mines closure should be avoided for a number of reasons related to the rational management of resources, environment protection, economic impact reduction at the local level, and social justice. In addition, coal and lignite have several non-electric uses which certainly do not demand quantities equivalent to those consumed by the power generation industry. However, they can contribute to maintaining a minimum productive activity and, in this way, mitigate the short- to medium-term impacts of the energy transition.

4.1 Non-electric uses of coal and lignite

The most prevalent non-electric use of coal is in steel metallurgy. Coal is used in 70% of the world's steel production. Steel plays a significant role in delivering renewable energy and other goods and services that growing economies need. For instance, each wind turbine requires 260 tons of steel made from 170 tons of coking coal and 300 tons of iron ore. In 2019, global metallurgical coal consumption rose 3.2% to 1,080 Mt, with China being by far the largest consumer, accounting for 64% (691 Mt) of the global total. Since there is no near-term substitute for coal in steel production, it can be safely predicted that coal demand for steel production will remain constant (IEA, 2020).

Furthermore, because of their relative affordability, coal and lignite are the most widely used energy sources in the manufacturing process of other energy-intensive materials such as cement, aluminum, and lime. However, in these cases, coal and lignite utilization is also subjected to CO_2 emissions control restrictions.

In-situ coal/lignite gasification, also known as underground coal/lignite gasification, appears to be both technically and economically feasible and exhibits many potential advantages over conventional mining methods. The gasification process creates synthesis gas (carbon monoxide and hydrogen) that can be used as fuel or feedstock for further chemical processes. An oxidant (usually air, oxygen, or steam) is injected into the coal seam and reacts with the coal and water present in the seam to produce synthesis gas extracted through a production well. In-situ gasification has less environmental impacts than conventional mining, including no discharge of tailings, reduced sulfur emissions, and reduced ash discharge. Thus, in the coming years, it is expected to compete against other fuels not just on an economic basis but also based on overall environmental performance, after improvements in hydraulic control of the process, which is crucial to prevent groundwater pollution, and incorporation of carbon capture and sequestration technologies (Brown, 2012; Koukouzas et al., 2013; Sheng et al., 2015; yang et al., 2015).

Coal and lignite are also used to produce activated carbon, carbon fibres, hydrogen, liquid fuels, silicon metal, coal tar, graphene and many other chemicals. These materials are vital in transport, infrastructures and modern life in general. Particularly, activated carbon is widely used in water filtration, gas purification and pharmaceuticals synthesis (IEA, 2018). Also, the potential of graphene production from lignite worths particular attention. In the frame of a ground-breaking project of the US National Energy Technology Laboratory (NETL) feedstocks of coal were converted into graphene, a material that is stronger than steel and possesses higher electrical and thermal conductivity than copper (Pham et al, 2019). The NETL team developed a process that converts lignite, bituminous and anthracite ranks of coal into graphene. Their process addresses cost challenges by using domestic coal feedstocks which are 15-30 times cheaper than the graphite currently used. The technology also uses inexpensive processing methods with product yields that are six to 10 times higher than current approaches. For this research NETL received a prestigious R&D 100 award for being among the 100 most technologically significant innovations introduced into the marketplace in 2020. NETL is working further on a method for making graphene quantum dots, small fluorescent nanoparticles, which can be used in composite plastics, batteries, water filtration systems, and 3D printing materials. This can be done in just a few hours producing from a ton of coal, which is valued at $60, nanomaterials that worth more than $300,000.

Several lignite deposits are enriched in rare earth elements (REE), that are crucial for the utilization of renewable energy and the development of computer technology, among other industrial uses. Because of their necessity in technologically advanced applications, the demand of REEs is enlarging. REEs can be recovered from different coal resources, such as coal tailings, acid mine drainage (AMD) and raw lignite and their extraction is considered as an option for the waste management of coal exploitation. Recovering REEs from coal waste bears an additional advantage, which is the decontamination of heavy metals in aqueous metallurgical waste (IEA, 2018).

The production of soil amendments and fertilizers (Giannouli et al., 2009; Giannatou et al., 2018) as well as the extraction of rocks, such as sands and clays contained in the overburden strata of lignite deposits (Koukouzas, 2007; Koukouzas et al., 2009) provide new products that may have various applications in the agriculture and the construction materials and ceramics industry.

The development of the aforementioned non-electric uses requires coal or lignite of strict quality standards. Therefore, a question still remains about the future uses of low-rank coals with widely varying quality characteristics. In this frame, among other alternatives, the present paper gives prominence to the co-combustion of lignite and biomass to meet the thermal needs of residential, industrial and agricultural activities. This option is ideally combined with utilising the energy content of farm residues and municipal solid waste that would otherwise dispose of in landfills since the relevant costs and logistics for their collection, transport, and storage are infeasible. In fact, these projects can be carried out with small, decentralized combustion plants on a local scale, minimizing fuel transport costs and promoting energy democracy. At the same time, it would be possible to find synergies in the exploitation of reclaimed lignite mining areas by growing certain plant species that maximize biomass production. This specific land use of the reclaimed mine surfaces has many advantages, considering potential problems of soil fertility and high content of toxic elements, limited water quantities for irrigation, restrictions relevant to the cultivation of edible plants, etc. Essentially, it incorporates some of the basic principles of the circular economy and the rational management of natural and energy resources.

4.2 Mine land repurposing

Expanding further the discussion on mine lands repurposing scenarios and development of new land uses, it should be emphasized that the early closure of the lignite mines, due to the energy transition strategy, results in a failure of the plans of land reclamation and implementation of other environmental protection measures required by the laws and regulations. Many works planned to be carried out in the next decades must have been completed within a few years, requiring increased efforts from all the involved parties and, of course, funding.

Regardless of the above, mine operators hold a broad portfolio of potential land uses that range from those maximizing profits to those trying to balance ecological restoration and financial targets. The first category of land uses is classified as the development of photovoltaic parks, an investment opportunity that lately attracts both giant enterprises of the energy sector and small investors organized in various forms of cooperative schemes. Moreover, further investigation deserves the feasibility study of constructing water reservoirs in the final pits of the surface lignite mines, which will be used to store energy produced by the photovoltaic parks to equalize the electricity supply to the grid between day and night.

Concerning the category of land uses that focus on ecological restoration, this is almost synonymous with forestation. It is usually carried out in sloped surfaces, and it is based on native species, aiming to improve the landscape aesthetics, control of soil erosions and, beyond these, at the production of biomass, as mentioned above, production of timber, development of beekeeping, etc. The same category of land uses are also classified as mild agricultural and livestock activities. The land uses of this category are usually mentioned, and their spatial distribution is plotted in maps included in the environmental permits of each lignite mine and in this way, their implementation constitutes a commitment for the mine operator (Pavloudakis et al., 2020).

5. Conclusions

In the face of the energy transition, the challenge for lignite mining enterprises and all other stakeholders refers to selecting the optimum mix of land uses that introduces a self-sustained and just for the local communities' development model. The obstacles encountered due to the one-dimensional growth are already known in many rural areas where lignite mining activities have developed. Thus, the exploitation of lignite deposits and reclaimed mine areas during and after the energy transition period should incorporate a series of actions that effectively address the threats of poverty, unemployment, social exclusion, migration, pollution and degradation of nature, landscape and quality of life in general.

Also, the entire procedure can be considered as an opportunity to remedy problems of the past, which are related to improper waste management and failure to apply correct land reclamation practices, such as the poor management of top soil removed in front of the excavation face of the mine.

All the measures and relevant investments should be made with the contribution of financial resources granted for this purpose, such as the European Fair Transition Fund. They should not focus on the area directly affected by the excavation and waste heaps development, but they must cover a greater geographical area around the lignite mines. Given the severity of the expected social and economic impacts, particularly in regions where the enormous size of the energy industry has resulted in the suspension of any other economic development efforts, this provision is necessary in order to take full advantage of the strengths and opportunities that characterize each lignite region in transition. At the same time, a broad group of beneficiaries of financial support does not jeopardize the participation of communities located in the proximity of the mines in development projects since it provides new opportunities for synergies and diversification. Regarding the management of human resources, a crucial parameter for the success of every energy transition program is the maintenance or development of activities, which will take advantage of the accumulation of knowledge and skills in the operation of mines and steam power plants.

References

[1] Bataille, C., M. Ahman, K. Neuhoff, L.J. Nilsson, M. Fischedick, S. Lechtenböhmer, B. Solano-Rodriquez, A. Denis-Ryan, S. Stiebert, H. Waisman, O. Sartor, S. Rahbar: A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement, *Journal of Cleaner Production*, 187, pp. 960-973, 2018.

[2] Brown, K. (2012), *In situ coal gasification: An emerging technology*, 29th Annual National Conference of the American Society of Mining and Reclamation, pp. 51-70. 10.21000/JASMR12010051., 2012.

[3] CORDIS, *Greece is first Balkan country to announce a coal phase-out date. The revolution has already started in Western Macedonia*, https://cordis.europa.eu/article/id/413274-greece-is-first-balkan-country-to-announce-a-coal-phase-out-date-the-revolution-has-already-s.2020.

[4] EC, *The European Green Deal*, Communication from the Commission to the European Parliament, The European Council, The European Economic and Social Committee and the Committee of the Regions, COM(2019) 640 final, Brussels, 11.12.2019, 24p.

[5] Giannatou, S., Vasilatos, C., Mitsis, I., Koukouzas, N.: Utilization of natural and synthetic zeolitic materials as soil amendments in abandoned mine sites. *Bulletin of the Geological Society of Greece*, 53 (1), 78-98., 2018.

[6] Giannouli, A., S. Kalaitzidis, G. Siavalas, A. Chatziapostolou, K. Christanis, S. Papazisimou, C. Papanicolaou, A. Foscolos: Evaluation of Greek low-rank coals as potential raw material for the production of soil amendments and organic fertilizers, *International Journal of Coal Geology*, 77, Issues 3–4, 2009, pp. 383-393.,2009.

[7] IEA, *Non-energy uses of coal*, IEA Clean Coal Centre CCC/291, November 2018, 90p.

[8] IEA, *Coal 2020*, IEA, Paris https://www.iea.org/reports/coal-2020.

[9] Koukouzas, N.: Mineralogy and geochemistry of diatomite associated with lignite seams in the Komnina Lignite Basin, Ptolemais, Northern Greece. *International Journal of Coal Geology*, 71 (2-3) 276-286.,2007.

[10] Koukouzas, N., Ward, C., Li, Z.: Mineralogy of lignites and associated strata in the Mavropigi field of the Ptolemais Basin, northern Greece, *International Journal of Coal Geology*, 81 (3) 182-190.,2009.

[11] Koukouzas, N., Katsimpardi, I. & Merachev, D.: Simulation of Underground Coal Gasification process in a Bulgarian Coal field. *Bulletin of the Geological Society of Greece*, vol. XLVII No 3. Proceedings of the 13th International Congress, Chania, Sept. 2013, 2090-2100.

[12] Pavloudakis, F., Roumpos, C., Karlopoulos, E., Koukouzas, N.: Sustainable rehabilitation of surface coal mining areas: The case of Greek lignite mines, *Energies*, 2020, 13, 3995; doi: 10.3390/en13153995, p.23, www.mdpi.com/journal/energies.

[13] Pham, V. H., C. Wang, J. Weidman, Y. Gao, C. S. Matranga: *Large scale synthesis of coal-derived carbon-based nanomaterials*, National Energy Technology Laboratory, 626 Cochrans Mill Road, Pittsburgh, PA 15236, USA and Leidos Research Support Team, 626 Cochrans Mill Road, Pittsburgh, PA 15236.,2019.

[14] Powell, C., G. W. Beall: Graphene oxide and graphene from low grade coal: Synthesis, characterization and applications, *Current Opinion in Colloid & Interface Science*, (20) 5–6, 2015, pp. 362-366.,2015.