“Decision-making in conditions of expansion of eco-innovations based on the socioeconomic effects in the system “company-region-state””

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DECISION-MAKING IN CONDITIONS OF EXPANSION OF ECO-INNOVATIONS BASED ON THE SOCIOECONOMIC EFFECTS IN THE SYSTEM "COMPANY-REGION-STATE"

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Abstract

The article examines the current issues of managing the effectiveness of eco-innovations and their impact on the "company-region-state" system using the example of waste management in Ukraine. The goal of the article is to justify the choice of an effective eco-innovation financing strategy, in which the most significant socio-economic effect is achieved for the investor. Systematization of literary sources and approaches to solving the problems of innovation management enables to determine an appropriate strategy to support resource-efficient activities in the region considering the economic efficiency of eco-innovations. The choice of mathematically sound management decisions in the system "company-region-state" should be made in respect with the consequences for the sustainable development of the region. The article presents the developed approach to calculating the sequence of investment in the management of eco-innovations using the example of solid waste management. The research methods are based on systematic approach, decision theory, and the Bellman dynamic equation. The system of innovations concerning solid waste management in the city of Sumy was profoundly studied. The research empirically confirms that the most effective strategy is to build a waste sorting station using a separate waste collection. The results of the study also substantiate that the implementation of solid waste separate collection in the city of Sumy currently requires a change in investment approach.

Keywords transfer, sustainable development, management, effect, system, eco-innovations

JEL Classification L26, O32, Q53

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INTRODUCTION

Sustainable development is still an urgent goal for Ukraine during the 2030 vision. The global experience of government stimulation of the transition to green economic growth, which shows that the levers of state regulation are effective when applied and targeted differently depending on the specifics of innovations and management (Shkarupa, Sineviciene, & Sysoyeva, 2018).

Previously, modern trends of the expansion of eco-innovations that cause the socioeconomic effects in the system "company-region-state" were be presented in the scientific papers in detail. According to O. Shkarupa and I. Shkarupa (2019), niche eco-innovations were defined as the primary object of the transfer – narrowly specialized segmental object-process eco-innovations in individual functional units of the economic system, which, through their scaling, geographical and sectoral diversification, become catalysts for green economic growth.

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Niche eco-innovations at the level of individual households, companies, and institutions are aimed at solving a specific, practical business problem (changing the level of material, energy, resource consumption of production, and/or consumption). With their expansion, geographical and sectoral diversification, the potential for their impact on economic development in the system “company-region-state” increases (carbon productivity increases, GDP per unit of energy consumption increases, and other indicators of green growth of the national economy) become beneficiaries of these entities that have introduced niche eco-modernization, and a much wider range of stakeholders (local communities, territorial communities, government organizations, investors, society at large). To diversify the forms, methods, and levers of state regulation of transfer of innovations, it is offered to allocate the following kinds of niche eco-innovations:

1) resource-optimizing (to increase the efficiency of resource use, energy consumption, etc.);
2) information (to improve the efficiency of management accounting and control the role of data);
3) technical and technological (to update the technologies, facilities, projects, programs, etc.);
4) consumer-oriented (to influence consumer expectations);
5) institutional and legal (to improve the system of standards, regulations, directives) (Shkarupa, 2019).

It should be noted that many resource-optimizing eco-innovations should be implemented in the waste management system. That is why this article will focus on decision-making processes based on waste management.

1. LITERATURE REVIEW AND THEORETICAL BASIS

The rate of accumulation of municipal solid waste produced in Ukraine is increasing every year. The scientific community is continuously looking for new ways to manage solid waste management and is forced to address the ever-evolving social and economic problems in this sphere. The standard method of simple disposal of waste does not solve environmental problems and is not economically feasible but creates new threats. Also, the production process requires constant updating of limited resources in Ukraine. This leads to the minimization of waste generation, as well as to the use of waste in the form of secondary raw materials. The main idea of the article is to analyze the experience in the field of solid waste management and to develop recommendations for finding effective management solutions for its use within the framework of ecological modernization of the solid waste management system in Ukraine.

According to Boronos, Shkarupa, and Konovalov (2016) the defining feature of the modern period of interaction between society and nature is the accumulation of a massive amount of various kinds of waste, as a result of which the ability of natural systems to self-cleaning and self-regulation is almost exhausted. Every five years, the amount of municipal solid waste in the industrially developed countries of the world grows by an average of 10% (Eurostat, 2020). Today, the well-being and the very existence of humanity depend on solving the problem of solid waste. So, only a resident of Europe annually leaves behind about 300 kilograms of garbage, and this is not counting the waste of enterprises. Therefore, improving the robust waste management system today is defined as the main task in the field of environmental protection, and, hence, the economy. Ukraine annually accumulates more than 40,000,000 cubic meters of solid waste (about 10,000,000 tons), which are stored in authorized, but environmentally hazardous landfills. Besides, many unauthorized “wild” landfills are being also created. In general, landfills, storage facilities, sludge collectors occupy 165,000 hectares; it is about 4% of the territory of Ukraine. Non-industrial waste is concentrated in 700 city landfills (80% of these landfills do not have measures to protect groundwater and air from pollution) (Eurostat, 2020).

The priority goal of the modern policy in the field of solid waste management is to prevent and reduce the production of waste and its harmful effects (Vergara & Tchobanoglous, 2012). This can be achieved by applying clean technologies, saving natural resources, developing environmentally friendly products and proper technologies for the final disposal of hazardous substances containing waste intended for recycling. The main goal is the recycling of waste through recycling, reuse, improvement, or any other process to produce recycled materials or the use of waste as an energy source ("energy recovery").

Currently, there is a great deal of research on eco-innovations management, especially in the area of waste management. However, the issues on solid waste management at the level of municipalities, cities, and rural settlements are insufficiently researched, the urgency of the problems of justification and choice of the rationale is increasingly clearly indicated in the models of organization of solid waste management. This article aims to substantiate the conceptual model of investment decision-making in the process of eco-innovations management in the system "company-region-state" for efficient management of the waste management area.

Abdulredha, Kot, Al Khaddar, Jordan, and Abdulridha (2020) recommend that solid waste management recycling should be encouraged through integrating the informal sector, improving public awareness, and introducing a formal recycling scheme to make the municipal solid waste management system effective and financially sustainable. Althaf, Babbitt, and Chen (2019) focus on modeling framework that can be used to inform economic strategies by identifying the term opportunities and risks in the end-of-life management of products. Dino, Mehta, Rossetti, Ajmone-Marsan, and De Luca (2018) highlight the need to measure the potential value of EW dumps for reusing and measuring the environmental impacts. Blomsma (2018) shows how to constructively engage with waste and resource management frameworks by clarifying their role in the societal discourse on waste and resources. Carlos, Gallardo, Edo-Alcón, and Abaso (2019) proposed a methodology to define all the times involved in the waste collection process. According to Jacobi, Haas, Wiedenhofer, and Mayer (2018), there is a strong nexus between the circular economy and energy use and that it subsequently could contribute to climate change mitigation.

One of the directions of governmental policy in Ukraine is the creation of conditions for the implementation of a separate collection of household waste by introducing the socio-economic mechanisms aimed at encouraging the educators of these waste to separate collection. The Act of Ukraine "On Waste", as amended in 2019, stipulates a direct requirement: during tenders for the provision of services for household waste management, local authorities should give preference to proposals that involve a large degree of recycling or disposal of household waste. The new version of the Law of Ukraine "On Housing and Communal Services" in 2019 imposes the additional obligations not only on companies providing garbage collection services but also on consumers of their services.

In 2019, the second stage of the implementation of the National Strategy for Waste Management in Ukraine until 2030, approved by the Cabinet of Ministers in November 2017, began. Foreign experts assisted in creating the National Strategy for Waste Management 2030 led by the European Bank for Reconstruction and Development. The first stage of the implementation of the Strategy took place in 2017–2018, the second will take place in 2019–2023, the third – in 2024–2030. The implementation of the document in practice should help to ensure that at least 15% of household waste is recycled by 2023, thanks to the introduction of waste sorting lines and waste recycling plants. As well as increasing the share of the population, it collects household waste separately, at least up to 23%. By 2030, these figures should increase to 50 and 48%. For this, 250-300 new waste collection/collection centers and 90 waste sorting lines should appear in Ukraine. The number of landfills should be reduced from about five and a half thousand to 100-150 thousand.

2. METHODS

The environmental and socio-economic efficiency of landfill utilization as secondary resources and their involvement in the economic turnover should be assessed by determining the economic effect of solid waste treatment and the cost-effectiveness of attracting waste to industrial processing. It is necessary to distinguish the social effect derived from the attraction of solid domestic

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waste throughout the national economy, and the economic effect of the use of waste on a particular entity.

To make a management decision in the system "company-region-state" to invest in alternative options for extracting resources from waste, it is proposed to use a recurrent dynamic Bellman programming, which determines the conditional optimal effect on the overall gain for the enterprise. Bellman equation is the basic method of solving the task, namely finding the optimal policy and investment functions.

The recurrence relation of Bellman determines the conditional optimal gain $Ef_{SWM\,i}\left(P_{i-1}\right)$ (from the i-th step to the final iteration) through the winning function $Ef_{SWM\,i+1}\left(P_i\right)$:

$$Ef_{SWM\,i}\left(P_{i-1}\right)=\max_{s_i}\left\{f_i\left(P_{i-1},s_i\right)+\right.$$
$$\left.+Ef_{SWM\,i+1}\left(w_i\left(P_{i-1},s_i\right)\right)\right\}. \tag{1}$$

This gain corresponds to the conditionally optimal control at the i-th step, where P_0 is the initial state of the system; P_n is the end state of the system; $S=\left(s_1,s_2,\ldots,s_n\right)$ is the optimal investment strategy; $Ef_{SWM}=f_i\left(P_{i-1},s_i\right)$ is a gain that gives the strategy s_i, at the i-th control step if the system was in the state P_{i-1}, $P_i=w_i\left(P_{i-1},s_i\right)$ is the change of system state under the influence of s_i control strategy.

3. RESULTS

Having analyzed the state of solid household waste (SHW) management in Ukraine, it was concluded that there is a need for urgent changes in the field of improving the effectiveness of SHW management. One of the major changes is the introduction of separate waste collection for Ukraine. Calculation of the general indicator of ecological and economic effect on the implementation of the system of separate collection for Ukraine as a whole is not worth the aim of diploma work. Besides, it is very difficult to develop such generalized calculations, taking into account regional peculiarities. Therefore, the local city of Sumy value is calculated.

Separate collection of municipal solid waste is carried out to reduce the amount of landfilled solid waste, to receive secondary raw materials, and to remove hazardous waste present in the SHW, to improve the environmental status of each region and country as a whole.

By implementing a separate collection of solid waste, it will be effective to carry out different activities at the following stages:

- to determine the scope of rendering of the SHW export service;
- to identify the components that are present in the solid household waste and to calculate the average daily and annual average indicators for the generated secondary raw material in the solid household waste;
- to justify the introduction of necessary buildings, structures, and special machines that will process waste into secondary raw materials;
- to choose the technological scheme of separate collection of solid household waste;
- to choose the types and calculate how many containers are necessary to buy to collect the municipal solid waste management as secondary raw material, to buy these containers;
- to choose a rational scheme for the placement and location of containers, if necessary, then build the container sites;
- to define the system and mode of collection of SHW as secondary raw materials;
- to choose the types and quantities of transportation that will be specially equipped to collect and transport waste (Ignatenko, 2013).

The existing statistical information on the formation of solid waste in the city of Sumy is presented in Table 1.

Regarding the analysis of official statistics, according to the state statistical report in the form of "1-SHW" and independent results of researches, which the specialists of LLC "Ukrcomun Research

Table 1. Volumes of solid waste in Sumy

Name	Year			
	2019	2023*	2028*	2033*
Estimated population, thousand people	265.60	251.40	242.00	232.60
Annual volumes (potential) of separate collection of secondary raw materials, thousand m3	207.09	201.74	198.36	195.92
Annual volumes (possible) of residual waste in separate collection and procurement of secondary raw materials, thousand m3	406.86	394.04	389.72	384.93
Annual volumes of large-scale waste generation, thousand m3	55.43	56.54	57.97	59.43
Annual volumes of the formation of repair waste (from housing repair), thousand m3	20.23	21.05	22.12	23.25

Note: *Forecast estimations (authors' research).

Institute Project" conducted in December 2019, showed that in recent years, the morphological composition solid waste in the city of Sumy and Sumy region had not changed significantly. Table 2 shows the statistics of the morphological composition of municipal solid waste in containers near residential complexes in Sumy (Information portal of Sumy City Council, 2019).

Table 2. Weighted average morphological composition of SHW in containers of residential buildings in Sumy, 2019

Source: Information portal of Sumy City Council, 2019.

No.	Waste category	Share, %
1	Food waste	40.1
2	Paper, cardboard	11.8
3	Polymers	12.2
4	Glass	14.0
5	Ferrous metals	0.7
6	Non-ferrous metals	0.3
7	Textile	2.6
8	Tree	0.1
9	Bones, skin, rubber	0.5
10	Combined wastes, other	0.5
11	MSW residues after removal of components	17.2

Let us consider 3 variants of implementation of separate sorting:

1) solid waste collection is carried out by means of a unitary (gross) system – when SHW is collected in one type of container (for the collection of resource components in a particular container), and sent for sorting. The stationary sorting line costs UAH 3.5 million;

2) solid waste collection is carried out by means of a separate system – separately, one collects different components of SHW in certain containers (2 colors of typical plastic containers: 2,117 pieces of blue for recyclables, 2,600 for a mixed waste of conventional SHW in gray). As for the total number of containers, they are 4,717 units in 2020;

3) solid household waste is collected using a conventional system – with separate SHW components collected in several specific containers and disposed of without sorting.

The population determines the number of landfill containers in Sumy and the monitoring of the rules for the provision of solid waste disposal services. In the calculations, one believes that the number of containers satisfies certain conditions. Considering all of the above, the total volume of SHW storage containers should be more than the actual volume of their filling by 25%. Therefore, the required number of containers to collect resource components into one container (2 days' export) is 2,117 units in 2020, and the required number of containers for the collection of conventional solid waste (once a day) – 2,600 pcs.

Concerning the morphological composition of solid waste that will enter the main container, some components will not be removed as a result of some contamination, precisely by collecting all the debris in the general container and mixing it. Usually, too small granulometry fractions will be encountered, and it should be possible to extract it manually.

Analyzing the data on the morphological composition of municipal solid waste and establishing a certain amount of their formation in Sumy in 2019, the data on the gross cost of resource waste are presented (Table 3).

It should also be noted that there may be some reductions in the amount of recyclables in Option

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Table 3. Morphological composition of mixed municipal solid waste in Sumy and cost estimate of recyclables in annual volumes of household waste

Name of recyclables	Market price, UAH/kg	The recycle content of SHW, % by weight	Year 2019	
			Gross content of recyclables, thousand tons	Gross value of recyclables, mln
Waste paper (cardboard, paper)	1.5	11.83	1.02	1.53
Plastic	4.0	4.41	0.38	1.52
Polymer film	3.0	0.42	0.04	0.11
PTFE bottles (without lids)	3.0	3.09	0.27	0.81
Glass	0.6	14.05	1.21	0.73
Total	–	33.8	2.92	4.69

2 associated with the additional sorting process. The price of recycled raw materials in 2019 averaged: waste paper – 1,500 UAH/t, cullet – 600 UAH/t, plastics and polymers – 3,000-4,000 UAH/t (Information portal of Sumy City Council, 2013).

Among the costs for the sale of the secondary resource are the depreciation costs (all other costs are unknown). Containers for separate collection of household waste cost about UAH 20 thousand for one unit.

Costs for the removal of resource components under different alternatives will include the construction of a sorting station of UAH 3.5 million, remuneration of workers for the collection of SHW, sorters, administration, social payments, transport costs, depreciation, and other expenses. The return on investment is the largest item of expenditure (well above all other aggregate costs). Thus, in this study, the magnitude of these costs is critical.

Let us suppose that all investment funds are invested by the enterprise to implement the first option. In this case, the maximum gain will be UAH 3.353 million, as shown in Table 5.

Let us determine the optimal management strategy when allocating funds, among other options.

According to Table 5, the maximum gain in the distribution of investments between projects is UAH 6.226 million. In this case, it is advisable to allocate 75% of the investment to the first option. Other investment resources (25%) account for the implementation of other options (Table 6). Thus, the optimal investment plan for an enterprise is as follows: Option 1 can receive 75% of the financing, Option 2 – 25%, which will provide the maximum profit (3.423 + 2.803 = UAH 6.226 million).

According to the calculations, it is advisable to finance the first option; the strategy of build-

Table 4. Estimated data for choosing the option investment strategy

Option number	Investment in the project, UAH mln	Depreciation charge per year, mln	Profit, mln 2019	2020*	2021*	2022*
1	7.734	1.547	3.143	3.163	3.423	3.693
2	9.434	1.887	2.803	2.823	3.083	3.353
3	4.717	0.943	0	0	0	0

Note: *Forecast estimations (authors' research).

Table 5. Calculation of the maximum payoff in the first variant

Winning function	$Ef_{SWM1}(P_i)$	0	1	2	3	4
$Ef_{SWM\,i+1}(P_i)$	0	–	–	–	–	–
0	0	–	–	–	–	–
1	2.8032	–	–		2.8032	–
2	2.8232	–	–	2.8232	–	–
3	3.0832	–	3.0832	–	–	–
4	3.3532	3.3532	–	–	–	–

Table 6. Calculation of maximum winnings for options

Winning function	$Ef_{SWM1}(P_i)$	0	1	2	3	4
$Ef_{SWM\,i+1}(P_i)$	0	0	2.8032	2.8232	3.0832	3.3532
0	0	0	2.8032	2.8232	3.0832	3.3532
1	3.1432	3.1432	5.9464	5.9664	6.2264	
2	3.1632	3.1632	5.9664	5.9864	–	–
3	3.4232	3.4232	6.2264	–	–	–
4	3.6932	3.6932	–	–	–	–

ing a sorting line is more economically justified. However, a separate way of collecting SHW is also acceptable but less profitable. The third option, which does not generally generate revenue from the sale of resource materials, is unacceptable.

According to the data obtained, one can draw the following conclusions: first, the efficiency of resource extraction will be the first of the proposed options, it has the highest efficiency; second, the construction of a waste sorting station without the introduction of at least a minimal separate collection is not effective; third, the implementation of a separate SHW collection in Sumy currently requires a change in approach and investment.

CONCLUSION

As a result of analysis and calculations, the following conclusions are formulated. In Ukraine, a basic level of regulatory support in the field of waste management has been practically created. However, there is a need to harmonize the European and domestic legal framework for waste management. Statistical data on the current state of the sphere of solid waste management in Ukraine indicate a formal approach to the separate collection of household waste from the authorities and enterprises and the population, the absence of waste sorting infrastructure, the lack of investment support at the state level and awareness-raising campaigns on separate collection of household waste. The development of the system of eco-innovations and their successful transfer from developed countries allows us to see priority areas for improving the current situation in Ukraine. This requires attracting the investment in the implementation and effective operation of the separate collection system, the introduction of effective modern technologies for organizing the production of modern equipment with the involvement of world experience and domestic developments, and the creation of a domestic industry for the production of equipment for the treatment of municipal solid waste; informing the public of the rules for waste management, increasing their environmental awareness. For this, it is necessary to carry out educational and informational campaigns containing four components: campaigns in the media; public awareness campaigns; educational campaigns; a guide for the treatment of solid waste.

It was proved that the first of the proposed options would be the best in terms of resource extraction efficiency; it has the greatest efficiency; secondly, the construction of a waste sorting station without the use of at least minimal separate collection is not very effective; thirdly, the introduction of a separate collection of solid waste in the city of Sumy currently needs to change the approach and investment.

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