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ECONOMIC AND MATHEMATICAL MODELLING IN WASTE RECYCLING PLANNING

ЕКОНОМІКО-МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ В ПЛАНУВАННІ ПЕРЕРОБКИ ВІДХОДІВ

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The article in the context of the global Sustainable Development Strategy for 2016–2030, which draws attention to the need to reduce waste by taking measures to prevent their formation, reduce them, recycle and reuse, substantiates the need to borrow Ukraine's experience from the European Union countries organizational and legal mechanisms to minimize waste generation and reuse as raw materials. As well as the feasibility of the use of economic and mathematical tools in the process of making management decisions aimed at the creation and development of facilities for recycling, in particular, for energy production. According to the experience of Poland and Bulgaria, an increase in the investment share and environmental conversion of a part of foreign debt for Ukraine is supported in the framework of international technical assistance (debt-for-environment swap).

Key words: *investment, waste, decentralization, energy efficiency, local budgets, modelling, recycling.*

Україна залишається однією з небагатьох європейських країн, де досі на неналежному рівні державна політика щодо стимулювання сортування та переробки сміття, в законодавстві відсутня конкретизація можливих форм державно-приватного партнерства для розміщення, утилізації, видалення та спалювання відходів. В статті в контексті глобальної Стратегії сталого розвитку на 2016-2030 роки, де звертається увага на необхідність скорочення обсягу відходів шляхом вживання заходів з попередження їх утворення, їх переробки і вторинного використання, обгрунтовується необхідність поширення в Україну досвіду країн Європейського Союзу, де діють організаційно-правові механізми, що забезпечують мінімізацію утворення відходів та залучення їх до повторного використання як сировини. Вивчаються економічні інструменти мінімізації утворення твердих побутових відходів в країнах Європейського Союзу. Звертається увага на необхідності вибору в якості одного з пріоритетів децентралізації влади та реформи місцевого самоуправління формування сучасної індустріальної бази поводження з відходами, а не тільки як важливої складової державної й регіональної екологічної політики. В статті пропонується застосування економіко-математичного інструментарію в процесі прийняття управлінських рішень, спрямованих на створення і розвиток потужностей з переробки сміття, зокрема, для виробництва енергії. Нарощування обсягів утилізації відходів дозволить здешевити енергоресурси для населення. Вивчена статистика проектів сміттєпереробних заводів на етапі реалізації в Україні, що потребують істотних капіталовкладень. Для планування розвитку і розміщення підприємств з переробки сміття адаптована економіко-математична модель частково цілочислового лінійного програмування з булевими змінними, критерієм оптимальності в якій є вимога мінімізації необхідних загальних зведених інвестиційних витрат, витрат на переробку сміття, на його транспортування до місця переробки та (або) на транспортування продукту переробки до споживачів. Обгрунтовуються програмні продукти, що дозволяють виконувати розрахунки на базі даної моделі. За досвідом Польщі й Болгарії, підтримується збільшення інвестиційної частки та екологічної конверсії частини зовнішньої заборгованості для України в рамках міжнародної технічної допомоги (debt-for-environment swap).

Ключові слова: *інвестування, відходи, децентралізація, енергоефективність, місцеві бюджети, моделювання, утилізація.*

В статье в контексте глобальной Стратегии устойчивого развития на 2016-2030 годы, где обращается внимание на необходимости уменьшения объёма отходов путём принятия мер по предотвращению

их образования, их сокращению, переработке и вторичному использованию, обосновывается необходимость заимствования в Украину опыта стран Европейского Союза, где действуют организационно-правовые механизмы, обеспечивающие минимизацию образования отходов и их повторного использования в качестве сырья. А также целесообразность применения экономико-математического инструментария в процессе принятия управленческих решений, направленных на создание и развитие мощностей по переработке мусора, в частности, для производства энергии. По опыту Польши и Болгарии, поддерживается увеличение инвестиционной доли и экологической конверсии части внешней задолженности для Украины в рамках международной технической помощи (debt-for-environment swap).

Ключевые слова: *инвестирование, отходы, децентрализация, энергоэффективность, местные бюджеты, моделирование, утилизация.*

Problem statement. Reducing the amount of waste by taking prevention measures to their formation, as well as to their reduction, processing and reuse is one of the subgoals of Global Sustainable Development for the period of 2016–2030 [1].

According to the Plan [2], such issues as increasing energy independence by raising domestic production of energy resources, modernizing the energy infrastructure, diversifying sources of energy supplies, ensuring efficient and safe waste management have been classified as priority actions to achieve a higher level of economic development in Ukraine.

Analysis of the last researches and publications. The problem of forming waste management systems in the context of promoting environmental safety and resource conservation has been considered in the works [3], [4]. Numerous Ukrainian scientists have distinguished development of the waste recycling industry as one of the main prerequisites for effective waste management, which requires further creation of the modern institutional basis for diversification of investment resources as for utilization of household garbage as well as industrial, agricultural and forestry wastage [5], [6], [7]. Waste management in the light of attracting alternative sources of energy supply has been presented in the published work by V.A. Golyan [8], which [9] substantiates the need of improving the institutional environment of investment provision for waste management in conditions of decentralization of power.

Open parts of a shared problem. However, the current practice of investment support for waste recycling suggests that secondary utilization projects have not been properly disseminated, leading to excessive waste accumulation, thus requiring researches on this issue in order to facilitate the attraction of domestic and foreign investment in waste management.

Problem definition. The main purpose of the following work is a statistical analysis of information on various types of waste accumulated in Ukraine, the study of waste management experience in the EU countries and justification of proposals regarding the appropriateness of the use of adequate economic and mathematical tools for the analysis of invariants for managerial decisions, aimed at the expansion of using considerable waste potential for energy production and usage of other wastes as secondary raw materials.

Statement of the main material. As of January 1, 2017, the total amount of waste accumulated in Ukraine due to all hazard classes amounted up to 12.4 billion tons. In 2016, the household sector itself generated 6.3 million tons of garbage, which was 2.1% of the total waste in the country [8]. Since 2014 the volume of waste generation has started to decrease, which is a consequence of the crisis in industrial production and is related to the inability to take into account waste in the temporarily occupied territories in Donetsk and Luhansk regions and in the annexed Crimea.

Ensuring an effective system of maximum reuse of solid domestic wastage as secondary resources in economic circulation and increasing the share of their utilization is one of the tasks of the Cabinet of Ministers of Ukraine defined by the Program [10]. Considering large volumes of various types of waste and low efficiency of their treatment in Ukraine, expansion of their use as secondary raw materials is in fact an important ecological task. The problem of modernizing the national waste management system has been updated due to the need for implementation of environmental directives of the European Union.

Within the framework of activities of IRENA Assembly (Abu Dhabi, January 2019) S. Savchuk, the Head of the State Agency for Energy Efficiency and Energy Conservation of Ukraine, has focused attention on the prospects of using significant waste capacity (10 million tons per year) for energy production in Ukraine during his meeting with the representatives of Masda, the leading energy renewable company, founded in 2006 in the UAE. This company conducts about 3 GW of “green” projects with a total value of 8.5 billion USD in more than 20 countries in the world. According to the results of the meeting, the parties have agreed to jointly consider potential projects of energy utilization of waste in Ukraine and to study the possibilities of their implementation regarding the participation of this Arab company [11].

In the period of 2016–2017, the expenditures of the consolidated budget for waste utilization decreased by 218.2 million and 49 million UAH respectively in comparison to 2012. The expenditures of budgets at all levels for waste utilization were mostly reduced in 2013–2014, due to political instability in the country and because of the reduction of budget opportunities in financing

environmental measures. In 2017 compared to 2016, the expenditures of the consolidated budget for waste utilization increased by 169.2 million UAH, though there was no significant growth of this type of expenditures as evidenced by the dynamics of consolidated budget on waste utilization at comparable prices at the beginning of 2007 (Fig. 1). The nominal waste utilization costs increased in 2017 compared to 2016 at the expense of both state and local budgets. The first increase amounted up to 69.5 million UAH, while the others were 99.9 million UAH.

The share of local budgets in total budget expenditures in the period of 2007–2017 has varied in the range of 11.6-35.5% (Fig. 2). In 2017 compared to 2014–2016, there was a decrease in the state budget share followed by an increase in the share of local budgets in the structure of expenditures of the consolidated budget of Ukraine for waste utilization.

The analysis of expenditures of state and local budgets for waste utilization shows a narrowing of investment participation of the state and territorial communities in the processes of efficient waste management. Expenditures, financed by state and local budgets, should be complemented by significant volumes of domestic and foreign private investments as based on the need to invest resources for the development of the waste recycling industry.

Increasing volumes of waste utilization will reduce energy costs for the population. Ukraine consumes more expensive natural gas than Sweden, Belgium, Poland, the Czech Republic, Norway, Estonia, and Latvia combined [12, p. 109], while renewable and alternative energy sources including the biogas energy from waste sites, landfill gas, gas from sewage disposal plants, etc. represent only 4% of all the energy consumed in the country. On the contrary, the electricity and heat supply in the capital of Sweden [13] in Stockholm is by 45% secured by waste recycling and its share in the country's energy supply reaches 20%. Thus, Stockholm is one of the cleanest and greenest capitals in the world, although there are five garbage collection plants and a waste-disposal plant. 12% of households in Berlin receive electricity and heat at the expense of garbage.

According to statistics, most of the waste collected in the landfills of Ukraine is of industrial type but the amount of household garbage is also impressive: each Ukrainian throws away up to 250-270 kg of rubbish per year. Despite the fact that almost 80% of waste is a dead rock from extraction and processing of commercial minerals, the phytogenic and animal-based waste is classified as the 4th class of hazard (the ecosystem is restored in three years), there are also 2% of more dangerous garbage on the landfills, for example, waste of ferrous metals and deposits of industrial waste, as well as domestic waste of the 3rd class of hazard; the combination of organic and inorganic chemistry and heavy metals belong to deadly hazardous waste of the 1st and 2nd classes, after which the ecology is practically not able to restore, and make up only 2%, being actually neutralized. However, according to environmentalists, the waste stored at urban landfills can hardly be classified as the 3rd class of danger since there are hundreds of tons of used batteries, accumulators, household

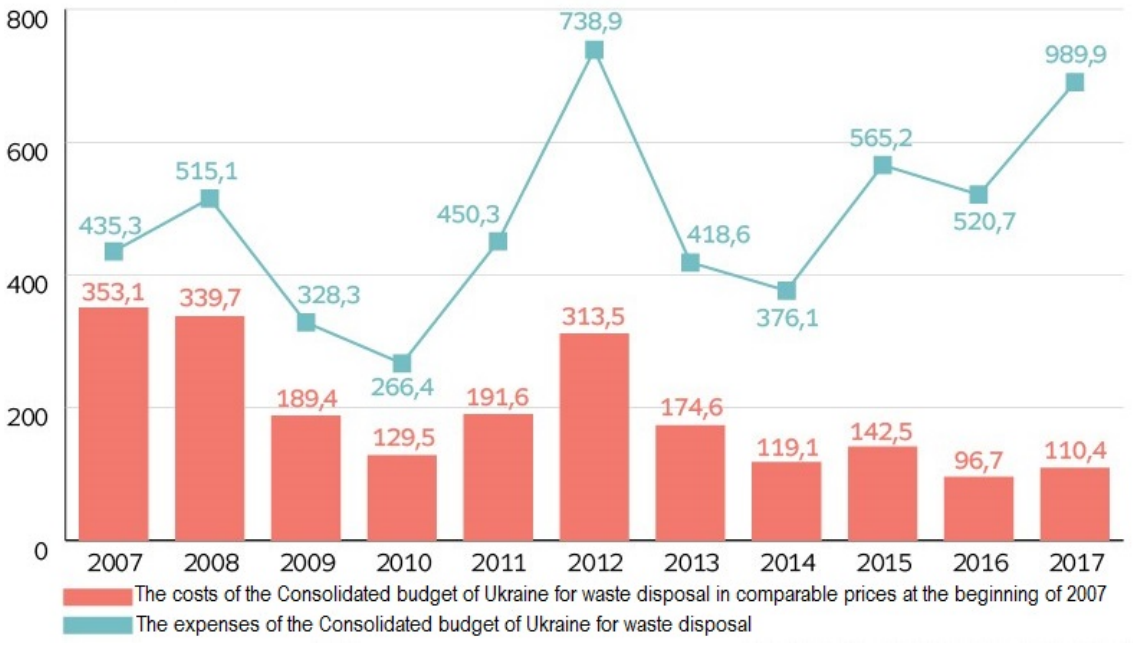

Fig. 1. Dynamics of expenditures of the Consolidated Budget of Ukraine for waste utilization, million UAH

Sources: State Treasury of Ukraine, calculations of the European Analytical Centre

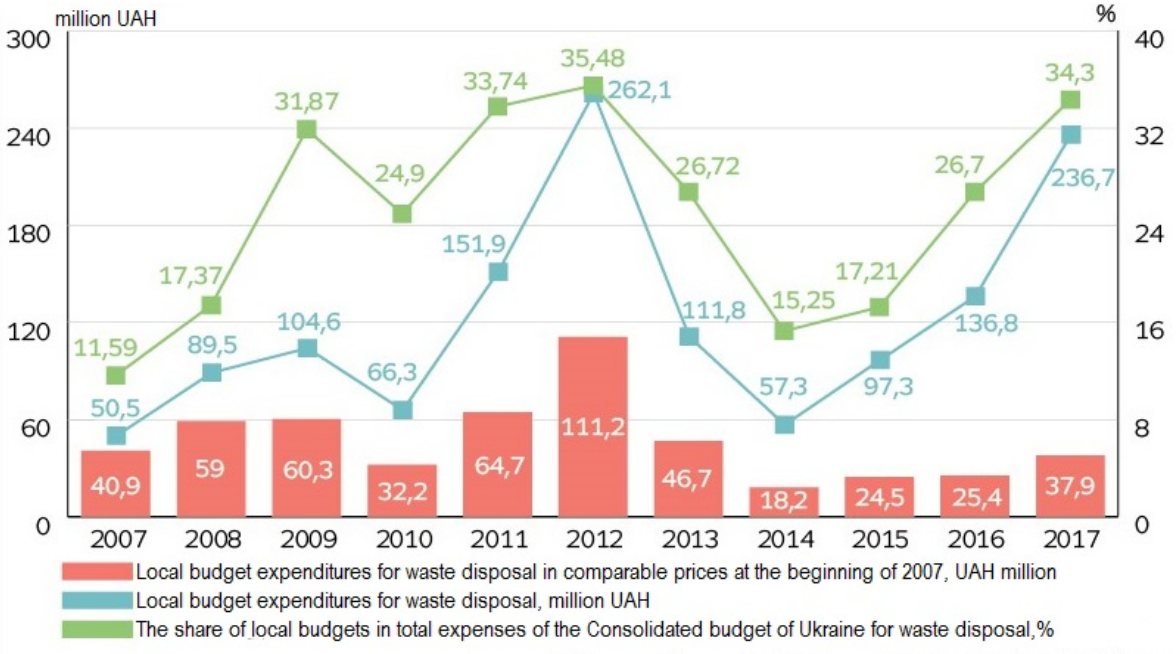

Fig. 2. Dynamics of expenditures of local budgets for waste utilization

Sources: State Treasury of Ukraine, calculations of the European Analytical Centre

waste, construction materials, varnishes, and paints polluting the environment. They are thrown away by people instead of being taken out for disposal. Due to the calculations of the State Service of Statistics of Ukraine, 3.1 thousand tons of cars (about 3000 units) can be found on landfills every year, of which only 3% can be disposed, as well as 42 thousand tons of plastic with only 5% being disposed, 22.3 thousand tons of glass with 10% utilized, 22.9 thousand tons of rubber with 28% recycled, 111 thousand tons of paper with 50% utilized [14].

Waste burning or burying with energy receipt is a technology of waste processing when their combustion generates heat and electricity. Besides, methane produced at landfills during the decomposition of the organic waste component is also used to obtain heat and electricity [15].

Volumes of waste generation, which can be used as secondary resources, are so large that they not only correspond to their value but often exceed the value of primary resources. In the EU countries, there are organizational and legal mechanisms ensuring minimization of waste generation and their re-use as raw materials [12, p. 112], however, the following organizational and legal basis for the use of waste as a secondary raw material in the main areas of waste management in Ukraine has not yet been established.

One of the main ways to reduce waste generation is to establish the responsibility of the manufacturer of this wastage in terms of waste collection, utilization or disposal (Fig. 3).

In Europe, separate garbage collection was introduced in the 1980s. In Sweden, 99% of all rubbish is recycled, in Germany, Austria, and Switzerland the amount of garbage processing reaches 97%. In these countries, landfills are closed due to uselessness, virtually all waste is processed quickly and with considerable benefits. Ukraine remains one of the few European states where there is still no state policy to promote waste sorting and processing. The law does not oblige manufacturers to process garbage, therefore, only 3% -8% of waste is recycled [17] (Table 1).

Table 1

Household waste recycling in Ukraine in 2015 [18]

Region	Volume, thousand tons
Kyiv	390
Rivne region	37
Kyiv region	36
Ternopil region	16
Kharkiv region	1
Chernivtsi region	0,9
Vinnytsia region	0,2
Total	481,1

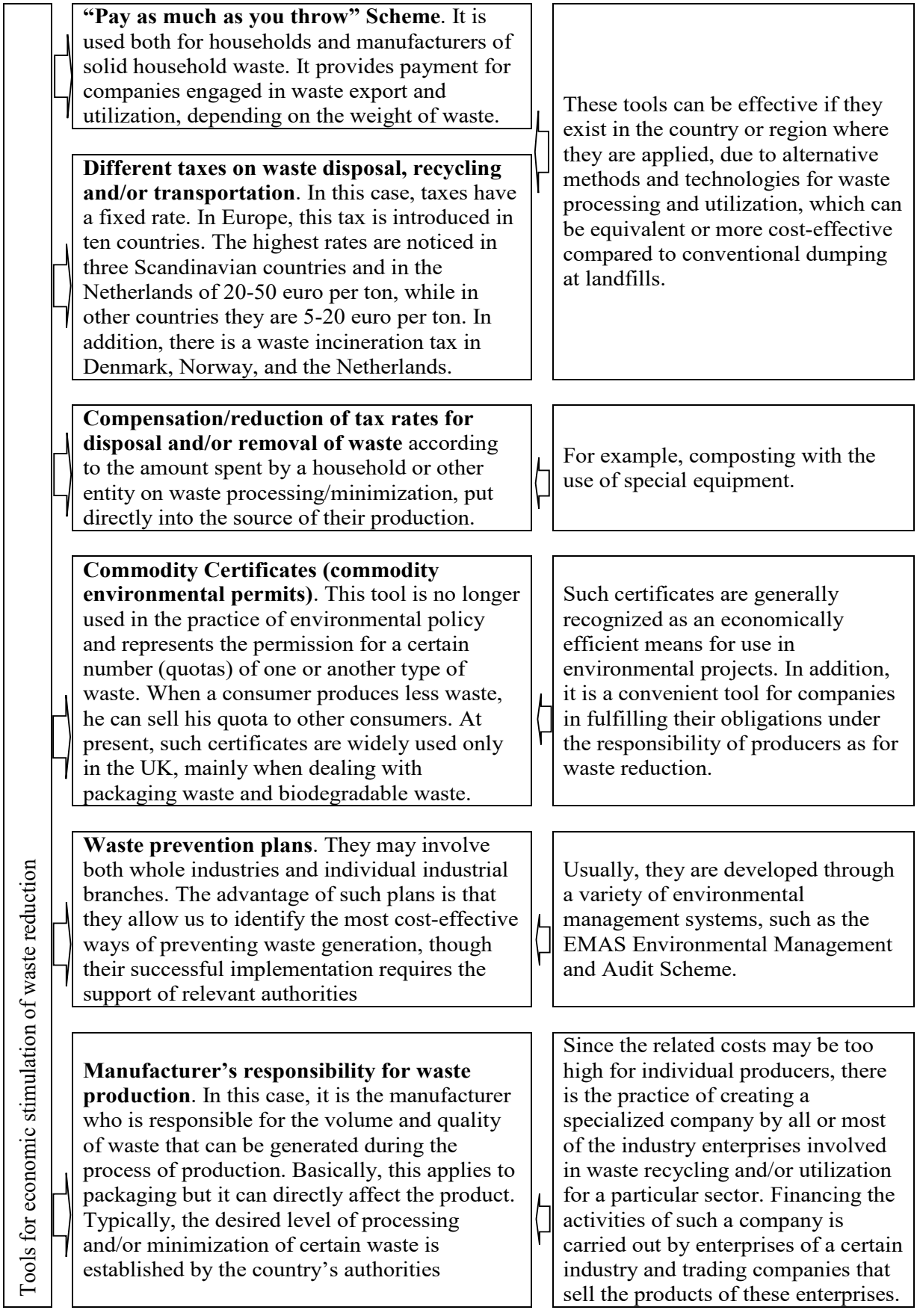

Fig. 3. Economic tools for minimizing solid waste formation in the EU [16]

There are about 2.6 thousand of waste-disposal plants in the world. Only in Japan, there are more than 100 of such plants, Germany itself employs more than 70 waste recycling plants [19]. In Ukraine, there are four plants: in Kyiv, Dnipro, Kharkiv and occupied Sevastopol, of which only one, the "Energia" Plant by Kyivenergo is functioning now (238 million UAH of investments during 2013–2018), burning waste for receipt of energy and heat and which, due to the events at Grybovytskyi landfill, has accepted garbage from Lviv as well. According to expert estimates, Ukraine will need to build 50 waste-disposal plants in order to unload the landfills, in view of the volume of buried waste. Construction of one universal reprocessing plant for all types of solid household waste requires about 20 million USD. Thus, in order to solve the problem of waste processing, the state needs to find at least 1 billion USD, which requires the involvement of investors (Table 2).

MS Social project owned by 100% Investment Capital Ukraine from the ICU group [20] invests from 7 to 10 million euro in the construction of the largest Ukrainian processing plant for unsorted solid waste by a special technology in the city of Zhytomyr. The depth of processing under this technology will reach 85-95% and its result will be the receipt of secondary raw materials, alternative RDF fuel for cement plants and compost from the organic fraction of solid household waste. The project capacity of the plant involves the processing of about 82 thousand tons of solid household waste per year. The Tehnix company from Croatia, the manufacturer of equipment and developer of MBO-Technology (mechanical, biological, and thermal treatment and processing of solid municipal waste), which has built and commissioned more than 50 similar waste-disposal plants in the countries of the European Union, was chosen as the contractor for the following project.

In order to solve the problem of waste processing capacity in Ukraine, attention should be paid to all possible variants of development of existing enterprises, as well as current projects of commissioning new enterprises. The role of local authorities in waste management is growing with the development of decentralization. An increase in the investment volume will be facilitated by the expansion of the list of public-private partnership agreements in the field of waste management. Due to the current version of the Law [21], waste management depends on agreements between public (municipal) and private partners, which creates certain institutional conditions for the application of such agreements in waste management practices. At the same time, the legislation lacks specification of possible forms of public-private partnership for placement, utilization, removal, and disposal of waste, that is, different models of cooperation of territorial communities with private partners (residents and/or non-residents) that have the necessary material and technical base and considerable experience of conducting entrepreneurial activity in the field of waste management, have not been determined [8].

The choice of specific options for the development and placement of enterprises is based upon the volume of investment resources that can be used to support and increase production capacity. The optimality criterion may be the requirement to minimize the necessary total consolidated investment costs, the cost of recycling garbage, its transportation to the place of processing and (or) transportation of the processed product to consumers [22, p. 21-25], [23, p. 191-193].

Tin order to construct an economic and mathematical model for the objective planning of development and placement of an enterprise (industry, corporation) with the optimal allocation of investment resources, the following designations for known variables (uncontrolled parameters) can be involved:

i – the enterprise number, existing or projected ($i = \overline{1;m}$);

j – the number of development option for the i-enterprise ($j = \overline{1;n_i}$);

N_{ij} – production capacity of i-enterprise due to its development for j-option;

I_{ij} – investment costs needed for implementation of j-option of development within the i-enterprise;

R – the maximum possible amount of investment costs, which will be directed towards ensuring the development of all enterprises;

e – normative coefficient of economic efficiency of investments (discount rate);

c_{ij} – the unit cost of production, which will be produced at the i-enterprise according to its development in j-option;

k – the number of consumer products ($k = \overline{1;p}$);

b_k – demand for products from k-consumer;

Table 2

Projects of waste processing plants at the stage of implementation in Ukraine [19]

Location of the enterprise	Investment volumes	Investor
Dnipro	120 mln USD	Eco Energy (Sweden)
Ternopil	45 mln EUR	Lone Star International (USA)
Kharkiv	44 mln USD	The World Bank
Kyiv region	40 mln EUR	Emic-Steam (Ukraine)
Odesa	25 mln USD	OHB Holding (South Korea)
Transcarpathia (Zakarpattia)	10 mln EUR	ABE Umwelt (Austria)

d_{ik} – costs for transportation of product units along the route from the i-enterprise to k-consumer.

Functioning as unknown units:

x_{ij} – a logical variable that reflects the fact of choice for implementation of j-option of development for the i-enterprise:

$$x_{ij} = \begin{cases} 1, \text{ if i - enterprise is developing according to j - option,} \\ 0 \text{ in the opposite case.} \end{cases}$$

y_{ij} – production volume at the i-enterprise in accordance with j-option of its development;

z_{ik} – transportation volume of products along the route from the i-enterprise to k-consumer;

v – total costs of investment, production, and transportation of products.

Taking into account the indicators given above, the economic and mathematical model of the objective of planning the development and placement of objects with the optimal allocation of investment resources has taken the following form:

$$v = e\sum_{i=1}^{m}\sum_{j=1}^{n_i} l_{ij}x_{ij} + \sum_{i=1}^{m}\sum_{j=1}^{n_i} c_{ij}y_{ij} + \sum_{i=1}^{m}\sum_{k=1}^{p} d_{ik}z_{ik} \to \min \qquad (1)$$

$$\begin{cases} \sum_{j=1}^{n_i} x_{ij} = 1, i = \overline{1;m}, \\ \sum_{i=1}^{m}\sum_{j=1}^{n_i} l_{ij}x_{ij} \le R, \\ 0 \le y_{ij} \le N_{ij}x_{ij}, i = \overline{1;m}, j = \overline{1;n_i}, \\ \sum_{j=1}^{n_i} y_{ij} = \sum_{k=1}^{p} z_{ik}, i = \overline{1;m}, \\ \sum_{i=1}^{m} z_{ik} \ge b_k, k = \overline{1;p}, \end{cases} \qquad (2)$$

$$\begin{aligned} & x_{ijj} \in \{0;1\}, i = \overline{1;m}, j = \overline{1;n_i}, \\ & z_k \ge 0, i = \overline{1;m}, k = \overline{1;p}. \end{aligned} \qquad (3)$$

The introduced mathematical model represents the problem of mixed integer linear programming with Boolean variables. The “Search Solution” add-in for MS Excel package can be used for its solving.

Conclusions. The main direction of the state policy for implementation of measures aimed at energy saving, energy efficiency, and energy receipt from alternative sources in Ukraine should be the creation of a comprehensive, consistent, and flexible system of financial incentives. Foundation of the modern industrial waste management base should not only be an important component of state and regional environmental policy but also one of the priorities of decentralization of power and local government reform.

Waste recycling in order to improve the quality of life and take more care of the environment is quite an expensive option, therefore, Ukraine should obviously consider its reorientation from research into the growth of investment share and environmental conversion of the external debt part in the framework of international technical assistance (debt-for-environment swap) since upon the signature of the EU Association Agreement Ukraine should implement European standards of law, which requires increased funding. Ecological conversion provides the possibility of transforming the part of obligations on external public debt into the county’s obligation to finance environmental measures on its own territory due to the predetermined amount in the native currency. Such eco-conversion has been already carried out in Poland, Bulgaria, and other countries.

REFERENCES:

1. Tsili staloho rozvytku 2016-2030 [Sustainable Development goals 2016-2030]. Retrieved from http://www.un.org.ua/ua/tsili-rozvytku-tysiacholittia/tsili-staloho-rozvytku (date of the application: 26.03.2019).

2. Serednostrokovyi plan priorytetnykh dii Uriadu do 2020 roku: Rozporiadzhennia Kabinetu Ministriv Ukrainy vid 3 kvitnia 2017 r. № 275-r [Medium-Term Plan for Priority Actions of the Government by 2020: Order of the Cabinet of Ministers of Ukraine, dated April 3, 2017, no. 275-p]. *Uriadovyi portal – Government portal*. Retrieved from https://www.kmu.gov.ua/ua/diyalnist/programa-diyalnosti-uryadu/serednostrokovij-plan-prioritetnih-dij-uryadu-do-2020-roku-ta-plan-prioritetnih-dij-uryadu-na-2017-rik (date of the application: 26.03.2019).

3. Hubanova, O.R. (2012). Teoretyko-metodolohichni zasady formuvannia orhanizatsiino-ekonomichnoho mekhanizmu stymuliuvannia vtorynnoho resursokorystuvannia [Theoretical and methodological principles of formation of organizational and economic mechanism of stimulation of secondary resource use]. *Visnyk Odeskoho derzhavnoho ekolohichnoho universytetu – Bulletin of the Odessa State Ecological University*, no. 13, pp. 9-37.

4. Mishchenko, V.S. & Vyhovska, H.P. (2009). *Orhanizatsiino-ekonomichnyi mekhanizm povodzhennia z vidkhodamy v Ukraini ta shliakhy yoho vdoskonalennia: monohrafiia [Organizational and economic mechanism of waste management in Ukraine and ways of its improvement: monograph]*. Kyiv: Naukova dumka (in Ukrainian).

5. Harkushenko, O.M. (2014). Rehuliuvannia utvorennia tverdykh pobutovykh vidkhodiv ta povodzhennia z nymy: neobkhidnist abo chynnyk politychnoho tysku [Regulation of the formation and handling of solid household wastes: the necessity or factor of political pressure]. *Naukovyi visnyk Uzhhorodskoho universytetu. Seriia Ekonomika – Scientific Bulletin of Uzhgorod University. Series Economics*, no. 2 (43), pp. 215-218.

6. Makovetska, Yu. (2010). Finansovo_ekonomichni vazheli zabezpechennia rozvytku vtorynnoho resursokorystuvannia [Financial_economic levers of development of secondary resource use]. *Ekonomist – Economist*, no. 12, pp. 76-78.

7. Mishchenko, V. & Omelianenko, T. (2012). Stanovlennia finansovoi bazy upravlinnia vidkhodamy v Ukraini [Formation of the financial base of waste management in Ukraine]. *Ekonomist – Economist*, no. 7, pp. 48-51.

8. Holian, V. (2018). Investytsii v pererobku vidkhodiv: yak podolaty pasyvnist vlady ta biznesu [Investments in waste processing: how to overcome the passivity of power and business]. *Dzerkalo tyzhnia – Mirror of the week*, no. 13 (359), p. 9.

9. Holian, V.A., Rudynets, M.V. & Roshkevych, V.F. (2018). Investuvannia proektiv pererobky vidkhodiv v umovakh detsentralizatsii: suchasnyi stan ta priorytety [Investment in waste processing projects under conditions of decentralization: current state and priorities]. *Investytsii: praktyka ta dosvid – Investments: practice and experience*, no. 9, pp. 6-12. Retrieved from http://www.investplan.com.ua/?op=1&z=6060&i=0 (date of the application: 26.03.2019).

10. Prohrama diialnosti Kabinetu Ministriv Ukrainy: Postanova Verkhovnoi Rady Ukrainy № 1099-VIII vid 14.04.2016 [Program of activity of the Cabinet of Ministers of Ukraine: Resolution of the Verkhovna Rada of Ukraine, no. 1099-VIII dated April 14, 2016]. Retrieved from http://zakon2.rada.gov.ua/laws/show/1099-19#n7 (date of the application: 26.03.2019).

11. Derzhenerhoefektyvnosti ta providna arabska kompaniia rozghlianuly shliakhy investuvannia v ukrainski proekty zelenoi enerhetyky ta pererobky smittia [State Department of Energy Efficiency and a leading Arabian company have considered ways to invest in Ukrainian green energy and garbage recycling projects]. Retrieved from https://www.kmu.gov.ua/ua/news/derzhenergoefektivnosti-ta-providna-arabska-kompaniya-rozglyanuli-shlyahi-investuvannya-v-ukrayinski-proekti-zelenoyi-energetiki-ta-pererobki-smittya (date of the application: 26.03.2019).

12. Tsili rozvytku tysyacholittya Ukrayina: 2000-2015. Natsionalna dopovid [Millennium Development Goals Ukraine: 2000-2015. National report]. Retrieved from http://un.org.ua/images/stories/docs/2015_MDGs_Ukraine_Report_ukr.pdf (date of the application: 26.03.2019).

13. Market leader. Retrieved from profi-forex.org (date of the application: 26.03.2019).

14. Panchenko, O. & Sierov, I. (2018). Na odnoho ukraintsia prypadaie 300 tonn vidkhodiv: yak zabrudniuiut krainu [One Ukrainian has 300 tons of waste: how to pollute the country]. *Sehodnia – Today*. Retrieved from http://ukr.segodnya.ua/economics/enews/na-odnogo-ukrainca-prihoditsya-300-tonn-othodov-kak-zagryaznyayut-stranu-721245.html (date of the application: 26.03.2019).

15. Sait «Ukraina komunalna« [Sait «Ukraine communal«]. Retrieved from jkg-portal.com.ua (date of the application: 26.03.2019).

16. Yushchenko, N.L. (2017). Perspektyvy zabezpechennia enerhopostachannia vnaslidok pererobky smittia v Ukraini [Perspectives of provision of energy supply as a result of rubbish recycling in Ukraine]. Proceedings from: *collection of international scientific papers «Ukraine-EU. Modern Technology, Business and Law« – Collection of international scientific papers «Ukraine-EU. Modern Technology, Business and Law«*, vol. (2), pp. 107-110.

17. Yak optymizuvaty utylizatsiiu vidkhodiv? [How to optimize waste utilization?]. *Uriadovyi kurier. Hazeta Kabinetu Ministriv Ukrainy – Uriadovy Courier. Newspaper of the Cabinet of Ministers of Ukraine*. Retrieved from http://ukurier.gov.ua/uk/articles/yak-optimizuvati-utilizaciyu-vidhodiv/ (date of the application: 26.03.2019).

18. *Ofitsiinyi veb-sait Ministerstva rehionalnoho rozvytku, budivnytstva ta zhytlovo-komunalnoho hospodarstva Ukrainy [Official website of the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine]*. www.minregion.gov.ua. Retrieved from http://www.minregion.gov.ua/ (date of the application: 26.03.2019).

19. *Sait Finance.UA [Site Finance.UA]*. news.finance.ua. Retrieved from http://news.finance.ua/ua/news/-/394107/ukrayinske-eldorado-chomu-vazhlyvi-investytsiyi-v-pererobku-vidhodiv (date of the application: 26.03.2019).

20. ICU pobuduie naibilshyi zavod z pererobky vidkhodiv v Ukraini [ICU will build the largest waste recycling plant in Ukraine]. Retrieved from https://biz.nv.ua/ukr/markets/icu-pobuduje-najbilshij-zavod-z-pererobki-vidkhodiv-v-ukrajini-2484776.html (date of the application: 26.03.2019).

21. Pro derzhavno-pryvatne partnerstvo: Zakon Ukrainy № 2189-VIII vid 10.06.2018 [On Public-Private Partnership. Law of Ukraine, no. 2189-VIII dated June 10, 2018]. Retrieved from https://zakon.rada.gov.ua/laws/show/2404-17 (date of the application: 26.03.2019).

22. Kihel, V.R. (2003). Matematychni metody rynkovoi ekonomiky [Mathematical methods of market economy]. Kyiv: Kondor (in Ukrainian).

23. Yushchenko, N.L. (2016). Ekonomiko-matematychni modeli v upravlinni ta ekonomitsi [Economics and Mathematical Models in Management and Economics]. Chernihiv: Chernih. nats. tekhnoloh. un-t (in Ukrainian).

REFERENCES (IN LANGUAGE ORIGINAL):

1. Цілі сталого розвитку 2016-2030. URL: http://www.un.org.ua/ua/tsili-rozvytku-tysiacholittia/tsili-staloho-rozvytku (дата звернення: 26.03.2019).

2. Середньостроковий план пріоритетних дій Уряду до 2020 року: Розпорядження Кабінету Міністрів України від 3 квітня 2017 р. № 275-р. *Урядовий портал*. URL: https://www.kmu.gov.ua/ua/diyalnist/programa-diyalnosti-uryadu/serednostrokovij-plan-prioritetnih-dij-uryadu-do-2020-roku-ta-plan-prioritetnih-dij-uryadu-na-2017-rik (дата звернення: 26.03.2019).

3. Губанова О.Р. Теоретико-методологічні засади формування організаційно-економічного механізму стимулювання вторинного ресурсокористування. *Вісник Одеського державного екологічного університету*. 2012. Вип. 13. С. 29-37.

4. Міщенко В.С., Виговська Г.П. Організаційно-економічний механізм поводження з відходами в Україні та шляхи його вдосконалення : монографія. Київ : Наукова думка, 2009. 294 с.

5. Гаркушенко О.М. Регулювання утворення твердих побутових відходів та поводження з ними: необхідність або чинник політичного тиску. *Науковий вісник Ужгородського університету. Серія «Економіка«*. 2014. Вип. 2 (43). С. 215-218.

6. Маковец ька Ю. Фінансово-економічні важелі забезпечення розвитку вторинного ресурсокористування. *Економіст*. 2010. № 12. С. 76-78.

7. Міщенко В., Омельяненко Т. Становлення фінансової бази управління відходами в Україні. *Економіст*. 2012. № 7. С. 48-51.

8. Голян В. Інвестиції в переробку відходів: як подолати пасивність влади та бізнесу. *Дзеркало тижня*. 2018. №13 (359). С. 9.

9. Голян В.А., Рудинець М.В., Рошкевич В.Ф. Інвестування проектів переробки відходів в умовах децентралізації: сучасний стан та пріоритети. *Інвестиції: практика та досвід*. 2018. № 9. С. 6-12. URL: http://www.investplan.com.ua/?op=1&z=6060&i=0 (дата звернення: 26.03.2019).

10. Програма діяльності Кабінету Міністрів України: Постанова Верховної Ради України № 1099-VIII від 14.04.2016 р. URL: http://zakon2.rada.gov.ua/laws/show/1099-19#n7 (дата звернення: 26.03.2019).

11. Держенергоефективності та провідна арабська компанія розглянули шляхи інвестування в українські проекти «зеленої« енергетики та переробки сміття. *Урядовий портал*. URL: https://www.kmu.gov.ua/ua/news/derzhenergoefektivnosti-ta-providna-arabska-kompaniya-rozglyanuli-shlyahi-investuvannya-v-ukrayinski-proekti-zelenoyi-energetiki-ta-pererobki-smittya (дата звернення: 26.03.2019).

12. Цілі розвитку тисячоліття Україна: 2000-2015. Національна доповідь. Київ, 2015. 125 с. URL: http://un.org.ua/images/stories/docs/2015_MDGs_Ukraine_Report_ukr.pdf (дата звернення: 26.03.2019).

13. Биржевой лидер. URL: profi-forex.org (дата звернення: 26.03.2019).

14. Панченко О., Сєров І. На одного українця припадає 300 тонн відходів: як забруднюють країну. *Сегодня*. URL: http://ukr.segodnya.ua/economics/enews/na-odnogo-ukrainca-prihoditsya-300-tonn-othodov-kak-zagryaznyayut-stranu-721245.html (дата звернення: 26.03.2019).

15. Україна комунальна. URL: jkg-portal.com.ua (дата звернення: 26.03.2019).

16. Ющенко Н.Л. Перспективи забезпечення енергопостачання внаслідок переробки сміття в Україні. *Ukraine – EU. Modern Technology, Business and Law* : collection of international scientific papers : in 2 parts. Parts 2. Current Issues of Legal Science and Practice. Management and Public Administration. Innovations in Education. Environmental Protection. Engineering and Technologies. Chernihiv : CNUT, 2017. P. 107-110.

17. Як оптимізувати утилізацію відходів? *Урядовий кур'єр*. URL: http://ukurier.gov.ua/uk/articles/yak-optimizuvati-utilizaciyu-vidhodiv/ (дата звернення: 26.03.2019).

18. Офіційний веб-сайт Міністерства регіонального розвитку, будівництва та житлово-комунального господарства України. URL: http://www.minregion.gov.ua/ (дата звернення: 26.03.2019).

19. Finance.UA. URL: http://news.finance.ua/ua/news/-/394107/ukrayinske-eldorado-chomu-vazhlyvi-investytsiyi-v-pererobku-vidhodiv (дата звернення: 26.03.2019).

20. ICU побудує найбільший завод з переробки відходів в Україні. URL: https://biz.nv.ua/ukr/markets/icu-pobuduje-najbilshij-zavod-z-pererobki-vidkhodiv-v-ukrajini-2484776.html (дата звернення: 26.03.2019).

21. Про державно-приватне партнерство: Закон України № 2189-VIII від 10.06.2018 р. URL: https://zakon.rada.gov.ua/laws/show/2404-17 (дата звернення: 26.03.2019).

22. Кігель В.Р. Математичні методи ринкової економіки : навчальний посібник. Київ : Кондор, 2003. 158 с.

23. Ющенко Н.Л. Економіко-математичні моделі в управлінні та економіці : навчальний посібник. Чернігів : Черніг. нац. технолог. ун-т, 2016. 278 с.