ENERGY ECO-CIRCULARITY IN ROMANIA

ECO-CIRCULARITATEA ENERGETICĂ ÎN ROMÂNIA

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Abstract: *Waste incineration technologies have evolved from simple waste disposal plants to waste-to-energy plants with the introduction of new emission control technologies. The total amount of waste in Romania is approximately 6.5-7 million t/year, and it is considered feasible that approximately 50% of the total be subjected to advanced energy-thermal treatment. On this basis, it is proposed to resort to advanced energy-thermal treatment of waste with the help of new technologies, from the sphere of innovative eco-technologies for the production of "urban energy". Through the valorization of energy-potential waste, it is possible to generate electricity and thermal energy on a national level in the equivalent of extracted energy coal, but replaced as such with waste from this "national urban mine". The present work is a Synthesis Report with takeovers, adaptations, updates from Ciuclea, I.-I. - Basics of the Circular Economy. Circular ecotechnologies for raw materials in urban energy infrastructures, Ed. M. Of., 2017, to which I. Georgescu-Ciuclea also contributed in the context of debates for contributions to solving the energy crisis. Waste can contribute to the actual group of "energy raw materials", replacing, occupying the dimensional and qualitative place of some classic non-renewable resources (fossil fuels, hydrocarbons, etc.).*

Keywords: energy from waste, energy eco-circularity, advanced energy-thermal treatment

Rezumat: *Tehnologiile de ardere a deşeurilor s-au dezvoltat de la instalaţiile simple de eliminare a deşeurilor la instalaţii de obţinere a energiei din deşeuri, cu introducerea de noi tehnologii de control al emisiilor. Cantitatea totală de deșeuri din România este de cca 6,5-7 milioane t/an, și se consideră că este fezabil ca aproximativ 50% din total să fie supusă tratării energo-termice avansate. Pe aceasta bază se propune recurgerea la Tratarea energo-termică avansată a deșeurilor cu ajutorul unor tehnologii noi, din sfera eco-tehnologiilor inovative pentru producere de "energie urbană". Prin valorificarea deșeurilor cu potențial energetic este posibilă realizarea pe plan național a energiei electrice și termice, în echivalent de huilă energetică extrasă, însă înlocuită ca atare cu deșeuri din această "mină urbană națională". Lucrarea de față este un Raport-Sinteză cu preluări, adaptări, actualizări din Ciuclea, I.-I. - Bazele Economiei Circulare. Ecotehnologii circulare pentru materii prime în infrastructuri energetice urbane, Ed. M. Of., 2017, în contextul dezbaterilor pentru contribuții la soluționarea*

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crizei energetice. Deșeurile pot fi contributive la constituirea grupei propriu-zise de „materii prime energetice”, înlocuind, ocupând locul dimensional și calitativ al unor resurse clasice neregenerabile (combustibili fosili, hidrocarburi etc.).

Cuvinte cheie: energie din deșeuri, eco-circularitate energetică, tratare energo-termică avansată

1. Introduction

Looking at the past, in the 19th century, waste was stored randomly, being a source of epidemics, and spontaneous combustion affected areas of human communities. The first waste incineration unit is registered in Nottingham in Great Britain (1874), and in 1903 in Frederiksberg, in Denmark, the first industrial waste recycling unit was put into operation, and energy was obtained. Towards the 1950s, due to the increase in the frequency of fires in landfills, the construction of specialized waste-to-energy units intensified in Munich, Zurich, Paris, Rotterdam, Sao Paolo, etc. In the 1960s, cases of corrosion and dangerous contamination caused by waste were identified, and by the 1970s, the energy crisis (peaking in 1973) and air pollution brought the issue of the construction of complex steam and electricity plants from waste to the fore. [3]

In Romania, since 2016, there is official consensus that the implementation of the Circular Economy Package issued by the European Commission will strengthen economic growth, stimulate global competitiveness and create new jobs, at the same time contributing to closing the circuit in the life cycle of products, bringing benefits to both the environment and the economy. [21] However, at the level of 2023, Romania does not consistently apply the circular economy.

The circular economy, used as a notion for a restorative industrial economy, is based on the fact that worldwide waste production by 2050 could reach 27 billion tons, and in Romania 8-10 million tons. In 2022, the total waste generated in the EU by all economic activities and households amounted to 2.803 billion tonnes. [5]

The total amount of waste generated is related, to a certain extent, to the size of the population and the economic size of a country. The smallest EU Member States generally reported the lowest levels of waste generation and the largest the highest levels. However, in comparable terms, relatively large amounts of waste were generated in Romania (approx. 6-7.5 million tons).

Currently, in Bucharest, at the Sectoral level and in the Bucharest-Ilfov Development Region, in the Territorial Administrative Units (UTAs) in the country, there is no sufficient and adequate infrastructure for taking over waste collected separately and even more mixed to be subjected, further, to the technological processes of sorting-processing for valorization, including for obtaining energy (electrical, thermal).

However, after going through all the stages and phases from collection, pre-sorting, sorting and transfer to valorization, including recycling, it is expected that the remaining fraction (ultimate refuse) of waste will be destined for burning in Integrated Advanced Energy-Thermal Treatment Complexes for obtaining electricity and/or thermal energy. Since the total amount of waste in Romania is about 6.5-7 million t/year, it is feasible that about 50% of the total is subjected to advanced energy-thermal treatment.

In Romania, the average calorific value of waste is 615 - 700 kcal/kg, respectively the result in energy is 0.71 - 0.81 kwh. In fact, 4.94 tons of municipal waste with energy product potential is the equivalent of 1 ton of energy coal, extracted from the underground with complex, complicated mining technologies, subsidized from the public budget, extremely dangerous and affecting the environment in the long term, with anthropogenic consequences over the duration of a biological cycle. [3]

On this basis, it is proposed to resort to advanced energy-thermal treatment of waste with the help of new technologies, from the sphere of innovative eco-technologies for the production of "urban energy". Through the valorization of energy-potential waste, it is possible to generate electricity and thermal energy on a national level, in the equivalent of 800 thousand - 1 million equivalent tons of energy coal, originating as such from this "national urban mine".

2. Waste management for energy - requirement for environmental sustainability

It is *energy* that almost completely crosses the sphere of ecological connections in society. (*fig. 1*)

In the whole of Romania, up to now (2023) the total amount of 1.208billion Euros has been spent on an overall of Integrated Waste Management Systems (SMIDs) / Integrated Waste Management Centers (CMIDs) almost bankrupt, registering the state of infrastructural degradation and lack of real, effective operational capacities for commitment to the Circular Economy. In the context, it is noted that to complete and remedy the infrastructural situation of the SMIDs/CMIDs in Romania, another 1.5-1.6 billion Euros are needed.

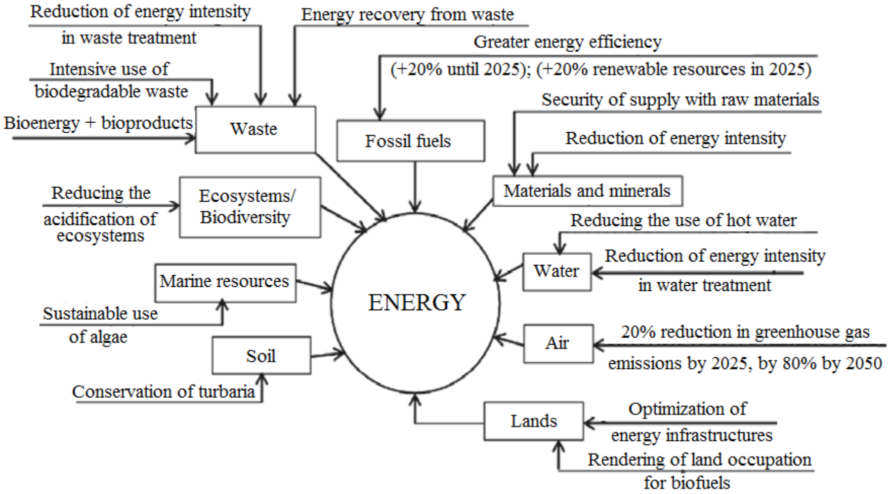

Figure 1. Energy use in a greening context in Romania and globally

The accelerated increase in the volume and the change in the characteristics of municipal waste are taking place, in the global trend and correlation, between: 1) urbanization, 2) waste generation and 3) the scarcity of resources in the economy, with reflection in the Gross Domestic Product in each country, including Romania. [6]

The transformation of waste into resources, respectively into raw materials in urban energy infrastructures, can take place against the background of the situation that shows that every year in the EU 2.7 billion tons of waste appear - of which 98 million tons are classified as hazardous waste. On average, only 40% of the total volume of solid waste is recycled or goes into processing/reprocessing, the rest ending up in final waste dumps. [3]

On the other hand, improving the insulation of buildings leads to improving the efficiency of energy use. Improving the construction and economic use of buildings in the EU can support approx. 42% of final energy consumption in the field, reducing total greenhouse gas emissions by 35%.

3. Recourse to "open, flexible, quasi-temporary standards" in the field of energy

It is estimated that in the long term society will be able to survive on the basis of tangible, physical, renewable energy resources in sufficient proportion to intangible resources (knowledge, which becomes dominant). Basically, with regard to energy, there are orientations towards situations with almost unlimited potential (nuclear energy, including fusion, renewable energy).

Fossil fuels are non-renewable resources used as energy sources, but they are considered to be significantly unsuitable to power a global civilization for more than a century if current consumption growth continues. For example, in Romania, the case study related to the exploitation and underground valorization of coal from the Valea Jiului coal basin shows the decrease in importance of caustobiolytic fossil fuels. [7]

The best strategic formula for harmonious economic development must ensure sufficient flexibility in the use of different primary energy sources, so that the scarcity of some resources does not lead to crisis situations. Even if renewable resources (solar energy, wind energy, etc.) seem quasi-infinite in abundance, they must come under indicator incidence (that is, be measured), in order to remove the uncertainties caused by their *quantitative and qualitative ignorance*. [9]

Basically, the need for generalized indicator systems stems from the obligation to organize and lead any kind of activity, action, approach, etc., to sustain personal and collective progress in the given, objective natural environment. By extension, we advance the thesis that action standards in the field of energy are useful, but on time-defined, cyclical intervals, because closing/locking in "action rules" can be appreciated as "managerial excess". The proposal, in the face of the appearance of the above contradiction, is to *resort to "open, flexible, quasi-temporary standards*". [7]

At the same time, it is expected that general and particular technical-scientific progress - related to the exploitation and valorization of energy resources - will ensure the reduction of sub-flows of residues/waste accompanying the general, global material flow. The eco-technological advance can determine *the tempering of the materials and energy market,* in the situation where their world prices are influenced by the production conditions (geological research, prospecting, underground or open mining, preparation of useful mineral substances), which are now perfected, becoming more absorbent (inclusive) for waste/residue. [2]

As early as 1976, a Research Report titled *Hannah Reekman*, [18] was completed for the European Commission of that time. The report specifies the objective called The Potential for Substituting Manpower for Energy. The authors, Walter Stahel and Genevieve Reday, in another Report with the same title (1977, to EC Brussels) [18] conceived an economic loop / an economic circular flow, emphasizing its effect on economic competitiveness, saving energy resources and preventing waste, closely related to the creation of new jobs. It was, in fact, one of the first credible, significantly substantiated signals aimed at sustainability and the promotion of sustainable energy in any type of economy.

In the modern economy, there are reasons for concern regarding the continuous exponential growth of energy and material consumption in all countries, with predilection in developed ones. The realistic assessment would be that one must insist on the means of reducing the rate of material growth, by improving the social and technological efficiency of production and resorting to the use of knowledge for the resizing of tangible, physical, material assets that are not high energy consumers. Continued research and development and the maintenance and adequate supply of energy complement the use of physical, concrete resources currently known. Contextually, it proves necessary to apply different methods of avoiding waste and conservation, which is sustainable for energy. [1]

4. Conceptualizing and reconceptualizing waste in energy

The essential finding for the last quarter of a century is that society's tendency to waste materials, resources, energy, etc. registers a relative awareness in relation to past historical periods. The increase in energy prices along with the visible deterioration of the environment are the basis of the reconceptualization, the rethinking of the way of action in the face of waste. The problem of energy waste is implicit, intrinsic to general human activity. Waste is a behavioral fact, also concretely reflected in the field of energy, in energy resources as such. [10]

Some ways of reducing or avoiding waste are known, practiced, applied for a long time, from one stage to another. Other ways could be identified from the discovery of directions in which research and development contribute to the improvement of technologies (introducing eco-technologies), or when progress is made in terms of circularity induced in tangible assets. [4], [15]

Knowing that energy waste affects competitiveness, the thesis is advanced that in the context of combating energy losses, any consumer must be examined in the field of competition of the industrial economy entering the era of global confrontations. The competition and motivation of commitment in scientific research in the service of eliminating or avoiding energy waste require eco-technological operationalizations in the consumption process. It is observed that in this framework the orderly composition of productive procedural legalities takes place with the transformations and self-regulations that ensure the birth and permanent direction of systems towards eco-systems and eco-technologies.

At the same time, in the general eco-technological management of production and waste for energy, the problem of waste (its reduction or avoidance) comes under the most radical decision-making incidence in consumer entities (institution, company, organization, association, etc.).

Raw materials and energy infrastructures must be provided quantitatively and qualitatively, but the dimensioning of the supply is also dependent on the size of the demand for electricity. Waste can contribute to the actual group of "energy raw materials", replacing, occupying the dimensional and qualitative place of some classic non-renewable resources (fossil fuels, hydrocarbons, etc.). Contextually, energy demand indirectly contributes to the establishment of energy raw material supply levels. Typically, the increase in energy demand should be less and less, relying on increasing efficiency of energy use or saving.

5. Energy recycling of municipal waste

In Romania, only 10-11% of municipal waste is recycled, the rest being stored in landfills, in warehouses assessed as non-compliant, which will have to be closed by 2025, according to the provisions agreed upon by the European legislative authorities (through directives). [13], [19] The main waste recovery operations are composting, co-incineration, incineration, biogas production and biofuel production. [17]

In comparable terms and by way of example, in Germany waste is recycled 47% or incinerated 35%, or composted 18%. [8]

We note that it is necessary to elucidate the correlations between the macrosystem represented by the urban energy environment and the systems with which they interact: 1) *Environment-Recycling-Energy* (ERE) System, 2) *Ecological* System (ECO), 3) *Recycling-Revalorification* System (REC) - REV). In fact, these correlations become conceptual support for Sustainable Development (DD) and Total Quality (TC). [16]

The urban energy environment is a macrosystem mainly characterized by systems and subsystems such as:

– *Energy Technology Process* (ETP), analyzed, defined by technological parameters and applied technological procedures;

– *Environment–Recycling–Energy* (ERE), which expresses the transformations of energy sources and resources necessary for the technological processes of ensuring municipal societal life;

– *The Ecological* system/subsystem (ECO), which reflects the ecological processing of the polluting outputs from the PTE and ERE systems;

– *Recycling–Revalorification* (REC–REV), which refers to the energy and material transformations that take place within the technological flows in the municipal societal area and includes (*fig. 2*), the subsystem of energy recycling (revalorization) (RE), respectively of materials (RM).

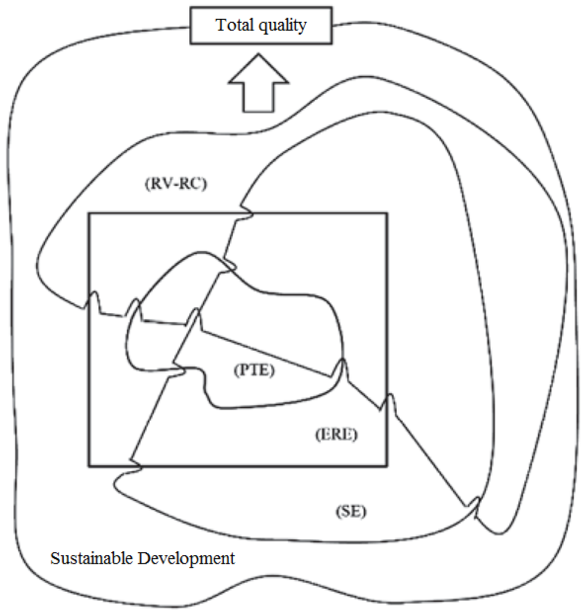

Figure 2 – Developments in the field of energy towards sustainable development (example for the municipal area of Bucharest relying on the recycling-energy recovery of waste) [3]:
(PTE) = the municipal Energy Technological Process system/subsystem;
(ERE) = the Environment–Recycling–Energy system/subsystem in the municipal area;
(SE) = the Municipal Ecological system/subsystem;
(RV–RC) = systems/subsystems Revalorization-Recycling.

The search for environmental protection options can be carried out within the production/energy production system itself, controlling production and overproduction on certain alignments with certain components of energy raw materials regulated quantitatively and qualitatively. For example, the effects of surface/surface mining of coal (usually lignite/brown coal) are associated with the effects of mining in the ecosystem or at great depth.

The energetic order refers to the exploitation and, further, to the production of energy, but this complex and extremely physically structured system is difficult to be organized and managed based on natural laws as long as the subjective laws of human intervention are registered. [14]

The ecological dangers of current energy technologies are of such a level that accelerating the development of other technologies is proving a priority.

Contemporary civilization cannot depend unequivocally only on a single source of energy. It is recognized, for example, that the energy produced by fission has medium or even long-term potential for the energy supply of human society, in procedural articulation with the energy obtained from fossil fuels.

However, the advance of nuclear fusion research would prove to be of interest. Some research approaches have been implemented in controlled fusion: 1) magnetic confinement (spatial confinement) and 2) inertial confinement in microexplosions induced by lasers or electron beams.

Since the last quarter of the last century, - *Chemtech*, April 1974, p. 231, [11] - scenarios have been imagined for the advanced, non-hazardous exploitation of fossil fuels. (*Table 1*)

Table 1. **Scenarios for the safe exploitation of fossil fuels, [11]**

Solid **materials**	***Liquid*** **matter**	***Gaseous*** **matter**	***Energy***
a_1) Underground exploitation, fully automated; remote controlled.	b_1) Distillation of coal underground (Underground pyrolysis).	c_1) Partial oxidation of coal in combustible gases ($CO+H_2$) (Underground gasification).	d_1) Total underground combustion for the production of steam at high pressure (Geothermal equivalent).
a_2) Cracking the coal seams and bringing the crushed coal to the surface by hydromonitoring – hydraulic mining.	b_2) Dissolving coal in a solvent and bringing the solution to the surface (Frasch process)	c_2) Hydrogenation of coal to methane (Underground hydrogasification)	
a_3) Carbon production without residues by combining underground gasification with CO_2+O_2 with an installation where the CO produced underground is decomposed into CO and C.			

Contextually, the technologies of: 1) underground gasification, 2) automatic extraction and 3) hydraulic extraction appear. However, the ecological impact of the gasification of solid fossil fuels on the energy supply is still relatively low. The production of a *substitute natural gas* (SNG) by catalytic methanation is joined to the classical hydrogasification. To make synthetic fuels from coal, efforts are focused on obtaining pipeline transportable high-calorific gas, low-calorific sulphide-free gas for power plant fuel, and synthetic petroleum.

The main attempt in the field should be focused on the idea of transforming the quality of a given amount of energy from an economically feasible form into a form without value (consumption), without losses.

However, there is the situation of energy losses on different types of substructures for its production. For example, in the requirements for the production of electricity/thermal energy, etc. the structure of average losses still shows the distance from the idea and practice of "zero losses". [12]

In economic and engineering science today (2023), the concept of introducing/assuming zero growth in energy (energy consumption) is being studied, more and more significantly, even if there is economic growth. (*fig. 3*).

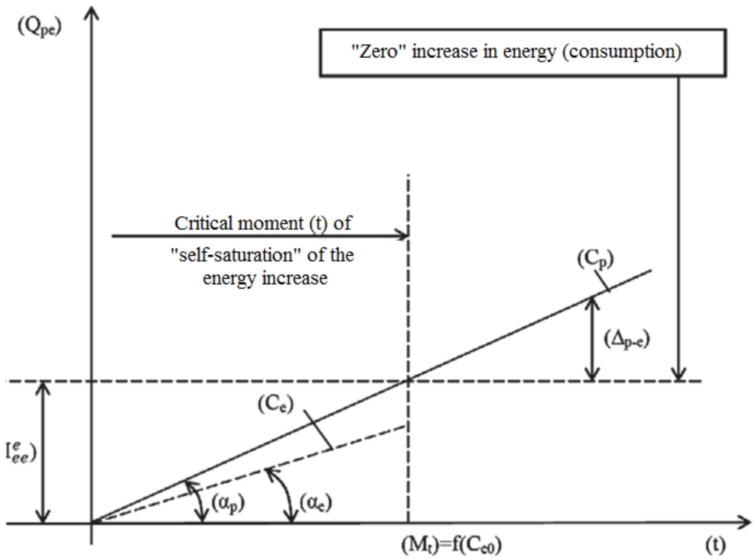

Figure 3 – The concept for the introduction of zero energy growth (energy consumption) [3]:
(M_t) = f(C_{eo}) = the positive critical moment of the start of "zero growth" of energy consumption (C_{eo}); (Δ_{p-e}) = gap between the directions of growth "production - energy consumption"; (C_p) = production increase; (C_e) = increase in energy consumption;
(I^e_{ee})= evolutionary interval of exponential growth of energy consumption;
(Q_{pe}) = quantities "production - energy/consumption"; (t) = time; α_p; α_e = growth angles (production – energy) ($\alpha_p \rightarrow$ max); ($\alpha_e \rightarrow$ min);

In other words, production growth (C_p) could always tend to be greater than energy consumption growth (C_e), the latter probably (theoretically) remaining constant (zero growth):

$$\begin{cases} (M_t) = f(C_{eo})\,|^{(t)} \\ \{\alpha_e < \alpha_p\} \longrightarrow [\{f(C_e)\} > \{f(C_p)\}] = (\Delta_{p\text{-}e}) \end{cases} \tag{1}$$

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The above relationships could be operationally possible if there were accelerated (or continuous) readjustments in the use of different types of solid fossil fuels to obtain electricity.

If the exhaustion of solid fossil fuels is more predictable (their volume explored, prospected, researched being more measurable, "more physical"), in the case of liquid and gaseous hydrocarbons, the problem becomes more complex. The more complicated situation in the mentioned sub-field comes from the generic difficulties and losses recorded, for example, in the exploitation of natural gas. In the face of such problematic situations, we appreciate that it is necessary to position any investment goal of energy weighting in a feasible joint work plan.

6. Conclusions

The transition to the circular economy is an opportunity to overturn economic blockages, as it is possible to establish the dominance of eco-technologies, which support the circularities that include the waste from which to obtain energy.

Ecosystems recycle any type of waste, so no resource is left unused.

The energy-thermo-advanced recovery of waste is proposed as a work option in the field of waste in Romania, given that the mentality, awareness and practical, effective realization of a real separate collection does not have the appropriate speed, does not immediately respond to the European requirements in the field, landfill storage is still operational, disapproved by the EU regulations on sustainable environment in Romania.

Against this background, the construction and operation of additional capacities for advanced energy-thermal treatment of waste in the Municipality of Bucharest and in each Development Region represents a realistic solution.

Waste represents a base of secondary resources, renewable sources of energy. Energy recovery (energy recovery) from waste incineration is proven to be current.

Waste incineration technologies have evolved from *simple waste disposal plants* to waste-to-energy plants with the introduction of new emission control technologies.

Obtaining energy from waste (*Waste to Energy* - WtE) leads to obtaining heat and electricity. A method of energy recovery of waste is *co-incineration* (burning of waste with the aim of generating energy or some material products).

The energy balance in the CHP cogeneration system (thermal and electric) shows that by supplying 30t/h of waste, after processing, 7.5 MW of electricity distributed in the network and 30 MW distributed in heating, through centralized heating, can be obtained.

The proposed scheme for energy recovery in the Integrated Complex highlights that superheated steam (40 bar/ 400^0 C) reaching the condensing turbine is transformed into low-pressure steam, in the conditions where a generator produces electricity distributed for own consumption and found in the Energy System National. [20]

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

The total investment opportunity in the field in Romania is: 150 million Euros/ Complex x 8 units = 1,200 million Euros. In fact, this is how a National Project of essential importance in the efficient, sustainable and competitive development of Romania is advanced.

In summary, the main results by making such an aggregated investment are the following:

– It creates approx. 4,000 new direct jobs and other approx. 12,000 indirect jobs, horizontally,

– Net income of approx. 160 million Euros/year, which shows the possibility of investment recovery in about 4 years,

– Increases the productivity of resources in Romania by approx. 8–10% compared to the current level (2023),

– During the recovery period of the networked investment (8 units), approx. 13 million tons of municipal waste, replacing the equivalent of approx. 3 million tons of energy coal extracted from underground with extremely harmful subsidies borne from the national public budget,

– the obligations/ targets of local communities and Romania's international responsibilities in the EU regarding waste management/ management are fulfilled;

– economic reconversion is ensured and clean, competitive technologies are promoted;

– an economic revitalization of the areas where the investment is made is ensured, knowledge and innovation are promoted through the Circular Economy,

– Romania is becoming a clean country, – a European and global example, fully complying with EU requirements in the field.

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