

INDUSTRIALIZATION OF MINING WASTE AND ENERGY IN THE CIRCULAR ECONOMY

Sorin Mihai RADU^{1*}, Adrian BĂRBULESCU², Ciprian COANDREȘ³,
Charles Rostand MVONGO MVODO⁴, Ioan Petru SCUTELNICU⁵,
Jamal KHAMIS⁶, Alexandru A. BURIAN⁷, Alexandra LIHOACĂ⁸

¹University of Petrosani, Romania, sorin_mihai_radu@yahoo.com

²University of Petrosani, Romania

³University of Petrosani, Romania

⁴Technical University (Engineering) Cameroun, charlesrostand@yahoo.fr

⁵Geological Institute of Romania, Bucharest, Romania, pink73@yahoo.com

⁶Ministry of Health, Damascus, Syria, jamal.khamis@ymail.com

⁷University of Petrosani, Romania

⁸University of Petrosani, Romania

DOI: 10.2478/minrv-2023-0007

Abstract: *In the field of underground and surface mining, offshore and onshore exploitation, hydrocarbon distribution, associations of circularity activities are required taking into account the protection of the environment, the safety and security of people, deposits and objectives in the specific productive infrastructures, as well as the responsibility in the regulatory/legislative framework assumed by directives, laws, rules and norms. The circular economy implies the transition to an eco-industry based on reducing the consumption of energy and raw materials, in which mining waste, municipal waste (in fact, all categories of waste, including hazardous waste) have destinations established from the design phases, being included in the cyclical spiral of reuse. The authors emphasize that in this framework, the waste/residues that appear in an exploitation/manufacturing process represent raw materials for other processes. The article deals with aspects related to the technological and managerial consistency in the problem of waste, Refuse-Derived Fuel, co-processing of waste in cement factories, the industrialization of waste for RDF through mechanical, biological treatment and advances the investment proposal of Unit for Advanced Energo-Thermal Treatment of Waste. It is concluded that regarding the industrialization of mining waste and energy in the circular economy, roadmaps are needed for the introduction and development of waste management / (Roadmap to Improve Waste Management) in Romania and other interested countries.*

Keywords: *industrialization of mining waste, energy from waste, circular economy, mechano-biological treatment of waste*

1. Introduction

Awareness of the possibility of crises, depletion of non-renewable resources (caustobiolytic fossil fuels), pollution of the subsoil, soil, water and air, aggravation of the state of underdevelopment to the extent that energy and primary mineral and energy resources are not provided, lead to the intensification of concerns for the identification structures, industrial and economic processes that offer solutions for individual and collective interest at the local, regional and global level.

As such, there are currently commitments at all levels to achieve economic and ecological objectives, to meet the needs of the current generation and future generations for sustainable existence.

In fact, the complexity of the contemporary societal advance can be overcome by relying on the edification of sustainable development based, in essence, on the identification and operationalization of new feasible, applicable, efficient energy-mining eco-industrial structures.

* Corresponding author: Radu Sorin Mihai, prof. Ph.D. eng., University of Petrosani, Petrosani, Romania, Contact details: University of Petrosani, 20 University Street, sorin_mihai_radu@yahoo.com

We find that in recent years energy-mining structures are the first involved in local, regional, regional and global crises which, in fact, are crises of material, physical eco-industrial structures in the conditions of the accelerated transition to the knowledge-based economy and society.

The eco-industrial development according to the principle "the assembly matters, the structures say nothing" must be replaced by a new type of energy-mining evolution, based on those structures that guarantee in the long term, without neglecting the near horizon, the achievement of some social objectives, ecological and economic in accordance with the general interest through the sufficient supply of useful mineral substances, respectively primary energy resources.

In Romania and in other global countries, the transition to the circular economy represents an opportunity to solve economic, industrial and social blockages. (Gâf-Deac, I.I., et al., 2015), [1]

In this framework, eco-innovative solutions are sought from authorities and entrepreneurs (through technologies and investments), based on the improvement of industrial management systems, respectively of waste and residue management, especially of energy-mining and municipal ones.

Basically, through the industrialization of mining waste and the exploitation of energy potential from waste through the circular economy, it is possible to establish *the dominance of eco-technologies* that determine circularities in which residues and waste are found and used.

2. Research from the specialized literature

The industrialization of mining waste, first of all, must be seen as a regulatory process.

The National Waste Management Plan"/ PNGD, (2018), [2], is assumed as a national document, recognizing that waste management is one of the critical problems facing Romania today.

Thus, the Plan summarizes the long-term vision, defines principles and objectives, the main task being to ensure planning consistency for the decision.

The text published in the Official Gazette of Romania, in force since February 8, 2016, refers to Decision no. 3/2016 on the Circular Economy Package: COM (2015) 614.

Also considered is the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions entitled "Closing the loop - an EU action plan for the circular economy", COM (2015) 593.

At the same time, the Proposal for a Directive amending Directive 1999/31/EC on waste disposal, COM (2015) 595, respectively the Proposal for a Directive amending Directive 2008/98/EC on waste, COM (2015) 596, is also important. amendment of Directive 94/62/EC on packaging and packaging waste.

A literature review on mining waste industrialization and energy in the circular economy

shows that in industrial green mining we are dealing with a restorative and regenerative system by design. (Bogatu, L., Coandres, C., et al., 2015), [3]

A general circular energy-mining economy model assumes that primary energy resource extraction units and energy production units (enterprises) in the first place must carry out their activities continuously according to the requirements of waste reduction, reuse and recycling, in an incipient manner at the microeconomic level.

In some conceptions, the idea of "stratified eco-circular work" is advanced (Balanay, R., Halong, A., 2016), [4], the primary set of impacts, respectively waste being greenized in mining extraction, further, the following layer with operations of this kind found in the energy industry.

This association/articulation of the layers of eco-circularity ensures continuity and meaning in the elimination of waste and its anthropogenic consequences.

For all these approaches: a) holistic knowledge and b) pro-active interventions towards circularity are necessary.

Zhao, Y., et al., (2012), [5], show levels of correlation between the development and use of energy-mining resource extraction and the applicative involvement of the circular economy, clarifying the connotation of the specific content of the principle of recovery, reuse, reuse of materials in general and of waste in a circularity regime.

Firpo, B.A., et al., (2021), [6], propose in a circular economic context the creation of a "technosol" type product made up of desulfurized coal waste (main constituent, fraction of 68% by mass from raw coal of waste), supplemented with rice husk ash (chaff, including grasses), steel mill slag and sewage sludge used in plant growth and environmental control.

It is about putting into practice the conditions for the manifestation of pedogenesis properties by placing a technosol layer suitable for plant growth, land protection, as a common practice to avoid anthropogenic damage caused by energy-mining waste.

Arad, V., et al., (2012), [7], significantly deals with the impact of coal mining in the Ji Valley on the environment and the rehabilitation of the area, and Orlova, T., et al., (2017), [8], develops elements of methodology and practice for the recovery of landfills and municipal solid waste dumps in an associated, energy-efficient waste management system (the international concept of the waste hierarchy, the rehabilitation of landfills and municipal solid waste dumps in a management system of waste).

Goldan, T., and Moraru, R., et al., (2012), [9], offer options for activities to restore the landscape of areas affected by coal processing activities, and Băbuț, G.B. and Moraru, R.I., (2013), [10], performs the analysis of ways to improve the legal framework for the protection and exploitation of mineral resources in terms of sustainable development imperatives, to which are added the results obtained by Dacian-Andrei; F., Onica, I., et al., (2017), [11], by monitoring the deformation of the land surface and analyzing the data for coal mining units.

Roșcanu Beloiu, R., Gâf-Deac, I.I., Rostand, M.M. Ch, Khamis, J., Burian, Al.A., and Scutelnicu, I.P., (2020), [14], deals, from a practical perspective, with the problem of super-compact structures of quality standards for health and security in the sustainable development of a mining basin in Romania, and Apostu, I.-M., Lazăr, M., and Faur, F., (2022), [12], speak suggestively about the implications of the disappearance of coal from the energy mix in Romania.

The authors highlight, through substantiated analyses, several scenarios with reference to the possibilities of replacing coal in the energy mix, emphasizing that this aspect would change the energy-mining perspectives in local/zonal mono-industrial realities.

In a circular economic context, of intervention to eliminate the impact on the environment from mining activities, the concept of "ecological reconstruction" is advanced, taking into account the largest lignite quarries in Romania, which occupied and degraded important areas of land, totaling almost 19,000 ha. (Lazar, M., et al., -2018), [13]

Recently, Radu, S.M., J. Khamis, J., I.P. Scutelnicu, I.P., Bărbulescu, A., et al., (2022), [14], respectively Valizadeh, S., et al., (2022), [15], presented a "bi-objective model with tasks of increasing revenues from waste recycling, generating energy from waste and reducing environmental pollutant emissions."

Rabbani, M., et al., (2020), [16], propose a nonlinear programming model with mixed integers, for solving multi-objective problems, using the "epsilon" constraint method, with Pareto solutions, and based on the results of the sensitivity analysis yield options for reducing source-to-disposal times, which reduce waste transfer time, when solutions to transport and environmental problems include economic and social aspects.

3. Research method/methodology

From a methodological point of view, field observations, case situations, quantitative evaluations through aggregation, integration of theoretical and practical indicators were used for the issue of mining waste industrialization and energy in the circular economy.

It started from the finding that the impact of mining activities on the environment is significant in relation to other industries in the general, global economy and, as such, the problems raise debates, analyses, proposals and recommendations of eco-industrial behavior, of feasible solutions in the context sustainability concerns.

Ensuring sustainability in the mining and energy sector is a difficult requirement, as the demand-availability ratio of minerals and primary energy resources shows limitations given the location of geological deposits, deposits, extraction, processing of useful mineral substances, management of externalities (outputs), protection of people and the environment.

The anthropogenic consequences, the techno-economic complexity of exploration, the highly structured, hard-to-innovate exploitation technologies, the social and environmental problems if approached aggregately imply the need for advanced scientific knowledge, show high real costs for people and the environment, from the local level to the global.

The solid mining waste of millions of tons/year (to which is added approx. 7.5 million tons/year of municipal, household waste in Romania) represents, quantitatively, the biggest challenge produced by an industrial operation (mining, in this case), dimensions and specific problem areas being found over long time intervals.

Due to the waste, in association with post-exploitation mining phenomena, such as subsidence, there is the disturbance of large areas (mining lands loaded with mining technological loads), changes in the topography and the physical and chemical conditions of the soil.

Industrial ecology is the supporting phrase for the circular economy.

In current mining science and practice, the circular mining economy is assumed as a general sustainable development policy.

However, the simple understanding that industrial ecology is associated with the life cycle of the activity/product and the extended responsibility of the producer (from exploitation to the valorization of useful mineral substances and primary energy resources) aimed at mitigating environmental problems is also considered.

An industrial system, such as the mining/energy system, must have the ability to operate within environmental limits.

Such a potential implies the integration of circularity in the processes of exploiting useful mineral substances, energy resources and energy production by properly managing waste, being included in the flows of raw materials, or exploited up to their total limit.

Circularity in the extractive-mining activity can start from the "mining system design", establishing sub-operations, complementary or implicit activities/intrinsic to mitigate the anthropogenic consequences: backfill-debleu from crushed rocks from the massif disturbed by tunnel digging/cutting in abatages, softening of the exploited space, recovery and greening of mine waters, methane gas capture, gasification, recovery of geothermal heat from underground, landscape integration by modeling using wooded tailings heaps, use of crushed rocks in constructions, embankments, etc.

Thus, it is possible to avoid dangers for terrestrial and aquatic ecosystems, forests and biodiversity.

Industrial mining and energy remodeling serves to formalize the capacity of the extractive-energy system to minimize anthropogenic repercussions on the environment.

So, from a methodological perspective, for this complex field and the problem of the industrialization of mining waste and the recovery of energy in the circular economy, recognized methods associated with modern research based mainly on data collection, their systematization, analysis, synthesis were used, analogy and comparative analysis.

4. Results and discussion

4.1. *Technological and managerial consistency in the waste problem*

We find that in Romania, as it happens in other countries (such as Syria, [14], Cameroon, [17]) targeted by the authors in this paper, or in other European areas, the lack of "environmental enterprise strategies", often predisposes any organizational entity to stagnation.

A change in the environmental enterprise, which operates in the energy-mining field, should refer to distinctly defined objectives and goals for the industrialization of mining waste and energy in the circular economy, because in other situations, in our opinion, the phenomenon of "evolutionary de-acceleration of the company", up to the stage of "negative growth"/losses.

A good vision from waste impact assessment mainly leads to benefits such as:

- the introduction into the economy of the EU and Romania of raw materials and secondary materials, which, in turn, will reduce the dependence of the EU and our country on imports of primary resources;
- by 2030, more than 180,000 jobs could be created;
- the industrialization of mining waste and energy in the circular economy contribute to the reduction of greenhouse gas emissions;
- extended liability of producers, reduced risks related to access to materials and ordinary materials in productive industrial processes;
- eliminating the storage of non-residual municipal waste by 2030.

By the end of 2025, the following minimum preparation objectives for reuse and recycling must be met in Romania: 60% for plastic; 65% for wood; 80% for ferrous metals; 80% for aluminum; 80% for glass; 90% for paper and cardboard.

By the end of 2030, at least 80% of the mass of all packaging waste must be prepared for reuse and recycling. Through the circular economy, basically, production situations with unlimited potential should be reached.

Waste management aiming at the industrialization of mining waste and energy in the circular economy is considered to be Romania's most pressing environmental problem.

Community objectives are difficult to achieve, because Romania registers enormous amounts of waste that remain unmanaged according to community requirements.

The acceptable framework for adequate management in the field must include the stable / sustainable management and organization of the waste field (fig. 1).

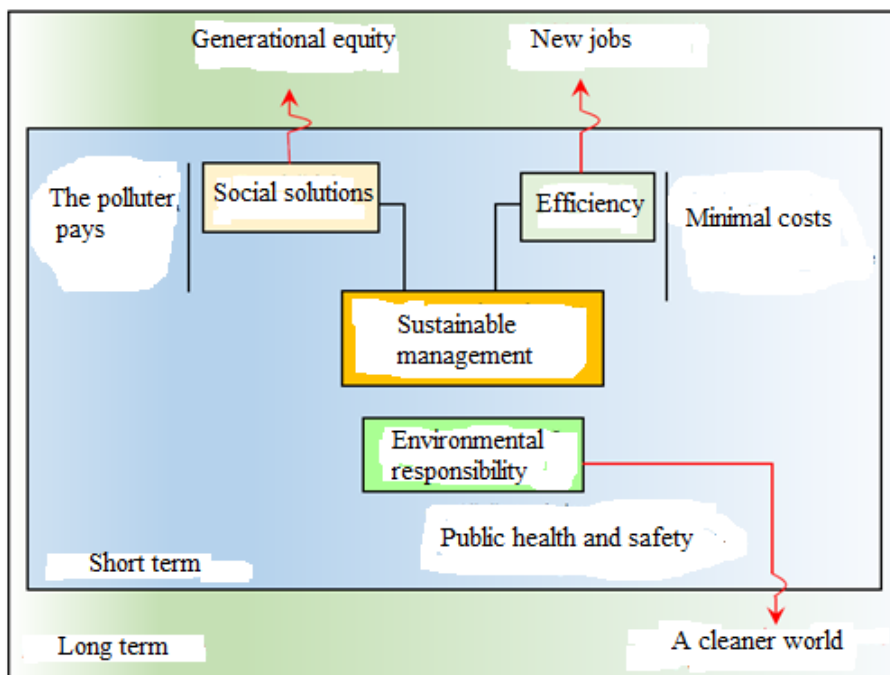


Figure 1 Stable / sustainable waste management
(Source: authors, 2020)

Since no intensive action is taken to solve the investment gaps and dysfunctions in the Integrated Waste Management Systems - SMIDs/ Integrated Waste Management Centers - CMIDs, in the context, it is recognized that in Romania, and similarly in other countries mentioned in the present study, related to waste and sanitation, show vulnerabilities with a high degree of strategic, operational, economic and social disturbance.

In most of the EU Member States and in other countries in the region, the separate collection at the source of municipal (household) and similar waste generation by the population and economic agents, institutions, other waste generators has been imposed and operates.

In Romania, the "productivity of the resource" must be increased.

At EU 27/28 level this is = 2 Euro/Kg of material; in Romania = it is only 0.40 Euro/Kg of material.

"Resource productivity" (the efficiency of the economy in using material resources to produce wealth) in Romania was the lowest in the EU in 2019.

It turns out that the economy is, on average, 40% less resource-efficient than at EU level.

The idea of "zero waste to landfill" is assumed, and recycling should be implemented, respectively the duration of recyclables should be longer.

So, in the matter of waste, we are witnessing an acute lack of internal strategic, tactical and managerial consistency (figure 2).

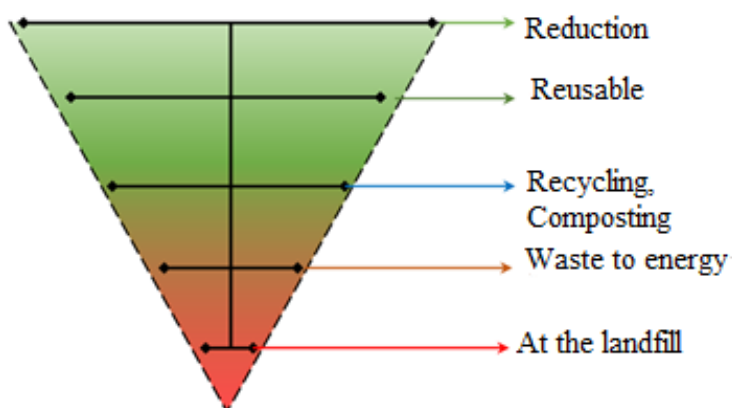


Figure 2. Reversing the top of the current hierarchy of effective waste management concerns in favor of recycling, composting and energy recovery over landfilling
(Source: authors, 2020)

4.2. Fuels derived from RDF waste (Refuse-Derived Fuel)

The implementation of fuel production from waste is a complex issue because:

- RDF are regulated in Europe based on the European Waste Catalog with code 19.12.10.

Refuse Derived Fuel (RDF) differs from SRF in that it is not produced according to standardized classification and specification requirements.

RDF includes high calorific fractions, which are taken from waste streams with a high calorific value and which have not been processed as much as SRF.

The various materials that are combustible are cut, crushed and pressed into molds.

The calorific value reaches 12-14 MJ/kg.

The industrialization of waste in these facilities is carried out on the basis of integrated environmental permits. Cement factories in Romania [Deva, Bicz, Fieni (Heidelberg Cement Romania), Alesd, Câmpulung (Holcim Romania), Medgidia, Hoghiz (CRH Ciment Romania)] have integrated co-incineration in the clinker process. (fig. 3)

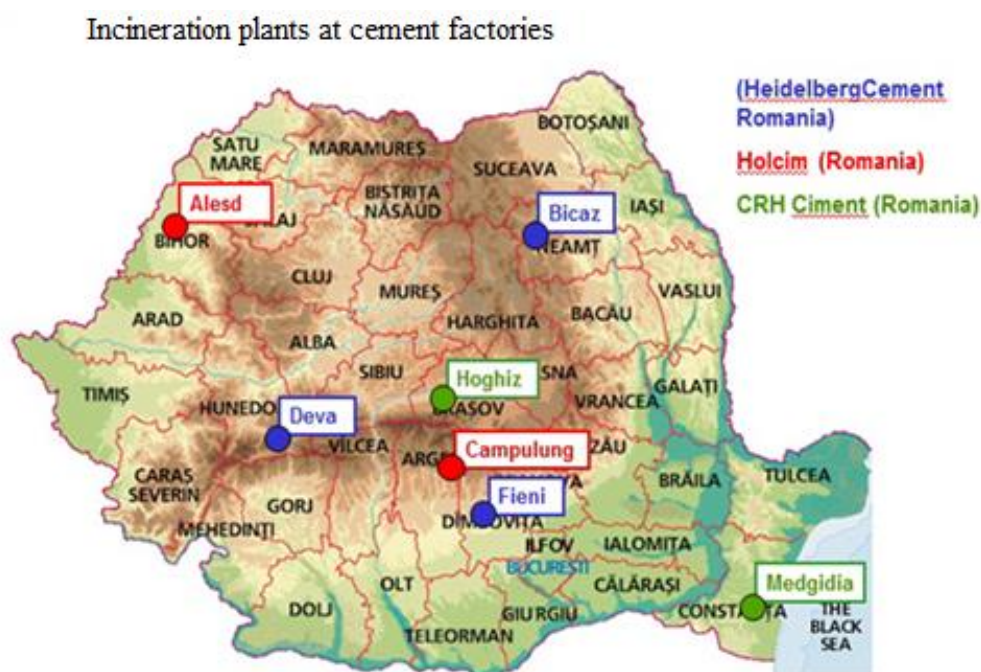


Figure 3. Distribution of RDF type consumers / cement plants on the territory of Romania (Source: taken from the virtual free space, [www. https://da.zf.ro/business-construct/](https://da.zf.ro/business-construct/) 2020)

Waste co-processing is practiced by most cement producers, and is also applied in other large energy-consuming industries.

The main advantages of waste co-processing in cement factories highlight the fact that the development of co-processing activity at the national level is based on the implementation of the best available technologies and best practices in the field.

Clinker kilns, which already exist in cement factories, provide the controlled conditions necessary for the safe burning of waste.

There are the investments already made, in specialized equipment for analyzing, handling, dosing, feeding and pre-treating waste, for monitoring emissions, and there are no slags or ashes that require further storage. In fact, the natural resources traditionally used in the manufacture of cement are conserved, and RDF ensures traceability, the safety of the population and the environment.

Cement factories are already licensed and co-process a range of over 100 types of waste, both industrial and sorted household.

During the technological course of the co-processing of waste with energy content, the energy resulting from co-incineration is recovered, as well as the mineral material resulting from combustion, embedded in the composition of the cement clinker.

However, in enterprises in the country and in the countries mentioned in the article (Syria and Cameroon) considering the development of a municipal waste treatment technology for the production of RDF alternative fuels with higher calorific value.

For the case of Romania, when obtaining a supply solution for cement factories and thermal power plants with enriched SRF/RDF, with high calorific value, it is considered to include in the composition of the deliverable, as appropriate, hard coal, lignite type coal, waste combustible coal from the heaps in the Petroșani and / or Oltenia / Vâlcea mining perimeters, combustible coal waste from the heaps from the thermal power plants Mintia, Paroșeni, Rovinari, Turceni, Ișalnița, other materials and combustible materials with the potential to increase the quality/calorific value of the waste in RDF.

4.4. Waste industrialization for RDF through mechanical, biological treatment

Treatment options are considered as follows:

- Mechanical treatment of municipal waste to finally sort the fraction with high calorific value, with few solid and metallic impurities for combustion in cement plants. This technology involves waste sorting and selection equipment and, where applicable, shredders or granulators.
- Biological treatment of municipal waste through an initial sorting, bio drying and then final sorting to produce high quality alternative fuels. This technology involves sorting equipment, a bioreactor for the bio-stabilization of waste and its drying, a complete final refining line that includes the full range of sorting and selection equipment.
- The complete solution for unloading SRF/RDF from walking floor semi-trailers and supplying alternative fuels to cement plants directly to the burner. It can be equipped with anti-fire system and dust removal system.

The physico-chemical analysis carried out in the laboratories must show that this RDF is of high quality and meets the acceptance criteria.

5. An investment proposal in the field

At the national level (in Romania), it is proposed to build, in a first stage of construction, some Units for the Advanced Energo-Thermal Treatment of Waste, 2 in each Development Region.

Next, the solution can be extended as an application through joint venture in other countries that have expressed interest in the field.

The characterization of the recommended investment mainly refers to:

- Total treatment/utilization capacity = approx. 225,000 tons/year (approx. 30 tons/hour), which can cover, for example, approx. 20 – 25% of the total requirement for the Bucharest - Ilfov Region, or the requirement of 2 - 4 counties;
- Thermal capacity of the Unit = approx. 70 MW;
- Amount of steam produced = approx. 84 tons/hour, at a temperature of approx. 400 degrees Celsius, at a pressure of approx. 40 barrels;
- In the combined electricity and heat system – CHP – electricity (approx. 7.5 MW) is simultaneously produced which is supplied to the National Energy System and thermal energy which is supplied to the municipal heating system (approx. 36 MW);

The duration of the Unit is approx. 36 months;

Initial investment costs = approx. 150 million Euros/Unit, total revenues/year = 60 million Euros/Unit, and the recovery period of the initial investment expenses is 5 years for each Unit.

The total investment opportunity in the field in Romania is:

$$150 \text{ million Euros/ Unit} \times 16 \text{ units} = 2,400 \text{ million Euros}$$

The main results by making this aggregate investment are the following:

- It creates approx. 8000 new direct jobs and other approx. 24,000 indirect jobs, horizontally,
- Net income of approx. 320 million Euros/year, which shows the possibility of investment recovery in approx. 7.5 years,
- Increases the productivity of resources in Romania by approx. 8-10% compared to the current level (2017),
- During the recovery period of the networked investment (16 units), approx. 26 million tons of municipal waste are treated thermally, replacing the equivalent of approx. 5.3 million tons of energy coal extracted from underground with extremely harmful subsidies borne from the national public budget.

6. Conclusions

We appreciate that regarding the industrialization of mining waste and energy in the circular economy, roadmaps are needed for the introduction and development of waste management / (Roadmap to Improve Waste Management) in Romania and other interested countries.

The proposals for measures and decisions regarding the general framework for achieving the objectives of recycling and valorization of municipal waste aim to accelerate the implementation of some measures to demonstrate that the decision-makers/investors are firmly committed to the achievement of controllable values in the studied complex system.

It is necessary to assume, through an official Declaration, the "zero waste to landfill" concept, introduced in the Work Agendas of the Ministries, Territorial Administrative Authorities.

There is a need to develop, approve and disseminate to those interested and with responsibilities a Manual of Work Procedures - Framework for the Integrated Environmental Management System (SMID), with the practical description of operations and technologies for waste, deposits, from the producer to advanced energy-thermal treatment, for the generation of knowledge/knowledge in the field.

References

- [1] **Gâf-Deac I.I., et al.**, 2015
Circular economy and ethics of profit sharing - The Economic Scientific Research – Theoretical, Empirical and Practical Approaches, ESPERA 2015, Intl. Academic Publishing Group, Peter Lang, Deutsche Nationalbibliothek, <http://dnb.d-nb.de>, ISBN 978-3-631-67330-0, E-ISBN 978-3-653-06571-8, E-ISBN 978-3-631-69664, E-ISBN 978-3-631-69665-1, DOI: 10.3726/978-3-653-06571-8, <http://www.peterlang.com/index.cfm?cid=165/> Internationaler Verlag der Wissenschaften, pp. 267-274
- [2] * * *, 2017
National Waste Management Plan/ PNGD, Official Gazette of Romania, Part I, no. 11 bis, approved by GD no. 942/20.12.2017, published on January 5, 2018
- [3] **Bogatu L., Coandres C., et al.**, 2015
Legal and economic conceptualizations for differentiating between natural resources, mineral resources and reserves, Knowledge-Based Development Review – RDBC, Nr. 2/ 2015, București, ISSN 2393-2112 / ISSN-L 2393-2112, p. 102-108
- [4] **Balanay R., Halong A.**, 2016
Charting Policy Directions for Mining's Sustainability with Circular Economy, Recycling, 2016, 1(2), 219-231; <https://doi.org/10.3390/recycling1020219>
- [5] **Zhao Y., Zang L., Li. Z., Qin J.**, 2012
Discussion on the Model of Mining Circular Economy, Energy Procedia, Volume 16, pp. 438-443, 2012, DOI: <https://doi.org/10.1016/j.egypro.2012.01.071>
- [6] **Firpo B.A., Weiler J., Schneider I.A.H.**, 2021
Technosol made from coal waste as a strategy to plant growth and environmental control, Energy Geoscience, Volume 2, Issue 2, 2021, pp. 160-166, <https://doi.org/10.1016/j.engeos.2020.09.006>
- [7] **Arad V., Arad S., Apostu S., Baraiac O.**, 2012
The impact of coal mining in Jiu Valley on environment and rehabilitation of the area, International Multidisciplinary Scientific GeoConference: SGEM; Sofia, Vol. 1, Sofia: Surveying Geology & Mining Ecology Management (SGEM). (2012): 877-884.

[8] **Orlova T., et al.**, 2017

Reclamation of landfills and dumps of municipal solid waste in a energy efficient waste management system: methodology and practice, 2017, IOP Conf. Ser.: Earth Environ. Sci. 90 012110, DOI 10.1088/1755-1315/90/1/012110

[9] **Goldan T., Moraru R., et al.**, 2012

Landscape restoration of areas affected by coal processing activities in western Jiu Valley, Romania, International Multidisciplinary Scientific GeoConference: SGEM; Sofia, Vol. 1, Sofia: Surveying Geology & Mining Ecology Management (SGEM). 2012, pp. 639-643

[10] **Băbuț G.B., Moraru R.I.**, 2013

Analysis of ways to improve the legal framework for mineral resources protection and valorisation in terms of sustainable development imperatives, International Multidisciplinary Scientific GeoConference: SGEM; Sofia, Vol. 1, Sofia: Surveying Geology & Mining Ecology Management (SGEM). (2013): 243-250.

[11] **Floarea D.A., Onica I.; Marian D.P.**, 2017

Monitoring surface land deformation and analysis of data for Lupeni Mine, Annals of the University of Petrosani, Mining Engineering. 2017, Vol. 18, p. 50-60

[12] **Apostu I.-M., Lazăr M., Faur F.**, 2021

Implications of coal disappearance from the energy mix in Romania, 10th Intl. Symposium on Occupational Health and Safety (SESAM 2021), MATEC Web of Conf., 354, 00057, 2022, DOI: <https://doi.org/10.1051/mateconf/202235400057>

[13] **Lazăr M., et al.**, 2018

Conceptual model for ecological land reconstruction -case study of Rovinari mining area, Annals of the University of Petrosani, Mining Engineering. 2018, Vol. 19, p.146-157

[14] **Radu S.M., Khamis, J., Scutelnicu, I.P., Bărbulescu, A., et al.**, 2022

Smart textiles for occupational safety and health at oil stations and offshore platforms in the Black Sea, Special issues, on special topic, ISI, - August 2021, Industria Textila, Issue 1/2022, [http:// revistaindustriatextila .ro/fees.html](http://revistaindustriatextila.ro/fees.html)

[15] **Valizadeh S., et al.**, 2022

Valorization of biomass through gasification for green hydrogen generation: A comprehensive review, Bioresource Technology, Volume 365, 2022, pp.128-143, <https://doi.org/10.1016/j.biortech.2022.128143>

[16] **Rabbani M., et al.**, 2020

Municipal solid waste management considering NGO's role in consumer environmental awareness and government regulations for air pollution, Journal of Modelling in Management, 4 August 2020, 229, ISSN: 1746-5664

[17] **Roșcanu Beloiu R., Gâf-Deac I.I., Rostand M.M. Ch, Khamis J., Burian Al.A., Scutelnicu I.P.**, 2020

Super-Compact Structures of Quality Standards for Health and Security in the Sustainable Development of a Mining Basin in Romania, Impact: International Journal of Research in Engineering & Technology, ISSN(P): 2347–4599; ISSN(E): 2321–8843, Vol. 8, Issue 2, Feb. 2020, pp. 11–22



This article is an open access article distributed under the Creative Commons BY SA 4.0 license. Authors retain all copyrights and agree to the terms of the above-mentioned CC BY SA 4.0 license.