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Resource Potential of Waste Usage as a Component of Environmental and Energy Safety of the State

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Abstract:

The article is devoted to the study of the resource potential of the use of waste as a component of the environmental and energy security of the state. The problem of handling solid waste is the most urgent component of ensuring national security for Ukraine, since the volumes of accumulated waste are considered as one of the factors of the progressive environmental crisis. The sphere of secondary use of resources in Ukraine is at the stage of active formation. Due to insufficient consideration of the value of secondary resource potential, lack of awareness and lack of proper marketing, underestimation of social (for example, creation of additional jobs) and environmental factors, and also due to mismanagement, a significant part of the waste that can be used as material and energy resources is lost. The purpose of the article is to assess the potential of waste use in order to form the state's environmental and energy security. The readiness of the citizens of Ukraine for separate collection of household waste was analyzed. The number of landfills and their area in Ukraine were determined. Technologies for the processing of municipal solid waste were characterized. The benefits of sorting and recycling solid waste were analyzed. The hierarchy of waste management priorities in the EU was built. The cost of processing recyclable materials was analyzed. An analytical assessment of the resource potential of production and consumption waste was made. Priority areas for their use have been identified. A comparative analysis of inertial and innovative scenarios for the development of the field of waste management in Ukraine for the period up to 2025 was carried out. Estimated amount of biogas that can be obtained from the annual volume of buried solid household waste was determined. SWOT analysis of implementation of the project for collecting and utilizing biogas of solid waste dumps was carried out. Proposals for improvement of the waste management structure at the state level were presented.

Keywords: resource potential; waste; environmental safety; energy security.

JEL Classification: O13; Q57; Q58.

Introduction

The problem of waste is complex and multifaceted both in Ukraine and in the whole world. The issue of waste accumulation and recycling combines environmental, resource and energy aspects, since waste is not only polluting the environment, but also carriers of useful components. The solution to the problem of efficient waste management is often hampered by the lack of public and commercial interests. Therefore, this problem requires separate regulation and organizational and economic provision.

Today, Ukraine is the leader in Europe in terms of waste. Indicators of the formation and accumulation of wastes in Ukraine indicate a threatening environmental situation in the country. According to the Ministry of Ecology and Natural Resources of Ukraine, about 35-36 billion tons of waste is deposited in our state, which occupy 7% of the territory.

In Ukraine, the ratio between processed and collected waste is approximately 54.8%. Of the total amount of waste collected in the EU 97.9% is processed. In the EU, this figure ranges from 59.5% in Slovenia to 100.9% in Belgium (an indicator above 100% is due to the processing of waste from other EU countries on the territory of the country). There is currently a discrepancy between progressive accumulation of waste and methods aimed at preventing their formation, disposal, disposal and use as energy. Today, the statement "waste is a problem, not resources" completely changed its essence, because waste today – this is primarily a commodity and resource, and therefore – it's money. An irrational and careless attitude towards waste creates a major problem in many countries, including Ukraine. Thus, the analysis of the resource potential of waste management as a component of the country's ecological and energy security is in line with the objectives of sustainable development and the construction of an environmentally friendly economy.

1. Literature Review

A significant number of researchers have dedicated their work to the problems of efficient use and management of waste.

Ishchenko, V.A. and P.M. Turchyk (2012) considered existing methods of handling solid household waste used in developed countries in view of the possibilities and peculiarities of their use in Ukraine. Scientists have suggested ways to improve the system of solid household waste management in Ukraine.

Pohribnyi I. Ya. (2013) investigated the problems of solid household waste management and gave an overview of the main provisions of individual regional waste management strategies in terms of compliance with the principles on which the integrated waste management system should be based.

Park J. Y. and Chertow M. R. (2014) give contemporary ideas promoting the importance of managing wastes as resources such as closed-loop or circular material economies, and sustainable materials management by reinforcing the notion of a resource-based paradigm rather than a waste-based one.

Kharchenko T. B. and Sahaidak Yu. A. (2014) investigated the peculiarities of processing and utilization of solid domestic waste in Ukraine. The authors described the main methods of recycling waste, their advantages and disadvantages.

Skrypnyk A. V. and Mikhno I. S. (2015) analyzed the state, problems and ways of waste utilization in Ukraine and the world, and examined the state's impact on this problem and tax mechanisms in different countries.

Arafat H. A. *et al.* (2015) investigates the environmental impacts for five municipal solid waste (MSW) treatment processes with energy recovery potential (incineration, gasification, anaerobic digestion, bio-landfills, and composting). In addition to environmental impacts quantification, the energy production potentials for the five processes were compared to provide a thorough assessment. Safranov T. A. *et al.* (2017) substantiated the structure of the cluster in the field of solid household waste management for certain regions of Ukraine.

Moya D. *et al.* (2017) assess the different waste-to-energy technologies developed to date. Also they studied integrated solid waste management systems with waste-to-energy technologies and provided some worldwide examples.

Scarlat, N., Fahl, F. and Dallemand, J. F. (2018) provide an overview of waste generation and treatment operations in the European Union (EU) and other European countries and an analysis of the possibilities for the use of municipal solid waste (MSW) for energy production. Zulauf *et al.* (2018) assess the potential of producing biofuels from agricultural crops and residues in Ukraine. Castillo-Giménez, J., Montañés, A., and Picazo-Tadeo, A. J. (2019) assess performance and convergence in the treatment of municipal waste by the members of the European Union-27 (EU-27) during the period 1995–2016.

The paper is a logical continuation of the authors' research (2019) into the use of waste as a valuable resource for the needs of the economy.

The purpose of this paper is to determine the advantages of sorting and recycling of solid household waste (1); conduct analysis of the attitude of Ukrainian citizens towards raising tariffs for collection and removal of solid waste for the introduction of European experience of effective waste treatment (2); conduct a comparative analysis of inertial and innovative scenarios for the development of efficient waste management in Ukraine (3); calculate the volume of biogas that can be obtained from the annual amount of buried solid waste (4); conduct SWOT analysis of implementation of the project for collecting and utilizing biogas in landfill sites (5).

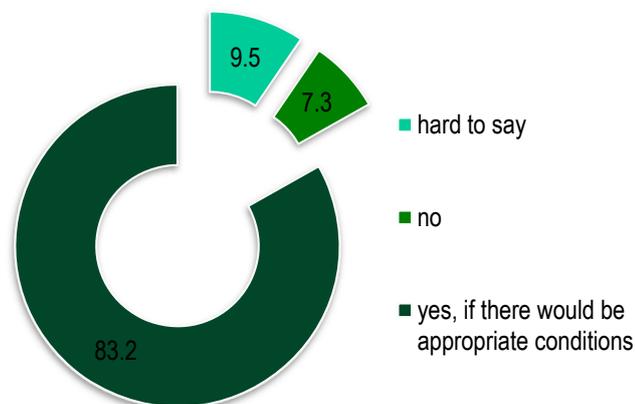
2. Methodology

When formulating separate theoretical positions in the process of performing the set scientific tasks, general scientific methods were used such as: dialectical, scientific abstraction; morphological analysis, generalization, analysis of hierarchies. Economic, mathematical, statistical and economic methods were used in the development of regulations for the treatment of solid waste with the producing valuable secondary resources and energy. For clarity of digital information, tabular and graphical methods were used. The use of the survey method allowed forming an idea of the readiness of the citizens of Ukraine for separate collection of household waste and the willingness to pay more for the removal of solid waste for the purpose of their effective disposal in accordance with European standards. The method of strategic analysis was used in the analysis of inertial and innovative scenarios for the development of the field of waste management in Ukraine. SWOT-analysis of the implementation of biogas collection and utilization projects from landfill solid waste was carried out for the analysis of the energy use of solid waste.

3. Case studies/experiments/ demonstrations/ application functionality

Historically, in Ukraine, in the past, the state represented by the city authorities was engaged in the disposal of solid household waste. Today, a significant amount of household waste is collected and recycled next to the city utilities and private enterprises. However, in this field of activity there are a number of problems of a different nature, starting with the environmental consciousness of citizens (Figure 1) and ending with imperfect legislation in the field of waste management, which today has only a declarative character.

Figure 1. Readiness of Ukrainian citizens to separate collection of household wastes,%



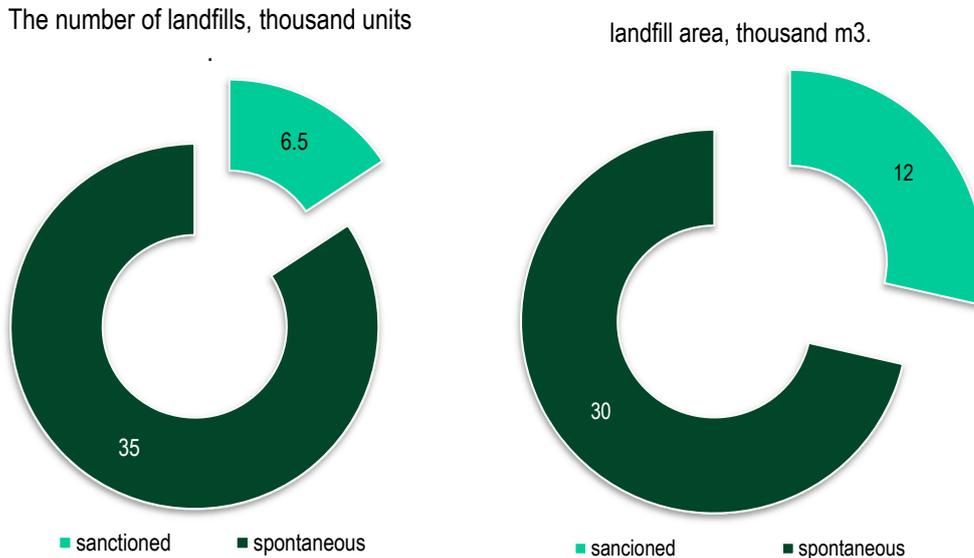
Source: the results of the survey, conducted by the authors

The removal of solid waste in landfills should be considered as a forced, temporary solution to a problem, which in principle is contrary to environmental and resource requirements. Since dumps are located near the cities, and infinitely the area of export of solid waste cannot increase, for all countries the problem of industrial processing of solid waste is a pressing issue.

Today, on the territory of Ukraine, there are 6,500 licensed landfills with a total area of 12 thousand square meters and 35 thousand natural garbage dumps with an area of 30 thousand square meters (Figure 2). With the EU norm, there are no more than 500 polygons per country, for Ukraine, these norms are simply unrealistic in the near term.

The introduction of separate garbage collection will help to increase the amount of secondary feedstock and load domestic processing enterprises. This will reduce the load on landfills by 30% and increase the volume of secondary feedstock by 20%.

Figure 2. The number of landfills and their area in Ukraine



Source: formed by the authors on the basis of the State Statistics Committee of Ukraine

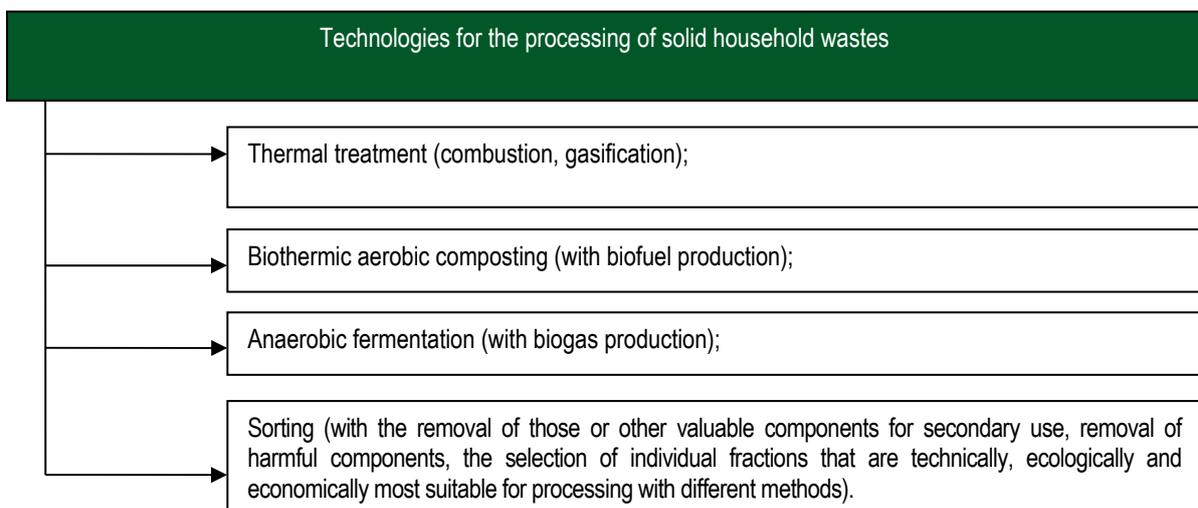
According to REMONDIS, the volume of solid household waste suitable for secondary use in Ukraine is at least 700 thousand tons per year. However, low tariffs for waste disposal and the insignificant cost of recycled materials do not contribute to investments in this industry.

It should be noted that Ukraine is importing solid waste from Poland, Slovenia, Czech Republic, Austria and Belarus. In particular, in 2017, Ukraine imported more than 400,000 tons of recycled materials, worth more than USD 853 million. In particular, waste paper was purchased for 70 million US dollars, secondary polymeric materials – for 14.4 million US dollars and broken glass for almost \$ 850,000 US dollars.

In terms of value, the market for solid domestic waste in developing countries is estimated at about \$ 120 billion. Most important are the US markets (46.5 billion dollars), EU countries with Norway and Switzerland (about 36 billion dollars) and Japan (about 30.5 billion dollars).

Industrial processing takes into account the requirements of ecology, resource saving and economy, is the cardinal way of solving the problem of accumulation of solid waste. The main technologies widely used for processing solid household waste are shown in Figure 3

Figure 3. Technologies for the processing of solid household wastes



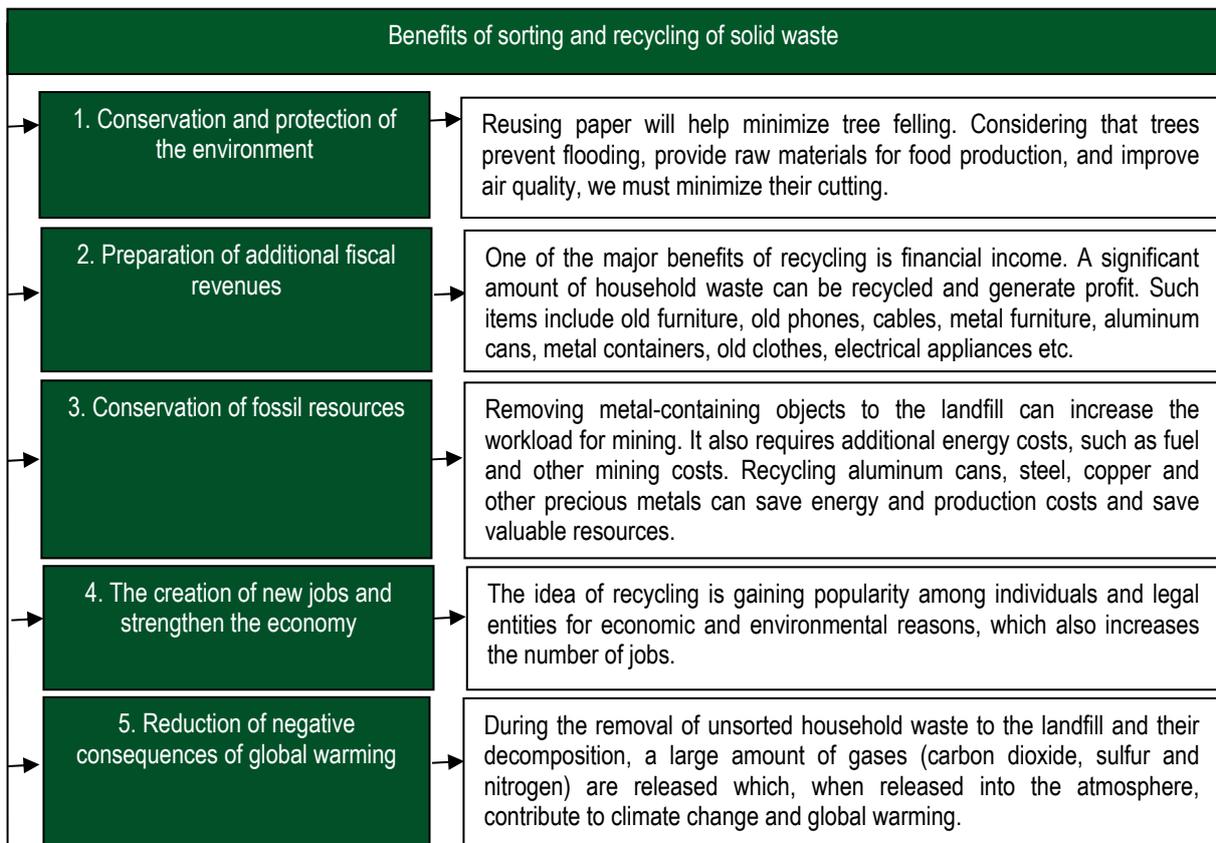
Source: formed by the authors

The following facts show the benefits of recycling solid waste:

- due to the relative simplicity of the technological processes, the paper is a favorable fraction of waste for processing. Waste paper is recycled into newspaper and toilet paper, cloth, cardboard, etc.;
- due to the special treatment of used tires, the secondary materials are then used to make floor mats, carpets, the soles of the shoes, the covering of tennis courts and in the construction of roads;
- leaves from the trees, which in Ukraine is often burned or simply taken to landfills is an excellent fertilizer for the soil;
- processed raw materials from glass can be used for manufacturing bricks, tiles, water filters, ceramics and others. The fact that in case of burial it does not decompose, and the secondary glass does not differ in quality from the original, is evidence in favor of glass processing;
- melted nonferrous metal can be subjected to multiple processing, without losing its properties. When using scrap metal as a raw material, an average of 95% less energy is consumed than in the production of a new metal;
- plastic consumption increases annually by 5-8%, so the issue of recycling is very urgent, because the polymer is derived from oil. In addition, for large corporations such as Coca-Cola, Nestle, AEG, and others, it is advantageous to use recyclables, as this reduces production costs and reduces the cost of final products.

The lack of necessary funds in budgets of all levels, an unattractive business climate in Ukraine for investors, political instability, inactivity of some local authorities and the population, as well as disputes over land issues at the local level contribute to the opening of new landfills in Ukraine instead of introducing modern solid household management waste systems and the creation of facilities for their recycling and disposal. At the same time, as opposed to the use of landfills, more effective approaches to waste management that have a number of socio-economic and environmental benefits should be applied. The positive aspects of effective management of solid waste management are shown in Figure 4.

Figure 4. Advantages of sorting and recycling of municipal solid waste



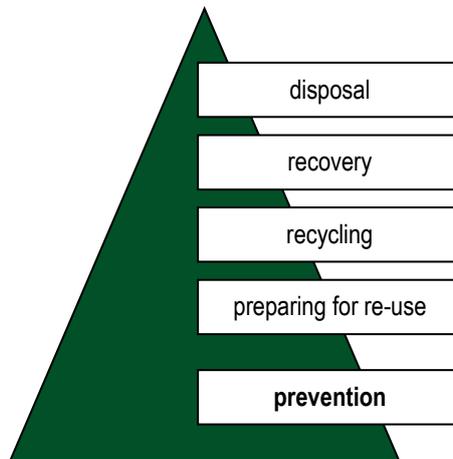
Source: formed by the authors

The main problems faced by waste management organizations are: the size of the costs of collecting, sorting, recycling waste and the subsequent distribution of secondary raw materials for various purposes; the

percentage of contributions from manufacturers of products and other organizations; inconsistency between waste treatment volumes and available processing facilities.

Ukraine has a National Waste Management Strategy until 2030, based on the expanded responsibility of producers that was created on the basis of the "European priorities" for waste management (Figure 5).

Figure. 5 Hierarchy of waste management priorities in the EU

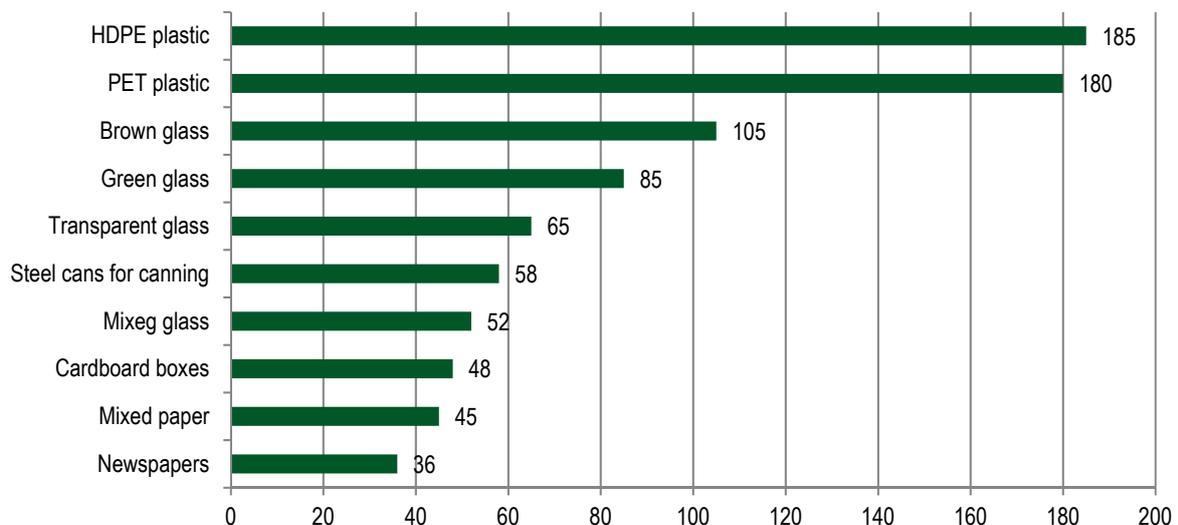


Source: European Commission, 2016

The strategy stipulates that local governments, local state administrations should create regional waste management facilities. The Law of Ukraine "On Housing and Communal Services", which entered into force in June 2018, introduced incentives for the population to separate sorting by non-payment for separately collected waste. The Law "On Waste" from January 1, 2018, not only obliged all citizens to sort garbage, but also imposed a fine for the failure to comply. However, it is not yet possible to follow requirements of this law, due to the difficulties of providing residential buildings with containers for separate garbage collection, availability of the processing facilities etc.

The main obstacle to the development of the secondary resources market (the market for household waste) is the lack of high-tech waste processing plants and their high cost, which is caused by the difficulty of separating the components of secondary raw materials from the rest of the solid household waste with the subsequent division into secondary materials (Figure 6). Therefore, the need to create cost-effective solid waste recycling technologies to obtain the end-product that is useful to society requires a rapid solution.

Figure 6. The cost of secondary waste recycling, USD / ton



Source: adapted by authors on the basis of Zavgorodnia, N.I., Shvovarov, O.A. (2013)

Now the cost of a modern incinerator is estimated at 150,000,000 euros, and the plant for the mechanical-biological recycling of waste - at 50-60 million euros. However, the effectiveness of this type of activity can be subject to payment of the territorial communities Information on special local rates and charges. In the course of the study, we found that the attitude of the citizens of Ukraine to raising tariffs for the collection and removal of solid household waste for the introduction of the European experience in the effective handling of them was the following (Figure 7).

Figure 7. Attitude of the Ukrainian citizens to raising tariffs for the collection and removal of solid household waste, %



Source: the results of the survey, conducted by the authors

Effective waste management is a national issue, and all stakeholders should cooperate in this direction. Due to the general integrated approach, in the future it will be possible to solve the problem of the accumulation and processing of solid household waste. In our opinion, in Ukraine, following the example of the leading countries, the cost of all types of goods should include such item of expenditure as “recycling and disposal costs”. The consumer will not notice a slight price increase, however, funds for recycling of garbage will already be included in the cost of goods that consumers will buy.

Successful implementation of effective waste management requires the development of strategic directions at the state level. A comparative analysis of the inertia and innovation scenarios for the development of the solid waste management industry in Ukraine for the period up to 2025 prepared by the International Finance Corporation is given in Table 1.

Table 1. Comparative analysis of inertial and innovative scenarios for the development of solid waste management in Ukraine for the period up to 2025 [+ -]

Measures	Inertia scenario, billion euros	Innovative scenario, billion euros
Modernization of solid waste collection, transportation and disposal system	5,9	5,1
Construction of new processing facilities without taking into account planned projects	0,5	4,3
Construction of new waste disposal facilities	7,4	5,1
Total	13,8	14,4
Level of processing, %	8	41
Specific costs, euro per year	35,4	30,1

Source: formed by the authors on the basis of IFC, World Bank Group

Today, Ukraine can choose a specific development scenario for the treatment of solid waste management, which is aimed at creating an environmentally safe infrastructure for waste disposal, and also provides for the accelerated introduction of recycling technologies.

The most appropriate for Ukraine is the innovative scenario. It will not only reduce the amount of landfill waste, but also return more than 104 million tons of valuable materials for economic circulation. As a consequence, a significant amount of primary resources will be saved.

Until 2025, the amount of additional income that can be obtained from the recycling of recycled materials and materials may be more than 7.2 billion euros. In addition, the development of modern recycling technologies will reduce emissions by 81.3 million tons of CO₂ equivalent.

One of the directions of the innovation scenario for the development of solid domestic waste management in Ukraine is the use of the organic part of waste from landfills for biogas production. The need for development of the energy uses of municipal solid waste is reflected in the relevant legal acts, in particular in the State building standards of Ukraine V.2.4-2-2005 "Municipal solid waste landfill. Basic design principles". The document describes the feasibility of utilization of biogas generated during the anaerobic decomposition of the organic component of household waste; methodology for predicting the amount of released biogas, taking into account the composition and properties of solid household waste, capacity and life of the landfill of solid household waste, etc.

The calculation of the expected amount of biogas released during anaerobic decomposition of 1 ton of solid household waste (SHW) is recommended to be carried out according to the formula:

$$V_{a,b} = P_{SHW} \times K_{e.d.o.} \times (1 - A) \cdot K_d, \quad (1)$$

where $V_{a,b}$ – estimated amount of biogas, m³;

P_{SHW} – the total mass of solid household waste stored at the landfill, kg;

$K_{e.d.o.}$ – the content of easily decomposable organic matter in 1 ton of waste ($K_{no} = 0,5...0,7$);

A – ash content of organic matter ($A = 0,2...0,3$);

K_d – the maximum possible degree of anaerobic decomposition of organic matter during the calculation period ($K_d = 0,4...0,5$).

Taking into account unforeseen circumstances, the specific volume of biogas that can be collected from 1 ton of municipal solid waste over the entire period of operation of the biogas collection system is determined by the formula:

$$V_{\phi_{a,b}} = V_{a,b} \cdot K_c \cdot K, \quad (2)$$

where $V_{\phi_{p,6}}$ – volume of biogas that can be collected from 1 ton of SHW, m³;

K_c – coefficient of efficiency of the biogas collection system ($K_c = 0,5$);

K – coefficient of adjustment for contingencies ($K = 0,65...0,70$).

On the basis of the proposed method, the theoretical amount of biogas that can be obtained from solid domestic waste landfills has been calculated: for typical region, for Vinnytsia region (the central region of Ukraine) and for Ukraine as a whole (Table 2).

Table 2. Estimated amount of biogas that can be obtained from the annual volume of landfilled solid waste

Indicator	Typical solid waste landfill	Vinnytsia region solid waste landfill	Ukraine as a whole solid waste landfill
The average annual mass of solid household waste stored at the landfill, thousand tons	250,0	276,9	≈11000,0
The content of rapidly decomposing organic matter, in municipal solid waste, thousand tons	150000	166140	66000000
Volume of biogas that can be collected from the mass of solid household outputs, thousand m ³ (optimistic scenario)	50625,0	56072,3	22275000,0
The volume of biogas that can be collected from the mass of municipal solid waste, taking into account unforeseen circumstances, thousand m ³ (pessimistic scenario)	16453,1	18223,5	7239375,0
The volume of natural gas that can be replaced by biogas from municipal solid waste, thousand m ³ (optimistic scenario)	35437,5	39250,6	1559250,0
The volume of natural gas that can be replaced by biogas from municipal solid waste, thousand m ³ (pessimistic scenario)	11517,2	12756,4	5067562,5

Source: calculated by the authors on the basis of the State Statistics Committee of Ukraine

Thus, 1 ton of solid household waste makes it possible to obtain 150-250 m³ of biogas (optimistic scenario), taking into account unforeseen circumstances – 70-120 m³ (pessimistic scenario). It is worth noting that the pessimistic scenario for Ukraine is more likely, considering the imperfection of the existing biogas collection systems and the possibility of unforeseen circumstances. Therefore, when organizing biogas production at a typical landfill of solid household waste from the average annual mass of waste (250 thousand tons), it is more likely to receive 16.4 million m³ of biogas, within Ukraine this figure is 723.9 million m³ (the optimistic scenario is 50.6 million m³ and 2227.5 million m³ respectively).

When converting biogas to natural gas, the coefficient is 0.65-0.7. Thus, on the basis of landfill biogas in Ukraine, it is theoretically possible to replace 0.5-1.6 billion m³ of natural gas.

The practical implementation of projects for the collection and utilization of biogas from municipal solid waste landfills has its strengths and weaknesses. Table 3 shows the results of the SWOT analysis of the implementation of these projects in Ukraine.

Table 3. SWOT analysis of the implementation of the project for the collection and utilization of biogas at landfills of municipal solid waste

Strengths	Weaknesses
<ul style="list-style-type: none"> ▪ reducing emissions of methane (greenhouse gas) and minimizing the risk of fires; ▪ reduction of solid household waste and, as a consequence, increase of solid household waste landfill; ▪ economic impact by reducing the cost of paying the environmental tax; ▪ economic benefits from the replacement of natural gas and electricity from traditional sources of biogas from solid waste. 	<ul style="list-style-type: none"> ▪ bureaucratic barriers in obtaining benefits for the import of equipment; ▪ imperfection of the mechanism of public-private partnership; ▪ outdated state construction standards for biogas collection systems; ▪ lack of experience in organizing the collection of biogas at landfills for municipal solid waste; ▪ failure to comply with delivery schedules of raw materials, process equipment, which can lead to higher prices for the project; ▪ long payback period of the project
Opportunities	Threats
<ul style="list-style-type: none"> ▪ raising funds through public-private partnership mechanisms; ▪ approximation to EU standards for solid waste management; ▪ implementation of comprehensive programs for processing solid household waste at the expense of funds from the sale of electricity and heat; ▪ the development of innovative technologies, the introduction of modern highly efficient methods of processing, utilization and disposal of solid household waste with the removal of the energy component. 	<ul style="list-style-type: none"> ▪ possible changes in taxation, introduction of licensing, quota for the relevant type of activity, etc. ; ▪ instability of legislation in the field of energy, land management, ecology; ▪ lack of state incentives for manufacturers to develop new technologies for the treatment of solid waste; ▪ uncertainty, according to the results of field studies, of the real volumes of biogas that can be removed from the body of landfills; ▪ unstable economic situation.

Source: formed by the authors

The main objective of an efficient organization of biogas production with the use of household waste is to maximize the use of strengths and opportunities while minimizing weaknesses and eliminating threats.

Electrical connection and sale of electricity generated on the basis of biogas at a “green tariff” of 13.2 Euro cent / KW • h. (According to the Laws of Ukraine "On Electric Power Industry" dated October 16, 1997 No. 575/97-VR with amendments and additions, "On Amendments to Certain Laws of Ukraine Concerning Ensuring Competitive Conditions for Production of Electricity from Alternative Energy Sources" dated June 4, 2015 No. 514-VIII, Resolutions of the National Commission for the State Regulation of Energy and Utilities of Ukraine dated June 27, 2019 No. 2070 "On Establishment of "green" electricity tariffs and surcharges to "green" tariffs for compliance with the level of use of Ukrainian-made equipment for business entities") makes such projects economically attractive.

Conclusion

The implementation of an innovative scenario for the development of the solid waste management sector in Ukraine is a necessary prerequisite for effective waste management. It will take at least 10-15 years to put in place management mechanisms and take appropriate action. However, it will provide wider and more sustainable

economic and environmental benefits. Thus, by 2025, more than 104 million tons of valuable materials and raw materials that were previously lost will be returned to economic circulation. This is expected to generate revenues of 7.2 billion euros. As a result of the development of recycling, the amount of waste that is exported to landfills will decrease. This, in turn, will reduce greenhouse gas emissions by 81.3 million tones in CO₂ equivalent.

The utilization of biogas at landfills will allow producing 1.76 million MWh of electricity, as well as about 2.2 million MWh of heat, thus solving the problem of increasing the share of renewable energy sources in the country's fuel and energy balance.

Today Ukraine faces the task to implement in the field of waste management efficient payment system that would allow operators to cover costs and encourage recycling and minimize the amount of solid waste disposal in landfills. At the same time, it is important that the introduction of such a system does not cause a drop in the standard of living of the population.

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