State Enterprise “Scientific, Research, Design and Technology Institute of Municipal Economy”

REPORT

“Evaluation of the Most Suitable Technical Solution for Organic Waste, Sorted Municipal and Commercial Green Waste Management in Uzhhorod”

within the framework of project implementation

“Contribution to Sustainable Management of Municipal Waste in Uzhhorod”
(Grant Agreement NAKOPA E-UKR.1-20 from November 14, 2020)
(DK 021:2015 “DK 021:2015: 90710000-7 - Environmental Management”)

Kyiv – 2023

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State Enterprise "Scientific, Research, Design and Technology Institute of Municipal Economy"

APPROVED BY
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"__" _____ 2023

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(Contract No. 19 from 26.09.2023)

Project Manager:
Acting Deputy Director,
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Kyiv – 2023

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ABSTRACT

Report: 100 pages, 2 parts, 27 tables, 17 figures, 2 annexes, 75 sources.

WASTE MANAGEMENT SYSTEM, SEPARATE COLLECTION, TRANSPORTATION, SORTING, TREATMENT, ANAEROBIC FERMENTATION, AEROBIC COMPOSTING, BURT, MUNICIPAL WASTE, SECONDARY RAW MATERIALS, BIO-WASTE, COMPOST, MUNICIPAL WASTE LANDFILL, SECONDARY MATERIALS MARKET

Provision of the service "Evaluation of the Most Suitable Technical Solution for Organic Waste, Sorted Municipal and Commercial Green Waste Management in Uzhhorod" (hereinafter – the Evaluation) is carried out based on Contract No. 19 dated 26.09.2023 (hereinafter – the Contract) between the State Enterprise "Scientific, Research Design and Technology Institute of Municipal Economy (Kyiv) and the Department of International Cooperation and Innovations of the Uzhhorod City Council of the Transcarpathian Oblast. The evaluation is carried out as part of the implementation of the project "Contribution to the sustainable management of municipal waste in Uzhhorod" (grant agreement NAKOPA-E- UKR.1-20 dated 14.11.2020), which is implemented with support funds from the budget of the Federal Ministry of Economic Cooperation and Development of Germany.

The purpose of the evaluation is to determine a technical solution acceptable for Uzhhorod for the management of organic waste, sorted municipal and commercial green waste, taking into account European experience based on the provisions of the European Directives on waste management and the provisions of domestic legislation, as well as on their updates and modifications.

The implementation of the project corresponds to the "Strategy for the development of Uzhhorod-2030", approved by the Decision of Session No. 1382 from 18.01.2019.

Receiving the Report: according to Contract No. 19 from 26.09.2023, SE "NDKTI MG", Kyiv, 35, Metropolitan Vasyl Lypkivskyi str.

INTRODUCTION

Elements and Principles of Evaluation

"Evaluation of the Most Suitable Technical Solution for Organic Waste, Sorted Municipal and Commercial Green Waste Management in Uzhhorod" (hereinafter - Evaluation) is carried out as part of the implementation of the project "Contribution to the Sustainable Management of Municipal Waste in Uzhhorod" and is carried out taking into account European approaches to waste management, based on the provisions of European directives on waste management, as well as on the provisions of the national legislation, their updates and modifications:

- Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste
- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste;
- Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC;
- Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control);
- Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances;
- Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (codification);
- Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment;
- European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste;
- Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE);
- Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC.

The implementation of the project corresponds to the "Strategy for the Development of the Uzhhorod-2030", approved by the Decision of Session No. 1382 from January 18, 2019.

The Evaluation is based on official information and the results of calculations and actual research.

The purpose of the project is to define a technical solution acceptable for Uzhhorod for organic waste, sorted municipal and commercial green waste management taking into account European experience and the provisions of domestic legislation.

Expected results

The main tasks of the Evaluation are:

- assessment of relevant technical solutions;
- study of suitable and accessible places for these technical solutions;
- financial analysis of various variants;
- comparative study of the feasibility of the proposed technical variants;
- development of a monitoring concept for a composting plant (compost quality).

At Stage 1 of the calendar plan of the Contract for the provision of the service "Evaluation of the Most Suitable Technical Solution for Organic Waste, Sorted Municipal and Commercial Green Waste Management in Uzhhorod", **Part I** "Evaluation of the most suitable technical solution for the management of organic waste, sorted municipal and commercial green waste" is being developed",

in which, by official information, data obtained by conducting actual research, and provided initial data:

- assessment of existing technical solutions for management of bio-waste (organic, green waste) was carried out, their advantages and disadvantages were indicated;
- available places in the city Uzhhorod for appropriate technical solutions for management of the generated bio-waste were analyzed, namely variants for placing a bio-waste treatment facility (composting station);
- approximate calculations of the main parameters (including load) of the composting station in Uzhhorod were carried out and a comparative financial analysis of bio-waste management variants according to various technological schemes was carried out;
- study of the feasibility of implementing the proposed technical variants for management of bio-waste and implementing the construction project of a bio-waste treatment facility in Uzhhorod;
- general concept of monitoring for composting station installations in Uzhhorod is proposed taking into account European experience.

At Stage 2 of the calendar plan of the Contract for the provision of the service "Evaluation of the Most Suitable Technical Solution for the organic waste, sorted municipal and commercial green waste management in the city o Uzhhorod", **Part II** "Analysis of the Secondary Raw Materials Market" is being developed, in which, according to official information, with the data obtained by conducting actual research and the provided initial data, an analysis of the market of secondary raw materials, in particular compost, was carried out:

- general characteristics of the state of the waste management system and the market of secondary raw materials in Ukraine are given - the legislative prerequisites of the field are established, the basic principles of pricing, factors that influence the formation of the market of secondary raw materials, and general trends of its development with the selection of the main problems and features, in particular in European countries, the main strategies for waste management in European countries and their impact on the economy of Ukraine are indicated;
- an assessment of the existing market of secondary raw materials in Ukraine (in particular, compost) was carried out by analyzing the collection of municipal waste and secondary raw materials, the volumes of waste generated and disposed of, and the general use of secondary raw materials were determined;
- the main operators of the market of secondary raw materials and processors of secondary raw materials in Ukraine were determined, the problems of the market of the market of secondary raw materials and their main potential consumers were analyzed;
- established actions regarding the implementation and operation of the proposed municipal and commercial system for the collection and treatment of bio-waste (organic, green waste);
- the general concept of compost consumers was developed, advice was given on the formation of the marketing strategy of the enterprise in the field of waste management and on the implementation of compost taking into account European experience.

GLOSSARY

Bio-waste means waste that is subject to anaerobic or aerobic decomposition, such as food waste or food industry waste at all stages of production and consumption, green waste.

Waste disposal is an operation that is not waste recovery, even if one of the consequences of such an operation is the use of substances or energy.

Waste recovery is an operation, as a result of which waste is used for useful purposes, replacing materials that should have been used to perform a certain function or that are prepared to perform this function in an enterprise or other economic activity.

Materials recovery – any operation for the recovery of materials, other than the production of energy and the conversion of waste into materials that can be used as fuel or for other energy production, which may include the preparation of waste for reuse, recycling, backfilling and other operations.

Waste – any substances, materials and objects that their owner gets rid of, intends to get rid of or must get rid of.

Food waste means all food as defined in the Law of Ukraine "On the basic principles and requirements for the safety and quality of food products"[1] that has become waste

Waste holder means the natural or legal person who generates the waste or who by the law, owns, uses and disposes of waste.

Waste landfilling means placement of waste on the surface or under the surface (underground) of the earth in a way that does not pose a threat to human health and the surrounding natural environment and does not involve further treatment of waste.

Waste storage means storage of waste at collection facilities, including before its treatment, for no more than one year from the moment of its generation, which is safe for human health and the natural environment by ecological and sanitary-epidemiological requirements.

Waste collection means the activity related to the extraction, purchase, accumulation and placement of waste in specially designated places or objects, including sorting of waste for further transportation to a waste treatment facility.

Inert waste means waste that does not undergo physical, chemical or biological changes and transformations, does not decompose, does not burn, does not decompose, does not harm other objects with which it comes into contact, and does not harm people's health and does not lead to environmental pollution.

Waste treatment facility is an installation, engineering structure, or other facility used for waste recovery or disposal operations.

Waste treatment means recovery or disposal operations, including preparation prior to recovery or disposal.

Waste management operations – collection, transportation, recovery and disposal of waste.

Waste transportation is an operation consisting of the transportation of waste from the place of its generation to the waste treatment facility, as well as from one place/facility to another.

Municipal waste means mixed waste and/or separately collected waste from municipals, including paper and cardboard, glass, metals, plastics, wood, textiles, packaging, bio-waste, waste electrical and electronic equipment, hazardous waste in municipal waste, bulky waste, repair waste, as well as mixed and/or separately collected waste from other sources, if this waste is similar in composition to municipal waste.

Municipal waste does not include waste from production, agriculture, forestry, fishing, septic tanks and sewage network and treatment, including sewage sludge, end-of-life vehicles or construction and demolition waste, street garbage, or medical waste.

Landfill means place of waste landfilling, intended for its placement on the surface or under the surface (underground) of the earth.

[1] https://zakon.rada.gov.ua/laws/show/771/97-%D0%B2%D1%80#Text

Municipal waste management service means operations of collection, transportation, recovery and disposal of municipal waste, as well as activities related to the organization of the municipal waste management system, carried out by the provider of the municipal waste management service.

Acceptance of waste means receipt of waste generated as a result of the consumption/use of products for the producers of which the extended producer responsibility is established by law, in places of sale, administrative, social, public, commercial, entertainment, recreational, tourist and other institutions, as well as mobile reception points waste by the procedure established by law.

Recycling means recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the retreatment of organic material but does not include energy recovery and the retreatment of materials that are to be used as fuels or for backfilling operations.

Separate collection of waste means the separate collection of waste depending on its type, characteristics and composition in a way that will facilitate its further treatment.

Municipal waste management system means a plant of measures for the collection, transportation and treatment of municipal waste, including the creation and provision of facilities, their supervision and further care of municipal waste disposal facilities, as well as the activities of business entities that carry out separate municipal waste management operations within a territorial community or several territorial communities.

Waste sorting means an operation related to the mechanical distribution of waste depending on its physical and chemical properties, material components, energy value, and other indicators to prepare it for treatment.

Operator in the field of waste management means a legal entity or an individual entrepreneur who collects, purchases, stores, transports, restores and/or disposes of waste by legislation.

Waste management means the collection, transport, recovery (including sorting, and disposal of waste), including the supervision of such operations and the after-care of disposal sites.

Waste producer means a natural person, a legal entity, as a result of whose activities waste is produced, as well as waste management entities that carry out sorting, mixing or other operations that lead to a change in the characteristics or composition of waste.

PART I.

ASSESSMENT OF THE MOST SUITABLE TECHNICAL SOLUTION FOR THE ORGANIC WASTE, SORTED MUNICIPAL AND COMMERCIAL GREEN WASTE MANAGEMENT

CHAPTER I. ASSESSMENT OF TECHNICAL SOLUTIONS FOR BIO-WASTE MANAGEMENT

1.1 General information on the management of bio-waste (municipal and commercial waste from green spaces and other biodegradable waste)

The concepts “waste from green areas” and “biodegradable waste” and the issue of managing these types of waste were introduced into Ukrainian legislation when the Law of Ukraine “On Waste Management” entered into force on 09.07.2023 as a component of bio-waste. In addition, the above-mentioned law provides for a reduction in landfilling of biodegradable waste, which fully complies with the requirements of Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste as amended by EU Regulation 1882/2003.

The system of management of municipal and commercial bio-waste, including waste from green areas and other biodegradable waste, includes a set of measures for their collection, transportation and treatment (recovery and disposal), including the creation of appropriate treatment facilities. The most common operation for removing waste after the operation for its recovery, which does not involve further treatment, is the burial of waste, namely, the unusable residue.

The choice of technical solutions for bio-waste management (collection, transportation and treatment) depends on many factors. Treatment of bio-waste consists of its restoration and/or removal, including its preparation for such operations, and depends on the adopted technological scheme of bio-waste collection. Recovery/removal of bio-waste takes place at waste treatment facilities by the accepted treatment technology (lists of operations for recovery/removal of municipal waste (MW) are provided in the Law of Ukraine “On Waste Management”). In the absence of waste treatment facilities, it is impossible to process the existing volumes of bio-waste generated in the settlement.

The main measures to solve the existing problems and threats related to municipal waste are the prevention of hazardous waste suitable for recycling and recovery from entering landfills by implementing a clear accounting mechanism and sharing information to control the situation and plan future activities in the field of hazardous waste management, increasing the level of coverage of the population by the service of removal of solid waste and expanding the practice of separate collection of solid waste, development of infrastructure for treatment solid waste using the best technologies and, accordingly, the most suitable technical solutions.

1.2 Preparation of bio-waste for treatment

For quality preparation for treatment, any type of waste should not be mixed with other types of waste or materials with different properties, that is, collected separately. That is why the separate collection of waste precedes the stage of waste treatment and ensures the efficiency of the entire subsequent treatment process. The introduction of a separate collection of waste depending on its type, characteristics and composition will create conditions for separate collection of bio-waste (municipal and commercial waste from green spaces and other biodegradable waste), which will further facilitate their treatment. Models of separate collection are formed depending on the accepted model of waste management, which is determined by the regional waste management plan in the region. The regulations “Methods of separate collection of municipal waste” are used for the separate collection of municipal waste and its implementation[2].

After choosing a technological scheme for the separate collection of waste in the city, the type of containers for collecting bio-waste is determined and their number is calculated, a rational scheme for the location of containers is established and, if necessary, container sites are built for them. By the Methodology for the collection of bio-waste, a brown container with the appropriate inscription “bio-waste” of various capacities, starting from 120 l and above, is installed at public facilities (Fig. 1.1 shows the examples of containers).

[2] https://zakon.rada.gov.ua/laws/show/z1157-11#Text

Capacity 0.120 m³ Capacity 0.240 m³ Capacity 1.1 m³

Figure 1.1 – Container for bio-waste

In the future, the selection of the types and number of specially equipped vehicles for the transportation of bio-waste is carried out, taking into account the system and mode of their transportation to the bio-waste management facility.

1.3 Most common methods of treatment bio-waste

Microbiological processes (anaerobic and aerobic) are most widely used to treat various components of bio-waste, which are provided by the ability of microorganisms and their enzymes to decompose/transform complex bio-waste to obtain useful products of microbiological synthesis and waste treatment (fermentation/fermentation and composting).

1.3.1 Anaerobic fermentation

During anaerobic fermentation, individual components of bio-waste undergo decomposition into methane, carbon dioxide and water under the influence of bacteria and in the absence of oxygen, pass through various stages. In principle, the technology is aimed at reducing the biological activity and reaction potential of waste, as well as obtaining biogas, which is used as an energy carrier. Fermentation is a biological stage integrated into the mechanical-biological treatment (MBT) of waste and occurs with subsequent composting of the sediment obtained in the fermentation process (it can be divided into solid and liquid fractions). The liquid part of the sediment can be used as a liquid fertilizer, the solid part is processed into compost.

The process of anaerobic fermentation technology is closed, so there are no emissions of harmful substances into the atmosphere, methane losses due to loose components of the system are up to 5% of the produced methane. In general, the positive effect of the method for preserving the climate consists in preventing the release of methane from bio-waste that should have been stored; reducing the emission of harmful substances due to the replacement of primary energy sources; reducing the need for mineral fuel.

The technological purpose of anaerobic fermentation is:

- energy production from waste;
- reducing the amount of waste that is taken out for disposal at the landfill;
- reducing the risk of waste during the operation of the MWTP.

Table 1.1 shows the list of wastes most suitable for the anaerobic fermentation method.

Table 1.1 – Types of waste most suitable for the anaerobic fermentation method

Type of waste	Features of use
Food and green waste (garden, vegetable garden)	–
Mixed municipal waste	especially for decontamination of small organic fractions, for example, before disposal at a landfill
Specific production or industry waste	separately collected waste (food waste, industrial food waste, separated fats, agricultural waste, liquid manure, meat plant waste, meat treatment waste (after pressure sterilization), market waste)
Other types of waste	sewage treatment plant sludge, biological sludge from aerobic treatment, organic substances

Table 1.2 shows the special characteristics and basic requirements for the application of the method of anaerobic fermentation of bio-waste (including the form and scope of its application).

Table 1.2 – Special characteristics and basic requirements for the application of the method of anaerobic fermentation of bio-waste

Special characteristics and application requirements	
Necessity of preliminary treatment	waste should be gathered separately and with necessity subject to grinding and proof to necessary size particles. Some waste (for example, waste slaughterhouses) before fermentation is necessary to disinfect
Possibilities of using the initial material	precipitate fermentation dehydrate, after it can be added to other components of bio-waste and apply for further composting and sanitization in those the same goals and compost, received by composting Direct application sediment on agricultural lands possible by certain conditions, respectively, allowed at the legislative level of the country. In other cases dried up remainder fermentation is used for receiving energy
Possibilities of removal and disposal of initial material	leftovers fermentation and sifted film subject to treatment by other ways (for example, thermal)
Necessity of further measures, additional treatment	liquid fraction of fermentation sludge contains residual concentrations of particles and all dissolved components, so further disposal is required, for example, in the form of transportation to local sewage treatment plants. Waste produced in the fermentation process must be taken to a landfill. At the same time, waste from screening and fermentation is generally suitable for composting or other types of treatment
Special safety requirements	the air leaving during the fermentation process (especially from the reception and mechanical treatment areas) must be collected and cleaned, or appropriate technical and organizational measures must be taken to divert (reduce the volume) emissions (especially odors)
Potential health risks	in the area of reception and mechanical treatment of waste, there is a risk of increasing the concentration of microorganisms and spores in the air. Therefore, they should take appropriate technical measures and use personal protective equipment
Aids and materials	water (50-200 l/t of waste) and some additives (coagulating agents (for example, ferric chloride); agents that inhibit foaming; substances to adjust the pH value)

Special characteristics and application requirements	
The need for personnel	depending from structures systems and technologies fermentation, necessary on smaller measures 3 employees. Qualified personnel are necessary especially in region management and monitoring technological processes
Required area, implementation features	the need for space for anaerobic fermentation plants (without an area for finishing the fermentation sludge) is wet fermentation units – 0.150-0.250 m²/t, sequential dry fermentation units – 0.125-0.275 m²/t, intermittent dry fermentation units – 0.125-0.200 m²/t

Units for anaerobic fermentation of bio-waste should be built in places with the presence of engineering communications, which have access to the power supply network, and if possible, near the areas of accumulation of the corresponding waste. As a rule, there is no need for their considerable distance from residential areas (as in the construction of most bio-waste treatment plants). There are no restrictions regarding climatic conditions, however, in cold climatic conditions, fermentation reactors must be equipped with thermal insulation and heated (especially during thermophilic processes). This technology is not suitable for regions with a high water deficit.

Key moments of the anaerobic fermentation process there is the type of contact of waste with microorganisms, the composition and moisture content of the input material (in liquid, paste-like, solid form) and the type (degree) of mixing. As a rule, anaerobic treatment includes the following phases:

- *preliminary treatment* – even with separate collection from separately collected municipal bio-waste, as a rule, it is necessary to remove unwanted impurities (polymers, metals, large fractions of waste), such separation can be carried out in dry or wet conditions. The material is then subjected to homogenization by grinding, thanks to which the next phase of fermentation and the organization of the process itself is improved. Both MBT technology and traditional methods and aggregates can be used for separation and grinding;
- *fermentation* - there are various methods of effective fermentation, which differ among themselves in terms of temperature conditions and the concentration of dry matter in the starting material. The general rule is as follows: the higher the temperature, the faster the fermentation process. Thermophilic installations operate at a temperature of about 55°C (50-65°C), and mesophilic ones at about 35°C (20-45°C), the share of dry matter in dry fermentation is approximately 20-40%, and in wet fermentation – from 5 to 20%. Thermophilic processes are less controllable and require higher energy consumption (biogas consumption for needs) to maintain the required temperature. In dry systems, only single-stage processes are always used, which are less sensitive to fluctuations in conditions compared to multi-stage processes. However, the yield of biogas in these systems is lower.

Table 1.3 shows the approximate investment, operating and specific total costs and possible revenues of the method of anaerobic fermentation of bio-waste.

Table 1.3 – Estimated performance indicators (costs and revenues) of the anaerobic fermentation method bio-waste

Investment costs	Operational costs	Specific general costs
Depending on the applied method, it is estimated*, EUR/t of raw material/year, for installations: - intermittent dry fermentation – 150-310;	Depending on the applied method, it is estimated*, EUR/t of raw material/year, for installations: - intermittent dry fermentation – 15-30;	No data available*

Investment costs	Operational costs	Specific general costs
- sequential dry fermentation – 250-480; - wet fermentation – 260-490; - fermentation (with partial production of electricity) – 40-100	- sequential dry fermentation – 18-38; - wet fermentation – 20-50; - fermentation (with partial production of electricity) – 5-15. Repair and maintenance is 4-6% of investment costs annually	
Possible income		
- from the sale of compost - from the realization of the received electricity (about 10-30 EUR/t of bio-waste)		

* with a total volume of input material of 20,000 tons /year, with a decrease in the amount of input material, specific costs increase due to constant cost items

Table 1.4 shows the main advantages and disadvantages of the anaerobic fermentation method.

Table 1.4 – Advantages and disadvantages of the method of anaerobic fermentation of bio-waste

Advantages	Disadvantages
1) can be treated as dry and wet bio-waste 2) the produced biogas can be used to produce electricity and heat, and, accordingly, for their own energy needs or profit 3) fermented substrates can be disposed of in liquid or solid forms 4) installations occupy a relatively small area 5) the technology leads to a reduction in the amount of waste sent to landfill and/or incineration, which helps to reduce the emission of harmful substances caused by these processes	1) the relative complexity of the technology, construction cost, and operating costs vary significantly depending on the type of installation 2) application of the technology may lead to additional water needs 3) limitation of the efficiency of the process for the initial mass containing a wood component, due to the impossibility of destruction of lignin and cellulose 4) the fermentation process is vulnerable and requires constant monitoring, the efficient operation of the system requires the appropriate qualification of personnel or operators who must be able to quickly respond to all changes in the biological process so that it does not collapse

1.3.2 Composting

The most common bio-waste treatment method is composting, a biological aerobic process that converts easily degradable bio-waste into carbon dioxide and stable organic matter. During oxygen composting, air reacts under certain conditions with organic materials to form CO_2, water and humus compounds. As a result of the processes of biological decomposition, the material naturally heats up. At the beginning of the process (the main phase), high temperatures occur (up to approximately 65-75°C), which determine the drying of the material and its sanitization. By the end of the process, the temperature slowly decreases. The solid residues of the process are compost and other residues (requiring further treatment).

During biological processing, significant volumes of CO_2 and other (greenhouse) gases are released. Nevertheless, in contrast to incineration or storage of untreated waste, during composting,

a significant part of carbon is bound in the substrate, which prevents its rapid release into the atmosphere.

The technological goal of composting is:

- production of commercial compost;
- reducing the amount of waste that is taken out for disposal at the landfill;
- reducing the danger of municipal waste during the operation of the landfill.

Table 1.5 shows the list of waste most suitable for the composting method.

Table 1.5 – Types of waste most suitable for composting

Type of waste	Features of use
Food and green waste (garden, vegetable garden)	–
Paper/cardboard/cardboard products	Only certain parameters (such as moisture-resistant or special paper) in small quantities and only in combination with other wet organic materials
Wood waste	Only unprocessed wood waste, material treatment of which is not economically beneficial
Specific production or industry waste	Kitchen waste and residues, agricultural and forestry waste, including manure, biodegradable food industry waste
Other types of waste	Separately collected, biodegradable materials without hazardous ingredients

Table 1.6 shows the special characteristics and basic requirements for the application of the bio-waste composting method (including the form and scope of its application).

Table 1.6 – Special characteristics and basic requirements for the application of the bio-waste composting method

Special characteristics and application requirements	
Necessity of preliminary treatment	waste is subject to separate collection, control for the presence of impurities containing harmful substances (for example, nutrients), as well as removal of these and other components that complicate the composting process (for example, large pieces of film). Large-sized waste from trimming trees and shrubs must be shredded
Possibilities of using the initial material	the resulting compost can be used mainly in agriculture, horticulture, landscaping, as a substrate for the cultivation of special crops (fruits, grapes, asparagus), to improve the soil and in private plots. Sawdust generated from trees can mainly be used for energy purposes (for example, in biomass power plants)
Possibilities of removal and disposal of initial material	composting waste (screened film, etc.) are subject to treatment in other ways (for example, thermal)
Necessity of further measures, additional treatment	absent, sanitation occurs during the composting process, but it is desirable to control the quality of compost. Sifting waste and seeping water are to be removed (processed)
Special safety requirements	exhaust air from composting facilities must be collected and cleaned, or appropriate technical and organizational measures must be taken to prevent (reduce the volume of) emissions (especially odors)
Potential health risks	in the zone of acceptance and mechanical treatment of waste, there is a risk of increasing the concentration of microorganisms and

Special characteristics and application requirements	
	spores in the air. Therefore, they should take appropriate technical measures and use personal protective equipment (aspiration, respirators)
Aids and materials	special aids and materials are not required
The need for personnel	the need largely depends on the performance of the installation. Approximately 10 people are employed at an average installation (1 director, 6-8 operators and repairmen, 1 employee for receiving and shipping). In the presence of pre-mechanized areas, the need for personnel increases, especially for manual sorting operations
Required area, implementation features	the space requirement for intensive composting facilities is about 0.2-0.3 m^2/t per year. The space requirement for open systems is much higher. It depends on the height of the sides, their shape and mixing technology. For triangular sides with a base width of 3 m, 1.4 m^2/m^3 is required. In the absence of automatic mixing, the required area can decrease to 1 m^2/m^3. For trapezoidal sides with a height of 3 m and a base width of 10 m, 0.45 m^2/m^3 is required. Often, the method of composting and the shape of the edges are chosen based on the size of the available site. When calculating the total area of the installation, you can use the following approximate data: - 5% – waste unloading area, - 10% – site for storing finished compost, - 10% – intermediate storage area and other areas, - 75% - composting area (of which 40% – for moving equipment)

Composting technologies in municipals have become widespread in practically all European countries - in the EU, 20% of private sector residents carry out municipal composting. Bio-waste composting has not yet been implemented at the industrial level in the settlements of Ukraine. Composting is done independently by a part of the residents on the territory of the manor building.

Composting can take place following the rules established by the central executive body, which ensures the formation of state policy in the field of housing and communal services, as directly in municipals - on homesteads, summer cottages and garden plots (independently implemented in compost pits or with the use of special composting devices), as well as centrally (generators on homesteads, summer cottages, and garden plots provide separate collection of bio-waste, which is then transported to specially equipped sites or to silo towers, where compost is placed). Subsequently, such compost is used for the needs of the green/agricultural sector of the city or, if necessary, for residents' municipals as fertilizer to improve the mineral nutrition of plants, and to accelerate the growth of crops and ornamental tree species.

Table 1.7 shows the approximate investment, operating and specific total costs and possible revenues of the bio-waste composting method.

Table 1.7 – Approximate indicators of operation (costs and income) of the method of bio- waste composting

Investment costs	Operational costs	Specific general costs
Mainly: - laying engineering communications – depending on local	1) insurance, current operation (fuel and lubricants, electricity, insurance, etc.);	About 30-70 EUR/t (composting municipal bio-waste is more expensive – 50-70 EUR/t than composting tree

Investment costs	Operational costs	Specific general costs
conditions and installation sizes and process type; - construction structures – 70-100 euros/t per year; - machines and equipment – 110-140 euros/t per year (the purchase of an irrigation unit costs approximately 2,000 euros)	2) repair and maintenance (% of investment volume): - building structures: about 1%; - machines and electrical engineering: about 3-4%; - mobile devices: 8-15%; - salary (depending on the situation on the labor market) *open composting = 35 euros/t, closed composting = 65 euros/t	and shrub trimming waste – 30-50 EUR/t) ** during the operation of composting systems, there is no sharp decrease in specific costs due to increased turnover, which is explained by the fact that costs due to the design of the installation grow in direct proportion to turnover
Possible income		
from the sale of commercial compost		

Table 1.8 shows the main advantages and disadvantages of the composting method.

Table 1.8 – Advantages and disadvantages of bio-waste composting method

Advantages	Disadvantages
1) production of a scarce product that is in high demand 2) the possibility of recycling a significant share of waste, which leads to the unloading of landfills and other waste treatment facilities, allowing to reduce the harmful environmental impact and the number of costs 3) relative simplicity of management of, high reliability of the system 4) relatively low volume of investment funds 5) the technology is widespread and there are no opponents	1) the possibility of treatment only some organic fractions of municipal waste 2) the need for separate collection of biological waste 3) a rather high need for space, a long treatment process 4) high requirements for the quality of the raw material (compost) can lead to problems in its sale 5) partly unpleasant odors near the installation

1.4 The existing bio-waste management system in Uzhhorod

1.4.1 Calculation of the amount of bio-waste

The group of bio-waste includes all organic components that are capable of biological decomposition: waste from green plantings (flowers, grass, leaves, weeds, etc.), food waste (vegetable and non-vegetable origin-remains of vegetables, fruits, bread, cereals, cheeses, meat, fish, animal feed, etc.) and other waste (bones, feces, etc.).

As a result of the calculations, the amount of waste generated from green spaces in Uzhhorod from public improvement facilities (parks, squares, etc.) and the adjacent territories of the multi-apartment sector, the adjacent territories of individual buildings with a plot of land (Table 1.9). When calculating the amount of waste from green spaces in private municipals and at the facilities of Uzhhorod, a part of the volume of bio-waste generation in the composition of mixed organic waste (only waste of vegetable origin) was taken into account, which is planned to be removed from organic waste by separate collection.

Table 1.9 – Characterization of volumes of bio-waste generation in Uzhhorod

Year	Number of calculation units for 2023, thousands of people	Waste generation rate (norm) from green spaces, kg/person per year	Estimated volume of waste from green spaces in private households, t/year	Estimated volume of waste from green spaces at landscaping facilities, t/year	Volume of bio-waste, as part of mixed municipal waste, t/year
2023	23.2	5.7	132.2	302.4	692.9
2030	33.0	5.7	188.1	699.0	721.9

Notes: The bulk density of leaf litter and clippings is 0.07 t/m³. The rate of waste generation from green areas (norm) is 0.007 m³/m². Only waste of vegetable origin is included in the volume of bio-waste generation in the composition of mixed municipal waste, the percentage of extraction is taken to be 0.05

It was established that the volume of waste generation from green spaces from the residential areas of the residential sector (multi-apartment and estate buildings) and the territories of non-production facilities (commercial, administrative, etc.) is significantly smaller compared to municipal greening facilities, which produce the main amount waste from green spaces in the city. According to the received data, the majority of waste from green spaces in Uzhhorod is generated by public improvement facilities (parks, squares, etc.). Volumes of generation of a part of bio-waste in the composition of mixed waste (only waste of vegetable origin), which can be removed by implementing a container scheme for their collection, are also significant and almost equal to volumes of waste generation from green plantings.

The generation of waste from green spaces in private municipals and landscaping objects (parks, squares, etc.) is seasonal (warm season) and has the greatest significance at the end of summer and autumn. The formation of a part of bio-waste in the composition of MW occurs continuously throughout the year. Characteristic short-term increases in the content of bio-waste in the composition of municipal waste are observed in August, September and on holidays.

These norms of formation are not included in the scope of providing services for the removal of hazardous materials. To be able to plan the economic activities of the enterprise in the field of waste management in the future, to optimize the work on the removal of waste from green areas and part of bio-waste from the composition of mixed waste (only waste of plant origin, collected separately) in Uzhhorod, it is necessary to take into account the results obtained in the scope of service provision from the removal of municipal waste by establishing the rate of generation of the corresponding waste.

1.4.2 Existing bio-waste management system

Waste from green areas is formed in the adjacent areas of residential areas, green areas and industrial zones of Uzhhorod in the process of taking care of green spaces, collected in the places of formation (during the performance of work by employees of communal enterprises, for example, when trimming trees, bushes and lawns) or accumulate at container sites, after which they are transported by dump trucks to designated sites for the storage of such waste and landfill sites. The population of the private sector of Uzhhorod, after carrying out work on their home plots, either composts part of it on the territory of their municipals or also carries out the removal of all bio-waste (including leaves and grass) by their transport or ordered removal from the communal service.

Another part of the generated bio-waste in Uzhhorod collects and accumulates a total amount of mixed municipal waste in the course of life in containers at container sites, after which it is transported by garbage trucks for disposal at the landfill. The population of the private sector of the city, after receiving such waste, composts either part of it on the territory of their municipals or also collects bio-waste without separating the components in individual/common containers within the framework of the city's municipal waste management system.

There is no separate statistical record of the volume of generation and removal of bio-waste.

Thus, as of 2023 in Uzhhorod *collection of* individual components of bio-waste (waste from green areas and other components of bio-waste) is carried out as part of the general system of collection of solid waste - without separation of bio-waste from the total volume of solid waste. Also, bio-waste generators can independently collect and process bio-waste by composting on homestead, country and garden plots following the rules established by the central executive authority[3].

Waste from green areas after collection *is transported* by specially equipped transport to the landfill site in the village Barvinok – city ones are transported by the utility company as needed and accumulated, commercial ones – based on relevant contracts (by order). The population of the city has the opportunity to order individual removal of the received waste from green areas from the communal service. Another part of the generated bio-waste after collection is transported by specially equipped transport to the waste disposal site in the village Barvinok in the total volume of mixed municipal waste according to the existing system of municipal waste management.

There is no centralized *treatment* of collected bio-waste in Uzhhorod. Due to the lack of introduction of modern technologies for the treatment of waste containing organic components capable of biological decomposition, only about 20% of the total volume of this type of waste is not removed to the landfill in the city - it is waste from green vegetation (fallen leaves and grass, clippings trees and bushes, etc.) and another share of bio-waste of plant origin from the population that composts on their homesteads.

1.4.3 Results of a sociological survey of residents to form measures for educational campaigns

According to the results of the study of the morphological composition of municipal waste generated in Uzhhorod, bio-waste is 38.6% by mass[4]. The average statistical generation of solid waste per resident in Uzhhorod per year is 436 kg. For comparison, the average statistical generation of solid waste per inhabitant per year in Poland is 362 kg[5]. Thus, one inhabitant of Uzhhorod generates about 17% more municipal waste than one inhabitant in Poland.

Directive 2008/98/EC[6], the requirements of which are embodied in the Law of Ukraine "On Waste Management", also calls for reducing the volume of waste generation[7]. The first step of the five-step hierarchy of waste management is aimed at developing measures to prevent the generation of waste. Development of measures for future educational campaigns should be based on behavioral analysis of citizens.

To identify the behavioral aspects that affect the amount of municipal waste generation, a survey of public opinion was conducted through a sociological survey. The survey was conducted using Google Forms on social networks and web pages of the Uzhhorod City Council. 299 respondents took part in the survey.

It should be noted the high level of public activity, orientation to ecologically based actions and willingness to interact with local authorities. Thus, 91.6% of respondents note the need to reduce the volume of municipal waste in everyday life. At the same time, 87% of respondents would use simple advice from local authorities on how to rationally and ecologically handle waste at home or work, if such advice were available.

61.2% of respondents thoroughly prepare for future purchases in the supermarket and make a list of the necessary goods. 29.1% sometimes make a list of products and 9.7% do not make a list of products for purchase at all. 51.2% of respondents sometimes find unnecessary food that they bought recently.

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[3] Rules for Composting Bio-waste by its Generators on Homestead, Summer Cottages and Garden Sites // https://zakon.rada.gov.ua/laws/show/z1271-23#Text

[4] "Analysis of the Current Waste Management System: Item 1.1 Analysis of the Current Waste Management System in Uzhhorod and Item 2.1. Analysis of the Biodegradable Waste Management in Uzhhorod" within the framework of the Project "Contribution to the Sustainable Management of Municipal Waste in Uzhhorod" (Grant Agreement NAKOPA E-UKR.1-20 from 14.11.2020), 2022

[5] Eurostat // http://surl.li/kjgck

[6] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste // https://www.kmu.gov.ua/storage/app/sites/1/55-GOEEI/ 2008-98-ec.pdf

[7] https://zakon.rada.gov.ua/laws/show/2320-20#Text

Only 4.3% of residents always throw away edible food, 34.1% do it sometimes, and 61.5% never throw away edible food.

76.6% of respondents sometimes find in their refrigerator food products that have already spoiled and are not suitable for consumption, and 12.7% often find this to be the case.

34.1% of respondents at home or work sometimes throw food products that can still be used into the garbage can.

Only 19.4% of residents indicated that they have an active composting plant or pit in their households. 32.8% of respondents use food waste for their household as animal feed or for obtaining compost.

91.3% of respondents are ready to collect food waste separately in a special separate waste container if they know that there is a composting station in the city. 60.5% of respondents are ready to use compost obtained from food waste as fertilizer on their plots of land.

1.5 Proposed technical solutions for bio-waste management in Uzhhorod

The issue of bio-waste treatment and consumption of the products of their treatment concerns important social, economic and environmental relations that require comprehensive regulation.

1.5.1 Formation of measures for educational campaigns

According to the results of the assessment of behavioral aspects, which were clarified with the help of a sociological survey of the residents of Uzhhorod, the following conclusions can be formulated and appropriate measures can be formulated:

1. There is a high level of potential population involvement in future waste management innovations. The population is ready to support the introduction of a separate collection of bio-waste and the creation of a composting station. Part of the population is ready to use the received compost of appropriate quality for their own municipal needs.
2. Bio-waste is the largest share of municipal waste. Therefore, when creating measures for educational campaigns on environmentally responsible waste management at the municipal level, it can start with measures aimed at reducing bio-waste content.
3. Educational campaigns should include the following:
   a) encouraging citizens to make planned purchases;
   b) encouraging periodic checks of the refrigerator (reminders, creation of a symbolic Refrigerator Day, etc.);
   c) drawing attention to healthy food and food culture in general;
   d) educational activities on the inadmissibility of throwing away food products that have not yet expired;
   e) encouraging composting in municipals on homestead plots.
4. It is necessary to create simple and clear rules of behavior of citizens on waste management in municipals. These rules should contain simple provisions aimed at minimizing waste generation, proper collection of waste by type (collection points) necessary sources of additional information, and contact details of special communal services. These rules can be broadcast through the official social pages of local self-government bodies, and special city applications or distributed to citizens in paper form.

1.5.2 Proposed variants of the bio-waste management system

See Annex A for possible variants for bio-waste management in Uzhhorod.

Collection and transportation

The presence of a large volume of biodegradable waste (waste from green areas, food waste) leads to their excessive accumulation and the need for removal by residents and, as a result, to the contamination of other solid waste and separated secondary raw materials, to which they are added,

further, when they get into to landfills - worsens the ecological and sanitary condition of landfills, since the biological decomposition of organic components of landfills is the main reason for the formation of leachate and biogas, which are harmful migrations into the surrounding natural environment. Therefore, it is important to separate bio-waste, which can make up to 40% (by mass) according to the morphological composition of solid waste in Uzhhorod, from the total amount of municipal waste by implementing a *separate collection* and *separate transportation* to the waste treatment facility. Accordingly, this requires the introduction of other methods of treatment such as waste in Uzhhorod.

Bio-waste treatment

Currently, there is an urgent need to introduce modern bio-waste treatment technologies in Uzhhorod, including municipal and commercial waste from green areas and part of bio-waste from mixed waste. One of the priority directions in the development of the field of bio-waste management is the use of biological treatment methods (aerobic composting and anaerobic fermentation), which allow for to reduction of the volume of waste by obtaining target products (including the return of a part of organic materials for reuse) and significantly reduce the amount of waste to be disposed of at landfills.

Determination of the bio-waste treatment method

As of 2023, for the conditions of Uzhhorod, based on the above-mentioned descriptions of the most common methods of bio-waste treatment, the available amount of generation and composition of bio-waste components in Uzhhorod, the use of anaerobic fermentation technology of bio-waste is impractical due to the presence of special requirements for the operation of installations and high implementation costs and further operation. Installations for anaerobic fermentation of bio-waste should be built in places with the presence of engineering communications, which have access to the power supply network, and if possible, near the areas of accumulation of the corresponding waste. There are no restrictions regarding climatic conditions, however, in cold climatic conditions, fermentation reactors must be equipped with thermal insulation and heated (especially for thermophilic processes). This technology is not suitable for regions with a high water deficit. In the long term, when economic feasibility is established, it is possible to introduce the method of anaerobic fermentation of bio-waste, which is a renewable source of energy.

Therefore, the priority method of management of separately collected bio-waste (municipal and commercial waste from green spaces and biodegradable waste), which has the property of undergoing anaerobic or aerobic decomposition, for implementation in Uzhhorod, is the composting method, which is explained by the presence of a large share of bio-waste as a part of the WW, the lowest level of capital investment and operating costs compared to alternative methods of waste treatment (waste incineration, disposal at MW landfills) and compliance with environmental safety requirements. The main difference between this method and the biostabilization of mixed municipal waste is that to produce high-quality compost that can be used for various purposes (and removed from the landfill), the method requires separately collected material to avoid contamination of the final product.

At the initial stage of the implementation of the bio-waste management system in Uzhhorod, its treatment can be started with a relatively simple method, for example, with centralized composting of separately collected municipal and commercial green waste (waste from landscaping, gardens, etc.) and similar waste that requires minimal pre-treatment and will produce high-quality compost that can be used as a soil conditioner, suitable for use in agriculture and for other purposes. In addition, some residents of individual buildings in Uzhhorod (private sector houses) with a plot of land have the opportunity to organize the storage (composting) of waste from green areas (fallen leaves, grass clippings and branches after pruning trees in autumn and spring) in their yard. Therefore, for residents of individual buildings, it is proposed to introduce a separate collection of bio-waste, which should include stimulation and encouragement by local self-government bodies of residents to separate collection and composting of bio-waste in private municipals by installing individual composters in the yards of municipals (Fig. 1.2) and simultaneously conducting powerful informational work with the population.

Figure 1.2 – Individual composter of industrial production

Household owners based on their needs determine the number and parameters of individual composting equipment. For a household of 2-3 people, an individual composter with a capacity of 1 m^3 can be recommended. By encouraging private sector residents, it is possible to involve up to 10% of the population in composting in city municipals by 2030. This will remove approximately 5% of the total volume of municipal waste generation. Another part of the bio-waste generated in the private sector will enter the municipal waste collection system in a “grey” container with mixed waste.

First of all, the waste that will be composted at the first stages of the implementation of the method – classified green waste (leaves, young cuttings, garden waste from municipals) and separately collected food waste (mainly kitchen waste and food scraps, which are usually fine-grained with a high degree of moisture and a minimum C/N ratio, therefore ideal for mixing with green waste).

The main condition for obtaining commercial compost is the need to separately collect compostable waste and exclude its mixing with other types of municipal waste. Improperly collected bio-waste containing plastic, glass or metal is not suitable for composting. Composting of mixed MSW can be used as a preliminary phase before waste disposal.

The presence of harmful substances in the raw materials is not allowed - additional processing of the raw materials before composting allows to improve their quality, but does not ensure the separation of fractions from mixed household waste that meet the high requirements for the purity of compost. Necessary preliminary mechanical treatment may include the following operations: separation of impurities and pollution; grinding; separation of metals. In addition, preliminary mechanical treatment allows to obtain the optimal C/N ratio and the necessary structure of the starting material of composting by combining different bio-wastes - leaves (high carbon, low nitrogen) can be combined with food waste (high nitrogen), which allows to reduce the amount of ammonia, which is released in the first stages of composting.

Initially, bio-waste composting should be carried out using separately collected green waste generated only in Uzhhorod. In the future, it is necessary to gradually expand the list of waste accepted by the composting station for treatment, adding separately collected other municipal and commercial waste, which has the greatest suitability for composting, and create an opportunity to accept bio-waste from other communities. In this way, the generated bio-waste will be transformed into a safer and more stable product.

For further reporting at the regional level, regarding the implementation of targets set by the National Waste Management Strategy in Ukraine until 2030[8], it is necessary to establish a system of accounting (calculations) of bio-waste that will be composted.

[8] https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80

Given the low density of separately collected green waste, it is economically impractical to transport it to a remote treatment facility, for example, to a regional waste disposal site, therefore variants for centralized composting of separately collected green waste involve the creation of such a facility (composting station) at the territory of the city, where they will be delivered and crushed. The resulting raw materials will then be formed into compost rows and left to decompose into final compost through natural processes supported by periodic turning. The final product will have a high potential for use in crop production and horticulture.

At the first stage of implementation of the separately collected bio-waste management system, revenues from the sale of compost will be zero. Therefore, to improve the bio-waste management system and increase its economic efficiency, local compost markets will additionally need to be developed for the possibility of its implementation. It is also advisable to prepare compost according to the specific needs of the market by incorporating different types of composted humus or other natural additives that can improve the resulting compost.

1.5.3 Assessment of existing composting technologies

The range of composting technologies is extremely wide and ranges from simple to technically complex and precisely controlled. There are two fundamentally different *composting systems*: *open* (clamp) and *closed.* Table 1.10 shows the main difference between the systems.

Table 1.10 – Advantages and disadvantages of open and closed composting systems

	Open systems	**Closed systems**
Advantages	- low volume of investments - low operating costs	- optimal management - purposeful regulation of emissions - fast composting process
Disadvantages	- frequent problems with an unpleasant smell - a long process of composting - strong dependence on climatic conditions without additional measures (temperature, humidity)	- a high volume of investments

A combination of open and closed composting systems on the same site is common. Closed systems are more suitable for preliminary composting, and open systems are used for the final decomposition and ripening of compost. When planning the creation of a composting facility, one of the criteria for choosing a composting system is always the optimal use of the available space, taking into account the increase in the cost of planning and covering.

As the treatment technology becomes more complicated, the costs increase, but so do the capabilities of the technology and the value of the output material.

Composting is the simplest way of disposal and recycling of bio-waste. If disposal at landfills takes 50-100 years, then composting takes 6-18 months, depending on climatic conditions. The simplest variant is the use of individual composters on private plots of individual buildings in the city (private sector houses).

The main technical solutions for waste composting are listed below.

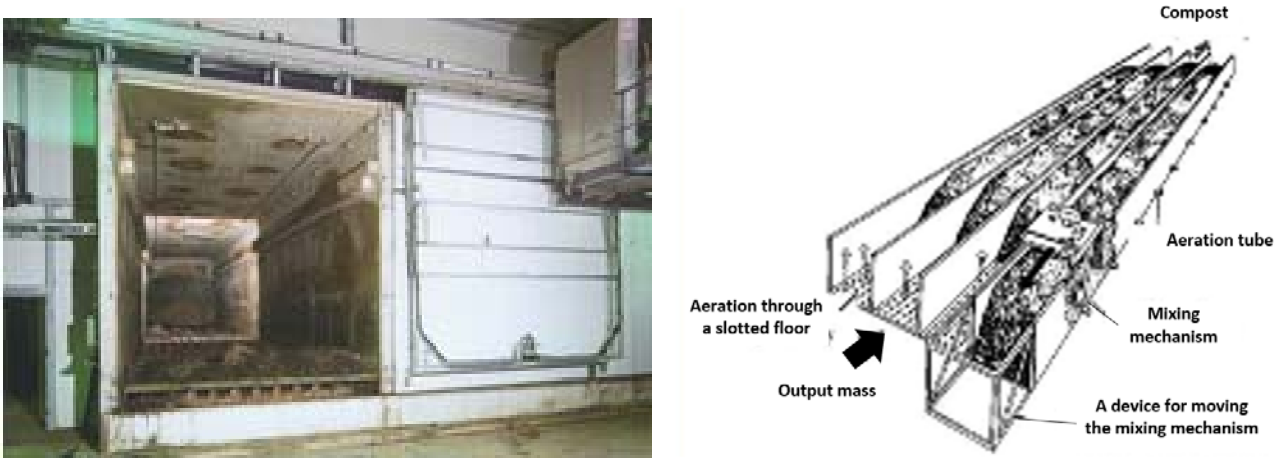
Closed composting systems

Composting is carried out in a partially closed room to prevent emissions from the treatment facility. Construction requires significant costs, so only the phase of intensive decomposition of bio-waste is carried out in a closed room.

Composting in the tunnel and rows (clamps)

One of the possible variants for closed composting systems is composting in a tunnel and closed rows (clamps) (under film, metal sheets, etc.), which is a quasi-dynamic method (the decomposing materials are mixed and rested several times during the process). Composting in the tunnel takes place in a cubic concrete structure. The decomposition process is usually continuous, but a sequential process is also possible.

Compost tunnels have a process chamber for composting, closed in the upper part, and compost rows (clamps) the material is stored between two concrete walls without a roof (Fig. 1.3, *a*, *b*).



a *b*

Figure 1.3 – An example of composting in a tunnel (*a*) and in rows (clamps) (*b*)

In practice, a system with a width of 3-5 m is used. The length of the tunnel can be different, usually, it is from 20-50 m. Rows (clamps) can be up to 2.2 m with a non-aerated system and 3.5 m with an aerated system. Compost material is turned over by an automatic device moving along a tunnel or row (clamp). The device provides looseness and moistening of the material, compaction (clumping) is compensated and such compost is transported from the entrance to the exit of the tunnel (continuous method).

An automatic fill and discharge system is available as a variant, and if the tunnel or row (clamp) is wide enough, a front wheel loader can be used. It is beneficial to combine it with an aerated floor to supply oxygen, which has a positive effect on the decomposition process. If the tunnels are located close to each other, the space-saving is enormous, the confined space is minimized. Usually, the time of action of the compost material is in a flexible range of days – up to 4 weeks.

Composting in closed rows (clamps) combines the advantages of an open and closed composting system, is a method of accelerated compost production (on average, the process takes 30 days), has various technical variants, is characterized by low treatment costs and a low construction cost with full control of emissions, as well as quality properties of compost.

The technical implementation variant – composting in rows (clamps) covered with metal sheets (Fig. 1.4) has the estimated geometric characteristics of the installation design and row of bio-waste (Table. 1.11).

Bio-waste composting in the clamps covered with metal sheets lasts 4 weeks and involves the laying of a series of perforated pipes with a diameter of 50-100 mm with hole sizes of 8-10 mm and air supply from 15 to 25 m^3/h per 1 ton of bio-waste.

Figure 1.4 – Installation for composting in rows (clamps) covered with metal sheets

Table 1.11 – Design characteristics for composting

Parameter	Value
Row height, m	3.5
The width of the lower base of the row, m	4.0
The width of the upper base of the row, m	2.0
Cross-sectional area, m²	10.5
Length of one row, m	50.0
Total area of one structure, m²	200.0

For an active composting process, it is recommended to maintain the optimal humidity of the row at a level not lower than 60%. If the temperature drops in the middle of the row, it should be moistened until the optimal humidity is reached, by watering the row (in most cases with filtrate that can be formed during the technological cycle). When preparing ready-made compost for sale, it is sifted to remove the remains of inorganic substances.

The variant of the technical execution – composting in rows (clamps) with the use of a membrane (Fig. 1.5) as protection against the release of odor occurs by installing a semi-permeable membrane on static composting blocks, which must be combined with a forced ventilation system. During irrigation manipulations, the membrane must be removed – that is, in the short term, it is impossible to prevent the release of odors and dust (bioaerosols). A semi-permeable membrane can make a significant contribution to odor reduction in the composting process, but due to the effort involved in the management of and periodic turning; this type of composting is generally not cost-effective.

Figure 1.5 – Composting in the clamps with a membrane
(source: https://www.compost-systems.com/en/solutions/windrow-composting-membrane)

Composting in a bio drum

Another closed composting system is drum composting when the decomposition process is carried out by a dynamic method since the material moves continuously in a horizontal cylindrical container that rotates around its axis (Fig. 1.6).

Depending on the manufacturer, the standard diameter of the bio drum is 1.5-5 m, the length is 20-100 m. A side effect of the drum is the degeneration of the source material with the effect of grinding.

Figure 1.6 – Examples of a closed composting system in a bio drum
(source: https://tehnix.hr/en/)

Computer-controlled air and water systems are also usually automatically controlled. Systems can be filled by mobile loaders or a fixed belt system.

The normal duration of drum composting is between 48 hours and 7 days (depending on the use of auxiliaries such as surfactants to speed up the process). Released material is usually very loose, so screening for impurities immediately after release is recommended.

The system is expensive to implement due to the use of equipment and auxiliary means and substances.

Composting in a box or container

A closed composting system that is also widely used is composting using a compost box or container.

Composting in a box (Fig. 1.7) takes place in a special fixed composting box made of concrete or metal, which has aeration and a floor for drying, and often an automatic humidification system that ensures the supply of oxygen and moisture to the closed box. The compost box is an individually controlled installation in a compact design and various standard sizes for static composting of bio-waste, in which agitation can be reduced to mixing or loosening of the material.

Figure 1.7 – Example of a closed box composting system
(source: https://www.compost-systems.com/en/solutions/box-composting)

The compost box is closed on all sides, has a long and rectangular shape and is installed horizontally. A system with a width of 2-6 m, with a possible length of the box from 5 to 30 m. The height of filling with bio-waste varies from 1.5 to 3 m. The use of a compost box is especially beneficial at the first stage of composting with an intense odor. It is possible to organize the ventilation of the compost box with the help of suction or exhaust ventilation, as well as with the help of circulating air. Exhaust air can be cleaned using biofilters or semi-permeable membranes.

Composting in a container (Fig. 1.8) takes place in a mobile metal compost container, which is equipped with an aeration and humidification system in the same way as a compost box. A version with a dynamic composting process and internal mixing of components is also available as a static system.

Container technology is a modern solution for the treatment of bio-waste, it can be equipped with intelligent software solutions, and active process monitoring and odor control systems thanks to the sealed design, and have different execution solutions for different logistics requirements and increased logistics flexibility.

Compost boxes and containers are filled and emptied using a mobile loader, so large waste treatment facilities are specially equipped with automatic devices. The current composting process is managed by a computer-controlled system without the possibility of manual intervention.

Figure 1.8 – Examples of closed composting system in a container
(source: https://tehnix.hr/en/ and
https://www.compost-systems.com/en/solutions/container-composting)

Open composting systems

In an open composting system, the compost material is not isolated from the environment; it is usually used for small composting capacities, due to low implementation costs and the possibility of easy control of the process.

Composting in open unreinforced clamps

The simplest technical solution in terms of possible costs is composting in open, unreinforced sides, where bio-waste is composted directly on the top layer of the soil (without soil compaction) (Fig. 1.9). However, in this case, special requirements regarding the location must be observed (for example, protection of groundwater).

Figure 1.9 – Composting in open unreinforced clamps
(source: https://www.compost-systems.com/en/solutions/open-unpaved-windrow-composting)

Composting in open reinforced ridges/clamps

The most common variant of open composting is composting in clamps on a reinforced base (Fig. 1.10). Depending on the material, location and facility, additional special emission control measures may be required (sheltering of clamps, ventilation system, limitation of size and type of clamp, collection of filtration water, harrowing of clamps).

Figure 1.10 – Composting in open, reinforced clamps
(source: https://www.compost-systems.com/en/solutions/open-paved-windrow-composting)

During the composting of bio-waste **using a triangular ridge** (Fig. 1.11), a smoke effect specific to a triangular ridge is used. Hot air from the ridge rises to the top, and fresh air is drawn in at the bottom by suction, which creates a natural flow of air through the ridge, which, in combination with the favorable ratio of the surface area to the volume of the ridge, ensures its effective ventilation.

The smoke effect only works with very bulky material, such as waste from pruning branches, and the height of the ridge can reach 3 m. When adding wet materials, such as organic fractions of waste or sewage sludge, the height of the ridge should be limited to 1.5-2 m. Regular overturning of the ridge prevents its sedimentation and forms air channels and also guarantees the looseness of the structure of the ridge with a uniform flow of air through its core.

Figure 1.11 – Open composting system in triangular ridges
(source: https://tehnix.hr/en/)

Optimal decomposition of compost material occurs in a short time. In addition to the advantage of increased automatic ventilation of the ridge compared to a trapezoidal or flat ridge, triangular ridges have the advantage of selective sequential treatment, due to the small size of the ridge. As a result, all the compost material collected during one week can be combined into a separate ridge, and processed separately from the material that appears during the next week. If it combines several weeks' worth of material into a flat ridge, the ridges that require turning are moved, which also has a positive effect on the treatment facility's running costs. Another advantage of triangular ridges is the efficient drainage of rainwater. In practice, it can be seen that water penetrates only 20 cm into the ridge, and a large amount of rainwater simply flows down the sides.

A triangular and flat compost clamp (Fig. 1.12) has a more effective volume performance compared to a trapezoidal pile because the material can be laid in layers without voids and cavities, which implies a higher level of heat retention in cold conditions. However, this advantage has several disadvantages in the composting process; namely, the smoke effect for automatic side aeration does not work in this case. If the clamp is not sufficiently supplied with oxygen, it is not correctly turned over, and then as a result, the composting time increases and the odors increase due to the activation of anaerobic processes. Overheating may occur in the clamp core, which affects the reduction of microbial activity. In addition, all rainwater enters the unprotected clamps, which can cause waterlogging and landslides of the clamp. For this reason, controlled decomposition processes in a flat clamp are more difficult and require much more time for the material to break down than in a triangular clamp.

Figure 1.12 – Open composting system in triangular and flat clamps
(source: https://tehnix.hr/en/)

If due to lack of space, it is not possible to avoid composting with a flat straight clamp, it is necessary to ensure a sufficient supply of fresh air with the help of active aeration. The usual overturning, because otherwise the uniform supply of fresh air is endangered, prevents the precipitation effect. In rainy areas, it is recommended to place compost sites under the roof to prevent them from flooding.

Composting in clamps under the roof

Unlike composting in open and reinforced clamps, during composting under the roof (Fig. 1.13), the filtration water is not diluted by precipitation, which significantly reduces the amount of eluate. Rainwater is collected separately and can enter untreated. In hot climates, the roof provides additional protection against drying out. In addition, an automatic watering system can be installed on the roof to maintain the required moisture level of the compost.

Composting in clamps with natural aeration and mixing assumes that the bio-waste mixture will not be isolated from the surrounding environment. The duration of the technological cycle is 6 weeks. Table 1.12 shows the geometric characteristics of the bio-waste clamp.

Figure 1.13 – External view of the composting facility in clamps under the roof (source: https://www.compost-systems.com/en/solutions/sheltered-windrow-composting and https://tehnix.hr/en/)

Table 1.12 – Characteristics of clamps

Parameter	Value
Row height, m	2.0
The width of the lower base of the clamp, m	3.3
The width of the upper base of the clamp, m	0.9
Cross-sectional area, m²	4.2
Length of one clamp, m	145.0

Based on the results of the analysis and evaluation of various existing composting technologies, it was established that composting is a flexible process that can be both simple and high-tech in implementation.

The final choice of composting technology should be made according to several criteria depending on local conditions (taking into account natural and climatic conditions, sanitary conditions and quantitative and qualitative parameters of organic matter, sanitary and hygienic requirements, requirements for the use of the finished product, technical capabilities of enterprises, etc.), however First of all, the technologies must have positive experience of implementation in other countries and in Ukraine, which will ensure effective and economically expedient management of bio-waste.

CHAPTER II. STUDY OF AVAILABLE PLACES FOR APPROPRIATE TECHNICAL SOLUTIONS FOR BIO-WASTE MANAGEMENT IN THE CITY OF UZHHOROD

2.1 Features of the location of composting facilities

Sites and installations for composting can be built throughout the area, but preferably near the places of generation of the corresponding waste. Sites cannot be placed on slopes of more than 10%, near valleys, and reservoirs. It is desirable to place composting sites and structures near transport highways to organize the removal and sale of composting products, entrances and exits should be suitable for access by trucks. As with the construction of most bio-waste treatment plants, it is recommended to maintain a certain distance from residential areas due to unpleasant odors and the presence of pest animals. According to DSP 173-96[9], the sanitary and protective zone must be at least 300 m.

2.2 Determination of available locations of composting facilities in Uzhhorod

To solve the issue of bio-waste management in Uzhhorod, it is necessary to determine the appropriate territory and create a suitable enterprise (composting station) where installations for bio-waste treatment (composting facilities) will be placed.

2.2.1 Site for placing a bio-waste treatment facility

It is recommended to accept the area of the land plot for the location of the bio-waste treatment facility (composting station) following the requirements of GBN B.2.2-35077234-001[10]. In the future, the area of the land plot for construction will be 0.18 hectares, excluding administrative and municipal buildings. The boundaries are determined by the dimensions of the site of the composting station, which will be surrounded by a fence around the perimeter.

Implementation of the project for the construction of a bio-waste treatment facility (composting station) for Uzhhorod is proposed within the boundaries of the site located within the city limits:

- variant No. 1 – at coordinates 48.626280, 22.250021 (Fig. 2.1, *a)*;
- variant No. 2 – at coordinates 48.606692, 22.316811 (Fig. 2.1, *b)*.

See Annex B for the recommended locations of the specified plots on the territory of the city (2 variants).

Figure 2.1 – Site plan for the location of the bio-waste treatment facility (composting station) for Uzhhorod

[9] DSP 173-96 "State Sanitary Rules for Planning and Development of Settlements"// http://surl.li/hivnz
[10] GBN V.2.2-35077234-001:2011 "Enterprises for Sorting and Processing Solid Municipal Waste. Requirements for Technological Design"

2.2.2 Planned objects and structures of the bio-waste treatment facility

Functional zoning

Functional zoning of the site of the composting station: unloading area (5% of the area), commercial compost storage area (10% of the area), treatment (composting) area (75%) and other areas (10% of the area).

The bio-waste composting station includes:

- the department for preliminary examination of raw materials (mixtures) (for inspection of incoming material and removal of impurities, grinding, crushing, sieving, etc.);
- the aeration department (for saturating raw materials with oxygen and releasing carbon monoxide);
- the department for the composting process - depending on the technology variants - tunnels, clamps or rows of stacks (implementation of the intensive decomposition phase and the maturation phase);
- the department for grinding and sieving finished compost (to achieve the level of established requirements for the received raw materials and improve its quality);
- storage facility for finished compost (placed around the perimeter of the plots composting).

The width of the access roads is 5 m; the passage between the compost rows is 1.2 m.

Fig 2.2 shows an example of placing a composting station on the site.

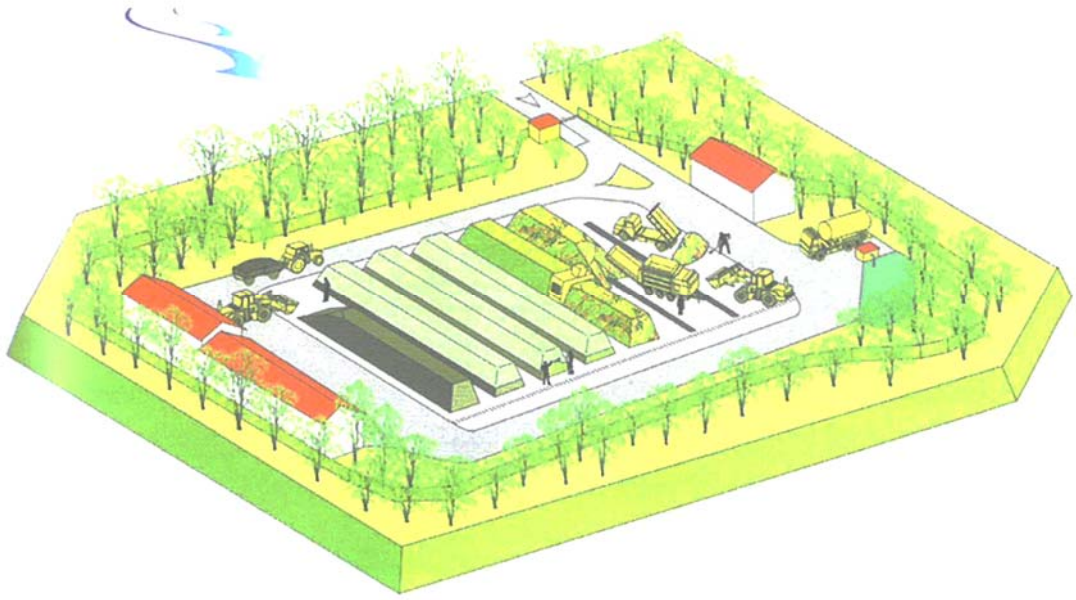


Figure 2.2 – Example of placing a composting station on the site
(source: https://tehnix.hr/en/)

Brief description of the characteristics of planned objects and structures

Unloading area of the composting station must be flat and planned in such a way that it is suitable for the entrance of heavy vehicles. It should not be placed under the roof. A fenced and covered area can be useful when management of odorous inputs. Site planning needs to consider that delivered material is not always easily compostable and storage areas must therefore be available (e.g. for bulky material such as branches and tree trimmings).

The territory *of the treatment* (*composting*) area of the composting station should also be levelled, since heavy vehicles (wheel loaders, cranes and side-turning machines) are used there, and should have a slope of 1-2% in the direction of the grooves or the axis of the turning machine, to

ensure the possibility of unhindered flow of sewage (filtrate) or rainwater between the clamps. If the annual rainfall exceeds 700 mm/m² or if heavy rains exceed 200 mm/m² within 24 hours, it is recommended that the composting area be placed under a roof. Rainwater from the roof must be collected separately from the leachate. Because all areas are in contact with the input material, the composting material must be properly levelled and have a leachate collection system. All collected surface water must be directed into a leachate collection tank.

In addition, when planning the site, it is necessary to ensure separate storage of material for composting in the disinfection phase (decomposition phase) from already disinfected material. In the general space of the site, areas for turning sides and maneuvering machines for turning sides should be provided.

The space required for grinding and screening should be at least 100 m². There should also be a reserve area for crushed and screened material.

The commercial compost storage area of the composting station is intended for the storage of finished products (compost) separately from other areas of the composting station. To prevent re-contamination (due to incoming unsanitized material and contamination by flying seeds), the composting facility should be in a closed room. The size of the warehouse will depend on the volume of sales and distribution of the final product and can be taken from the calculation of 3-6 months of compost maturation, taking into account the geometric parameters of the stacks and, accordingly, the seasonality of compost use. Ready compost can be stored by stacking up to a height of 6 m, but generally taking into account the capabilities of the front loaders used (usually 3-4 m).

For the conditions of Uzhhorod, it is advisable to consider an open composting system, which, compared to a closed one, has lower capital costs. At the same time, the quality of the compost does not decrease.

The open method of composting in clamps with passive (natural) aeration involves placing bio-waste in clamps of various shapes (triangular, trapezoidal or flat) with a height of 1.8 to 3.0 m, the formation of which is carried out by a forklift. When laying on sides with passive aeration, the starting material should have an average particle size of about 5 cm. The average duration of the composting process is approximately 10-60 weeks. The finished product obtained as a result (compost) is sifted and stored/packaged for sale (commercial compost). Screening after screening of compost (inert and ballast parts, metal parts) is sent for disposal at the landfill site.

Table 2.1 shows the recommended clamp parameters and composting terms for Uzhhorod.

Table 2.1 – Recommended clamps parameters and terms for composting

Clamp size						**Terms for composting, months**
Height, m	**Length, m**	**Width of lower basics, m**	**Area for lower basis, m ^{2}**	**Width of upper basis, m**	**Volume, m ^{3}**	
2.5-3.0	10-50	3-4	30-200	2-3	65-525	2.5-7.0

CHAPTER III. FINANCIAL ANALYSIS OF DIFFERENT VARIANTS OF BIO-WASTE MANAGEMENT IN UZHHOROD

3.1 Material balance of the composting station

Based on the volumes of bio-waste generation in Uzhhorod the calculated parameters of the material balance of the composting station in Uzhhorod were determined (Table 3.1).

Table 3.1 – Calculation parameters of the material balance of the composting station

Parameter	Units	Value
Total population served	persons	115,542
Volume of municipal waste generation	t/year	50,396
Design capacity of the composting station (1 shift per day) for 2025	t/year	1,200
	%	100
Obtaining commercial compost	t/year	420
	%	≈ 35
Obtaining screening after composting (disposal at the MW landfill)	t/year	180
Moisture evaporation and gas emissions	t/year	480
	%	40

The capacity of the composting station in Uzhhorod can be 1,200 t/year, and in 2030 – 1,600 t/year.

By the requirements of GBN B.2.2-35077234-001[11] for the adopted design capacity of the bio-waste composting station, the staff list of the company's employees was adopted (Table 3.2).

Table 3.2 – Estimated staff list of bio-waste composting station employees

No.	Profession and position	Estimated number of positions
1	Administrative and managerial employees	1
2	Master technologist	1
3	Mechanic	1
4	Operator	2
5	**Total**	**5**

3.2 Comparative analysis of various variants for management of bio-waste in Uzhhorod

The introduction of centralized composting of separately collected bio-waste in Uzhhorod will require investments in site preparation and treatment equipment sufficient to process up to 1,600 tons of bio-waste per year.

The estimated cost of construction works depends significantly on local conditions. The indicators of the Collections of resource elemental estimate standards for repair and construction works were used for the calculations[12]. The price may be specified when local conditions are established. The salary fund is based on the average salary in the Transcarpathian oblast, taking into account the accepted number of staff at the composting station (Table 3.2).

[11] GBN V.2.2-35077234-001:2011 "Buildings and Structures. Solid Municipal Waste Sorting and Processing Enterprises. Requirements for Technological Design"

[12] Estimated norms of Ukraine. Resource elemental estimate standards for repair and construction works. Instructions on the application of resource elemental estimate norms for repair and construction works (REKNr) // https://e-construction.gov.ua/laws_detail/2718383894184331215?doc_type=6

A comparative analysis of various variants for management of bio-waste, including sorted municipal and commercial green waste, Uzhhorod city, carried out for the following three bio-waste treatment technologies (Table 3.3):

- variant 1 (B1) – composting of bio-waste in rows covered with a membrane with a metal frame;
- variant 2 (B2) – bio-waste composting in tunnels;
- variant 3 (B3) – bio-waste composting in clamps with natural aeration.

Table 3.3 – Comparative analysis of various bio-waste management variants in Uzhhorod (as of the start of operation of the composting station, 2025)

No.	Characteristics of indicators	Unit	B1	B2	B3
1	The amount of generated waste that is sent to the composting station for treatment	t/year	1,600	1,600	1,600
2	Volume of commercial compost obtained (40% of item 1)	t/year	640	640	640
3	The amount of sifting (inert materials) that remain after bio-waste treatment and are subject to disposal at the landfill site (15% of item 1)	t/year	240	240	240
4	The volume of moisture consumption (filtrate, evaporation of the mixture) in the process of treatment bio-waste (45% of item 1)	t/year	640	640	640
5	Installation capacity of composting station equipment	kWh·t	10	15	2
6	Volumes of electricity consumption per year (item 5 and item 1)	kW/year	16,000	24,000	3,200
7	Volumes of water consumption by the composting station for technological and economic and drinking needs	m^3 /year	600	600	600
8	The number of workers at the composting station (1 manager, 6 operators, 1 receiver, 2 repair workers)	persons	6	6	6
9	Capital costs for the construction of composting station facilities, site preparation	million hryvnias	6,10	6.40	4.48
10	Capital costs for the purchase of machines and mechanisms	million hryvnias	7.68	8.96	6.72
11	Capital costs for design, authors and technical supervision	million hryvnias	1,2	1.3	1.0
12	Operational costs of water consumption by the composting station for technological and economic and drinking needs:				
12.1	- for centralized water supply	million hryvnias/year	0.013	0.013	0.013
12.2	- for centralized waste water treatment	million hryvnias/year	0.008	0.008	0.008
13	Operational costs for maintenance	million hryvnias/year	0.133	0.133	0.133

No.	Characteristics of indicators	Unit	B1	B2	B3
14	Operational costs for the operation of machines and mechanisms	million hryvnias/year	0.398	0.398	0.398
15	Operational costs for wages (including deductions for social events)	million hryvnias/year	1.2	1.2	1.2
16	Operational costs for electricity	million hryvnias/year	0.029	0.043	0.006
17	Operational costs for transport services	million hryvnias/year	0.06	0.06	0.06
18	Costs for laboratory services and product quality monitoring	million hryvnias/year	0.2	0.2	0.2
19	**Total Capital costs**	**million hryvnias**	**14.98**	**16.66**	**12.20**
20	**Total Operating costs**	**million hryvnias/year**	**2.04**	**2.05**	**2.02**
22	**Cost of commercial compost**	**hryvnias/ton**	**3,188.13**	**3,210.00**	**3,152.19**
23	Bio-waste treatment level indicator	%	85	85	85
24	Waste disposal level indicator	%	15	15	15
25	**Income from retail sales**	**million hryvnias/year**	**0.64**	**0.64**	**0.64**
26	**Tariff for bio-waste treatment service (including waste from green areas)**	**hryvnias/ton**	**875.25**	**884.00**	**860.88**

Thus, in Uzhhorod, depending on the chosen variant of bio-waste treatment technology, composting costs will range from approximately 860.88 to 884.00 UAH/t (without taking into account the planned income) and can be reduced with an increase in the volume of bio-waste treatment (in EU countries composting costs are 1,098-2,562 UAH/t (30-70 EUR/t)[13].

[13] https://www.kompost.de/

CHAPTER IV. COMPARATIVE STUDY OF THE FEASIBILITY OF IMPLEMENTATION OF THE PROPOSED BIO-WASTE MANAGEMENT VARIANTS FOR UZHHOROD

4.1 Conclusions regarding the state of the existing bio-waste management system in Uzhhorod

One of the components of bio-waste in Uzhhorod is *waste from green areas*, which are generated on the adjacent areas of residential areas (including the private sector), green areas of the city and industrial zones in the process of taking care of green areas.

Separate collection of waste from green spaces in Uzhhorod is not carried out centrally at the local level – waste is collected at the places of generation or accumulated at/near container sites, after which it is transported to the municipal landfill for municipal waste (MW) for disposal, without additional treatment. The management of waste from green spaces generated in residential buildings of individual construction (houses of the private sector) of the city with a plot of land is specific – maintaining order and cleanliness involves solving such issues by residents as seasonal pruning of trees and cleaning of fallen leaves, their collection and independent removal of waste due to the lack of a centralized management system for this type of waste. Often there are natural landfills of waste from green areas, arranged in unauthorized places, and seasonal burning of fallen leaves, which harm not only nature but also residents who live in the immediate vicinity.

According to the results of Analysis[4] of the existing state of waste management from green areas in Uzhhorod, the method of their collection, the level of availability of separate collection, problems and features of management - the issue of management of waste from green areas is not fully resolved, especially in the private sector, in particular - the places and methods of their collection, transportation, treatment is not defined, and the existing practice in the city at all stages (collection, transportation, treatment) has significant negative consequences (of an ecological nature and in the field of health care), despite some progress in improvement situations of the management system of other types of waste.

Ensuring appropriate maintenance of green areas for public use, and first of all in the central areas of Uzhhorod, is a necessary component of its socio-economic development, the implementation of its strategic choice as a European city and tourist center. A correctly planned system of green areas, removal and treatment of plant waste at the base of the municipal structure, provided it is constantly supported, can change the ecological situation for the better and significantly improve the appearance of the city.

The other most common component of bio-waste is food waste. Separate collection of such components of bio-waste in Uzhhorod is also not carried out centrally at the local level - waste is collected at the places of generation and accumulated at container sites as part of mixed solid waste, after which it is transported to the municipal solid waste landfill for disposal, without separation from the total volume of solid waste and additional treatment (as part of the general system of solid waste management).

Based on the results of the analysis of the current state of waste management in Uzhhorod, the method of its collection, the level of availability of separate collection, problems and features of management - the issue of food waste management is unresolved. In particular, the places and methods of their collection, transportation, and treatment are not defined, and the existing practice in the city at all stages (collection, transportation, treatment) has significant negative consequences (of an ecological nature and in the field of health care), despite the improvement of the situation in the private sector of the city, where residents can independently implement the use of this part of bio-waste for their own needs.

An important issue regarding any waste is its treatment. Removal of bio-waste from the total amount of landfill (including waste from green areas and food waste) increases the term of use of the landfill several times and minimizes the burden on the environment. In addition, bio-waste has resource potential when implementing a certain treatment technology. Therefore, for Uzhhorod, the

implementation of a planned and regular system of separate collection of bio-waste, the arrangement of container sites following the requirements of the current legislation and the creation of a bio-waste management facility are relevant. The methods used must be convenient and effective.

The bio-waste management system in Uzhhorod needs improvement and effective decision-making, which will ensure the implementation of the measures of the National Waste Management Plan in Ukraine until 2030[14] and the directions of the National Strategy for Waste Management in Ukraine until 2030, taking into account the features of the economic and social development of the city based on European standards.

The main goal of implementing a systemic approach to bio-waste management in the city is to develop and improve the quality of services in general in the field of municipal waste management and to create conditions for improving the living standards of its population.

As of 2023, Uzhhorod does not have separate infrastructural facilities for bio-waste management, including their treatment, which function following the requirements of current legislation. Processing of all received bio-waste takes place by burying it at the MW landfill in its natural form, which is irrational in modern conditions of constant reduction of raw materials and increases in their cost. Waste of vegetable origin such as grass, leaves, and chopped tree branches are suitable for treatment into compost, which is needed to maintain soil fertility in green areas of the city and ensure the proper condition of green areas (lawns, flowerbeds, bushes, trees). Grass clippings and autumn leaves are excellent raw materials for compost. Cut branches are used as mulch after grinding in specialized crushers. When treating other components of bio-waste, biogas is formed, the methane content of which makes it suitable for use as an energy source. That is why there is a need for Uzhhorod to create a bio-waste management facility to enable the introduction and use of modern management practices and methods of their treatment.

4.2 Study of the feasibility of implementing the proposed variants for bio-waste management in Uzhhorod

The general situation with MW both in the country and in Uzhhorod has remained unchanged in recent years. The volume of waste generation is growing faster than urbanization, and the main method of management of it remains landfilling. Extraction of bio-waste from MW for reuse and recycling is currently considered the most promising approach in municipal waste management systems and can significantly reduce the burden on landfills. Most often, composting technology is used for the disposal of bio-waste all over the world, which can be implemented on almost any scale. As practice shows, the introduction of bio-waste composting is an important step in the strategy of sustainable management of municipal waste.

Taking into account the gradual increase in green areas of Uzhhorod following the planned increase in the residential area in the general plan, an increase in the volume of waste from green spaces obtained in the process of their care is expected both in the general territories of the city and in individual homesteads of residents. In addition, there is an increase in the rate of food waste formation, which is connected, among other things, with an increase in the standard of living of the population.

Therefore, for Uzhhorod, there is a growing need for more careful attention to the removal and treatment of accumulated bio-waste, it is important to ensure the completeness of the removal and treatment of waste from green areas and food waste by implementing modern treatment methods and organizing the bio-waste management system.

Despite the relative simplicity of the technology and the high reliability of the system, the low volume of investments and capital investments, the technology of bio-waste treatment by composting is not developed in Ukraine. Currently, the only practical example of composting a part of municipal waste is its treatment at composting sites in Lviv (financed from the city budget), which is implemented by the KP “Green City”, which collects the appropriate fraction of solid waste in

[14] https://zakon.rada.gov.ua/laws/show/117-2019-%D1%80#Text

separate 240 l containers and their removal by separate special transport to the composting sites. A practical example of commercial waste composting (pure organic raw materials from the markets) is composting in Lutsk, implemented by the Pasternak-bio company (profitable activity).

The main problem with the application of composting technology – apart from the possibility of using limited types of waste (only waste of plant origin (bio-waste)) and the need to create a separate bio-waste management system (separate collection), is the lack of a market for the resulting compost or compost-like product.

The resulting compost can be used following SOU ZhKH 10.09-014[15] in agriculture, forestry and green construction as fertilizer, for land reclamation and as fuel with preliminary briquetting, which must be carried out according to standard technologies, which include preliminary drying of compost to a moisture content of 3% to 8% and treatment on the press.

According to BREFs, in some European countries, compost from waste is used as a material for covering (reclamation) landfills and covering layers of landfill[16].

Scope of commercial compost application (according to agrochemical, microbiological, toxicological and physicochemical indicators):

1) mainly in agriculture and horticulture;

2) greening of territories, as a substrate for the cultivation of special crops (fruits, grapes, asparagus), to improve the soil and in private plots;

3) for fertilizing home flowers and plants.

Compost from fallen leaves should be used only in green farming and land reclamation. In this regard, it is advisable to place equipped areas for composting fallen leaves on the territory of communal enterprises for the maintenance of green spaces.

In addition to using the obtained compost as a fertilizer for the city's own needs and use as a roofing material for the city landfill, Uzhhorod has a potential market for selling compost to enterprises in neighbouring territorial communities and, in the long term, for other landfill and quarry reclamation projects such as of Transcarpathian oblast, as well as Ukraine, in case of their financing and implementation.

Unfortunately, at the current level of Ukraine's economy, only relatively simple waste treatment projects can be implemented and developed in populated areas, in most cases the choice of technology will be determined by the principle of “reasonable sufficiency”, including because as the complexity of the implemented waste treatment technology increases specific capital costs for implementing a waste treatment facility are also increasing.

Therefore, at the initial stage of the implementation of the bio-waste management system in Uzhhorod, the primary priority should be the introduction of relatively simple bio-waste treatment technologies – individual composting of bio-waste in private municipals by installing individual composters in the yards of municipals and centralized composting of separately collected municipal and commercial green waste (waste landscaping, parks, gardens, etc.), part of food and similar waste, at least in the short term. In the medium- and long-term perspective, a more practical variant for the treatment of bio-waste (for example, its biological stabilization with the help of MBT facilities) should still be applied.

[15] SOU ZhKH 10.09-014:2010 "Municipal Waste. Technology of Processing Organic Matter Contained in Household Waste" // https://zakon.rada.gov.ua/rada/show/v0078662-10#Text

[16] BREFs (Best available technologies (BAT) reference documents) – reference documents on best available technologies and management practices

CHAPTER V. DEVELOPMENT OF THE MONITORING CONCEPT OF THE COMPOSTING PLANT IN UZHHOROD

5.1 General principles and technological scheme of the biological stage of bio-waste treatment

According to the definition of SOU ZhKH 03.09-014[15]:

- *aerobic treatment (composting)* is an aerobic process of decomposition of organic matter by various types of bacteria and fungi to obtain soil-like material;
- *organic matter included in municipal waste* is an organic part that undergoes biological decomposition (food waste, fallen leaves, garden and park waste, etc.).

Implementation of the process of bio-waste composting depends on the selected technology and the appropriate equipment of the treatment facility (composting plant). In the existing technological schemes of composting, individual nodes can be arranged depending on the equipment of the treatment facility. The construction and equipment of the treatment facility must ensure the reception and preparation of bio-waste, biothermal decontamination and final treatment and packaging of the obtained compost.

The layout variant of the bio-waste treatment facility (composting plant) includes:

- planned area on a waterproof base, covered with concrete slabs;
- reception area with two unloading stations;
- special equipment for forming clamps and stacks;
- crushing and sorting department, equipped with appropriate equipment (receiving hopper with plate feeder, magnetic separator, cylindrical drum, crusher for compost, filler hopper for ferrous scrap, etc.);
- humidification and fire extinguishing system consisting of pipelines for watering compost clamps.

Special hammer crushers are used for crushing bio-waste. Additional grinding occurs due to multiple shovelling of compostable material. Undivided fractions are separated on a control sieve. Bio-waste is unloaded on a levelled platform, where a special device is used to form rows (stack and) in which aerobic biothermal composting processes take place. The angle of laying the slopes is 45° (corresponds to the angle of the natural slope for compost). A distance of 1.2 m remains between the parallel and longitudinal stacks for the passage of special equipment.

In the process of composting, the moisture content of the material decreases, therefore, to increase the activity of the biothermal process, along with shovelling and forced aeration, the material is moistened. Before sending the mature compost to the consumer, it is sent to sieves, where it is cleaned of large ballast fractions. Screening from the control sieve (up to 10% of the weight of the waste) must be stored at the waste disposal site.

At certain times of the year, (compost is a seasonal product), finished products are placed in stacks located along the composting shop. These stacks hold a six-month supply of compost. In the process of composting, the density of the material increases from 0.2 to 0.6-0.8 t/m³.

By combining various components of bio-waste in stacks, the first necessary condition for composting is created - the ability to accumulate heat due to the low thermal conductivity of the mixture. Being able to accumulate heat, microorganisms can increase their population. However, to achieve the maximum effect of composting, it is necessary to ensure compliance with a number of the following factors:

- **particle dispersion** – the smaller the size of the waste particles, the greater the specific surface open to microorganisms, which theoretically should ensure a higher speed of the process. The optimum particle size should be 10-15 mm. However, small particles are packed very tightly, forming a material with high density and narrow pores, which limits the diffusion of oxygen

into the volume and the diffusion of carbon dioxide from the volume, which reduces the speed of the process;

- **nutrients** – the composting process depends on the activity of microorganisms that need a source of carbon for energy and a substance for the formation of new cells, as well as a source of nitrogen for the synthesis of cellular proteins. To a lesser extent, microorganisms need phosphorus, potassium, calcium, sodium, magnesium, sulfur, iron, cobalt, and zinc. In most composting processes, these needs are met at the expense of the original composition of biowaste, only the ratio of carbon to nitrogen (C/N) and occasionally the level of phosphorus may need adjustment. The optimal C/N ratio in the substrate is from 25:1 to 30:1;
- **additives –** to increase the speed of composting, various chemical, plant and bacterial additives are used. Except for the possible need for additional nitrogen, most wastes contain all the necessary nutrients and a wide range of microorganisms, making them amenable to composting. Fillers in the form of straw and fallen leaves are usually necessary to maintain a loose structure that provides aeration of the compost. Nitrogen deficiency is covered by adding ammonium nitrate, and phosphorus deficiency by phosphogypsum;
- **moisture** – water is essential in the composting process because nutrients for microorganisms dissolve in water before they become available for consumption. At a humidity of less than 30% of the total mass, the speed of biological processes drops sharply, and at a humidity of 20%, they may stop altogether. When the humidity is more than 60%, the voids in the compost structure are filled with water, which limits the access of oxygen to microorganisms. However, straw-type materials are resistant to high humidity. The recommended optimal humidity is within 40-60%. Water is lost during composting due to evaporation. In the case of using forced aeration, water losses can be significant, and there is a need to add water to the mixture;
- **free volume** – voids between particles are filled with gas (oxygen, nitrogen, carbon dioxide), water or a gas-liquid mixture. If the voids are filled with water, this greatly complicates the transfer of oxygen. It is established that the minimum free gas space should be about 30% or maintaining the density of the mixture at the level of 350 kg/m^3;
- **aeration –** oxygen is necessary for the metabolism of aerobic microorganisms involved in composting. Aeration is carried out due to mass mixing with the help of mechanisms. Aeration also has other functions in the composting process. The airflow removes carbon dioxide and water, which are formed in the process of the vital activity of microorganisms, and also removes heat due to evaporative heat transfer. The latter is especially important in rapid, mechanized composting systems. Oxygen demand changes during the process: it is low in the mesophilic stage, increases to a maximum in the thermophilic stage and falls to zero during cooling and ripening;
- **mixing** – carried out with the help of screws, in the management of the mixing process, treatment of most raw materials in thermophilic conditions is ensured. However, excessive mixing leads to cooling and drying of the compostable mixture, to breaks in the mycelium of actinomycetes and fungi, so it is performed most often once a day;
- **temperature of the process** – as a result of biological activity, the temperature in the stacks during composting rises. It is convenient to divide the composting process into four stages: mesophilic (I), thermophilic (II), cooling (III), and ripening (IV) (Fig. 5.1).

At the beginning of the composting process, bio-waste is at ambient temperature, its pH is weakly acidic. In the initial *mesophilic stage* (I), the microorganisms present in the waste begin to multiply rapidly, the temperature rises to 40°C, and the environment is acidified due to the formation of organic acids. When the temperature rises above 40°C, the original mesophiles begin to die and thermophiles prevail. This raises the temperature to 55-60°C, at which the mushrooms begin to become inactive. After 60°C, the reaction continues with spore-forming bacteria and actinomycetes, the pH of the medium becomes alkaline due to the release of ammonia during the breakdown of proteins.

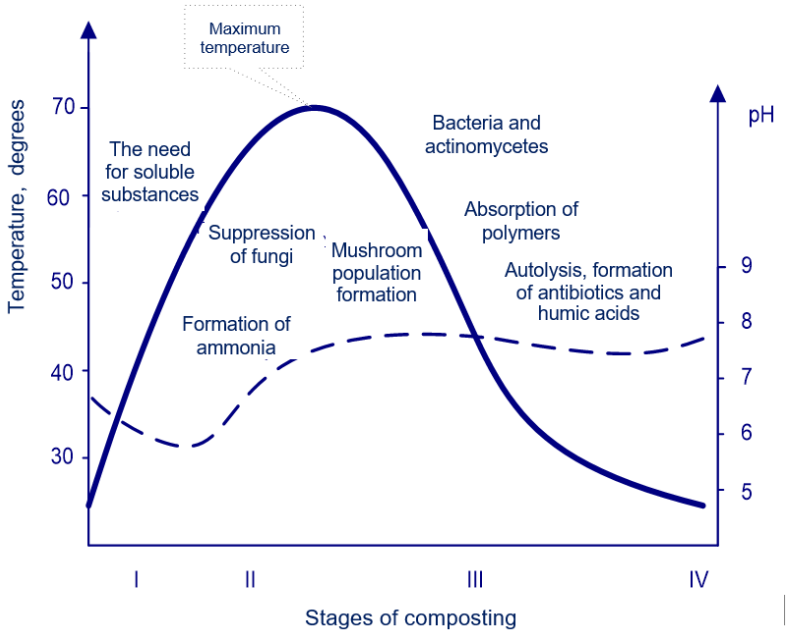


Figure 5.1 – Change in temperature (—) and pH (- -) during the composting process (general principle)

During the *thermophilic stage* (II), the most easily decomposed substrates are quickly consumed (sugar, starch, fats, proteins, etc.), and the reaction rate begins to fall after more stable substrates are drawn into it. At the same time, the rate of heat release becomes equal to the rate of heat loss. This corresponds to reaching the temperature maximum. At this point, the compost pile has reached a stable state. At the same time, easily digestible compounds are broken down, the main need for oxygen is satisfied, and the mixture does not produce gases, since new microorganisms bind easily available nitrogen and sulfur.

The maximum composting temperature should be at least 55°C. Most pathogenic microorganisms and helminth eggs are disinfected at this so-called pasteurization temperature. The temperature should be maintained for at least 3 days.

Then the compost enters the *stage* of *cooling* (III), during which the pH slowly drops, but remains alkaline. Thermophilic fungi from colder zones again capture the entire volume and, together with actinomycetes, consume polysaccharides, hemicellulose and cellulose, breaking them down into monosaccharides, which can then be utilized by a wide range of microorganisms. The rate of heat release becomes very low and the temperature drops to the ambient temperature.

The first three stages of composting: mesophilic, thermophilic and cooling proceed very quickly depending on the type of composting system. The final *stage of ripening* (IV), during which mixture losses and heat release are small, can last from one to several months. In this stage, complex reactions occur between lignin residues from bio-waste and proteins of dead microorganisms, which lead to the formation of humic acids. Compost does not heat up; anaerobic processes do not occur in it during storage, it does not take nitrogen from the soil when applied to it. The final pH value of the compost is slightly alkaline.

Too high temperature suppresses the process of biodegradation due to inhibition of the growth of microorganisms, not all species retain their activity at temperatures above 70°C. The threshold after which suppression occurs is a temperature of about 60°C, and therefore high temperatures for a long period should be excluded in rapid composting. Temperature control can be achieved by shovelling the compost during the process. Heat removal is carried out using an evaporative cooling system.

Compost is considered ready if it has passed the 3-day pasteurization period, its temperature has equalled the ambient temperature, and the structure is loose and dark, without extraneous odors or inclusions. A reasoned decision about the readiness of the compost is made based on the results of laboratory tests.

Since composting is a natural process of decomposition of organic matter, it depends on many factors that require control to avoid undesirable consequences: unpleasant smell, dust, and low quality of the final product. In the process of composting, there is a complex interaction between physical, chemical and biological factors that influence and change during composting. Therefore, control of parameters such as density, porosity, particle size, nutrient content, C/N ratio, temperature, pH, and moisture and oxygen consumption is key to optimizing composting, as it determines the optimal conditions for the development of microbial colonies involved in decomposition bio waste When carrying out composting, you should be guided by the relevant international standards for composting.

5.2 Main indicators of the quality of compost made from bio-waste

Different types of bio-waste have different concentrations of nutrients - nitrogen, phosphorus and potassium, and the presence of heavy metals in the obtained compost limits its wide use, considering that the application of compost on soils should occur without any negative consequences. In the case when the compost is not suitable for application to the soil due to its quality characteristics, it can be used as an alternative substrate cover for landfills. Therefore, the quality of the obtained compost is an important issue.

Compost quality is measured by several criteria: moisture, heavy metal concentration, stability, nutrient content, fractional composition, pathogenicity, stability, as well as acidity, electrical conductivity, C/N ratio.

The physico-chemical, agrochemical, microbiological and toxicological parameters of the formed compost must meet the requirements of SOU ZhKH 10.09-014.

Physico-chemical parameters compost

Physico-chemical indicators, in particular, particle size composition, organic matter content, moisture and acidity determine further use of compost and its value. SOU ZhKH 10.09-014 defines the minimum values of the physical and chemical indicators of compost, which make it possible to use it as a fertilizer in agriculture, to improve soil fertility (Table 5.1 shows the values of the main physical and chemical indicators of compost).

Table 5.1 – Physico-chemical parameters of bio-waste compost

The content of the fractions is larger than 50 mm, dry substance, %, no more	The mass fate of organic substances, on dry product, %, no less	Humidity, %	Reaction environment, pH
2	40	20-80	6.5-8.0

Agrochemical indicators of compost

The importance and effectiveness of bio-waste compost when used in agriculture, forestry, landscaping is determined by the presence of a significant amount of nutrients, especially macronutrients. The content of the most important macronutrients for plant nutrition – nitrogen, phosphorus and potassium – is indicated in the agrochemical indicators of compost. Table 5.2 shows the values of the main agrochemical indicators of compost according to SOU ZhKH 10.09-014.

Table 5.2 – Agrochemical indicators of bio-waste compost

Mass fraction of nutrients, ha dry product, %, no less		
general nitrogen	**phosphorus (P_2O_5) general**	**potassium (K_2O) general**
1.8	2.0	0.1

Toxicological indicators of compost

Assessment of toxicological indicators is necessary when using compost as a fertilizer. Due to the possible high concentration of heavy metals in the compost, accumulated through their absorption by plants and the entry of these elements from the soil into the food chain, there is a potential risk of exposure and the possibility of further use of the compost in agriculture may be excluded. Table 5.3 shows the average concentrations of heavy metals in compost for fertilizers are presented according to the requirements of SOU ZhKH 10.09-014.

Table 5.3 – Permissible average concentration of heavy metals in bio-waste compost

Element	Concentration, mg/kg of dry matter, no more	
	for use in agriculture	for use in forestry economy, green construction and for land reclamation
Iron	25,000	45,000
Cadmium	30	250
Cobalt	100	300
Manganese	2,000	7000
Copper	1,500	6000
Nickel	200	900
Mercury	15	50
Lead	750	2,000
Strontium	300	600
Chromium $^{3+}$	750	5,000
Zinc	2,500	9,000

Estimated market value of groups of compost of different quality

Table 5.4 shows the market value of different groups of compost as of 2023, according to expert assessments, depending on the quality assessment according to the criteria of SOU ZhKH 03.09-014, limitations in doses, application frequency and areas of application in agriculture. Table 5.5 shows the same for forestry, green construction and for land reclamation. Doses of adding compost to the soil are calculated according to the methods given in the SOU ZhKH 03.09-014.

Table 5.4 – Groups of compost according to quality assessment according to the criteria of SOU ZhKH 03.09-014, restrictions on doses, frequency of application and areas of application in agriculture

Group 1	Group 2	Group 3
Use as fertilizers (or for making compost) in doses adequate to standard fertilizers	Use in a dose of (4-5) t/ha per year based on dry matter or no more than 15 t/ha once every 3 years	Use in a dose of (5-6) t/ha based on dry matter once every 5 years with mandatory control of the background content of elements
Grain, fodder, industrial crops	Grain, fodder, industrial crops	Grain, fodder, industrial crops
The market value of compost is 620 UAH/t	There is no market value	There is no market value

Table 5.5 – Groups of compost according to the quality assessment according to the criteria of SOU ZhKH 03.09-014, limitations in doses, application frequency and areas of use in forestry, green construction and land reclamation

Group A	Group B	Group B
Use as fertilizers (or for making compost) in doses adequate to standard fertilizers	Use at a dose of (10-15) t/ha per year based on dry matter or no more than 50 t/ha once every 3 years	Use in a dose (10-20) t/ha of dry matter once every 5 years with mandatory control of the background content of elements
Forest crops, green construction	Forest crops, green construction	Forest crops, green construction, land reclamation
The market value of compost is 620 UAH /t	The market value of compost is 450 UAH /t	There is no market value

5.3 Establishing quality standards and implementing control and certification systems at bio-waste treatment facilities

Significant support in achieving and maintaining the required quality and environmental safety at bio-waste treatment facilities (composting facilities) can be provided by establishing appropriate quality standards and implementing control and certification systems.

Standards and technical requirements for composting have been developed in several EU member states, so the quality of the resulting product is ensured by checking compliance with relevant national standards. Aspects of the quality of the composting system include the quality of the input raw materials and acceptable physical and chemical parameters of the final product. In Ukraine, there is a standard SOU ZhKH 10.09-014, which regulates the quality indicators of organic fertilizers obtained by the decomposition of bio-waste, the document determines the suitability of compost for use, respectively, either in agriculture, landscaping, or reclamation.

The use of mechanisms of this kind is widely practised in Germany and other countries of the world. The most famous system, which served as a model in many cases, is the German system for quality assurance and control of composting products obtained from separately collected biological waste from municipals, as well as from horticulture and landscaping waste, according to RAL, the quality mark of which means not only high-quality products but also good professional practice in the operation of installations.

Bio compost quality assurance system (by standard RAL-GZ 251) contains the provisions of the BGK[17] regarding quality criteria and their compliance for composting products. At the same time, we are talking about obligations voluntarily accepted by composting enterprises to ensure high-quality, ecological composting. *The fermentation product quality assurance system* (according to the RAL-GZ 256/1 standard) covers the requirements of the BGK, as well as the quality and quality assurance procedure for solid and liquid fermentation products. In addition, here is about the voluntary commitment of enterprises in the fermentation industry.

These quality assurance systems impose several obligations on composting and fermentation enterprises concerning product analysis and verification of analyses by independent third-party organizations. The actions and decisions of BGK are officially recognized by the relevant authorities. In addition, the legislation already refers bio-waste, which supports constant monitoring by independent bodies, to the category of “products”, and not only to waste. As a result of recently adopted measures at the EU-wide level, it is expected that they will be finally granted the status of “product” shortly. Firms that are members of the BGK and undertake the relevant voluntary self-monitoring obligations are largely exempted from more stringent monitoring measures from government agencies and authorities and must submit fewer reports to these authorities.

[17] BGK (Bundesgütegemeinschaft Compost eV) – Federal Compost Quality Assurance Community

5.4 The concept of composting plant monitoring regarding the quality of compost in Uzhhorod

Sampling of compost (as fertilizer) for quality control must be carried out according to the list and according to the requirements of current legislation. In case of unsatisfactory test results for at least one of the indicators, the test must be repeated on a double number of samples. In case of unsatisfactory results of the re-check, the use of the batch of fertilizer is prohibited.

Periodic control should be carried out according to agrochemical indicators (N, P, K content) at least twice a year.

Control of sanitary and hygienic indicators of fertilizers is carried out following the Law of Ukraine "On Pesticides and Agrochemicals"[18]. The sanitary-epidemiological station must carry out verification control of the sanitary-hygienic indicators of products at least 4 times a year.

Monitoring of the composting plant regarding the quality of the compost is carried out as follows.

Selection of samples

A representative sample must be taken from the compost for laboratory analysis of the resulting compost parameters. For this purpose, separate samples are taken in different places on the side and then combined in one sample.

Separate samples must be taken from the coarse material to ensure a representative sample. If the size of the compost particles is less than 20 mm, an individual sample is required for every 10 tons, if the particle size is greater than 20 mm, one sample is required for every 5 tons of compost. The amount of material G (kg) for each sample depends on the maximum particle size d (mm) of the material being analyzed and can be calculated by the formula:

$$G = 0.06 \times d. \tag{5.1}$$

The minimum amount of material for a single sample is 0.6 kg (provided that the particle size is 0/10).

Determination of dry matter content

The analysis requires a laboratory scale (with an accuracy of ± 0.1 g) and an oven to heat the samples at approximately 105°C to measure the water content.

A sample of compost taken from a minimum depth of 20 cm (about 5 liters in volume) is distributed on a pre-weighed flat surface (dish). Next, this sample together with the surface is weighed and dried directly in the oven at 105°C to evaporate all the water from the sample. After approximately 24 hours, the sample is weighed, re-wetted and re-dried for several hours, and re-weighed. The process is repeated until a sample of the same weight is obtained.

The content of dry matter in the *DM sample* (%) is calculated by the formula:

$$DM = (M_{\text{dry}} - M_{\text{tare}}) / (M_{\text{wet}} - M_{\text{tare}}) + 100, \tag{5.2}$$

where M_{dry} is the weight of the original sample, g;
M_{tare} – weight of a flat surface (empty dish), g;
M_{wet} – weight of a dry sample and a flat surface (empty dish), g.

The moisture (water) content of the *MC sample* (%) is calculated by the formula:

$$MC = 100 - DM. \tag{5.3}$$

[18] https://zakon.rada.gov.ua/laws/show/86/95-%D0%B2%D1%80#Text

Determining the degree of decomposition (self-heating test)

The degree of decomposition or maturity of the material is used to assess the progress of the decomposition process and the biological stability of the compost, and can be determined by a simple self-heating test in a Dewar container (Fig. 5.2). The ability of the self-heating substance of the formed compost gives information about the degree of decomposition of the material (respectively, about the state of maturity of the compost and the degree of its readiness for use).

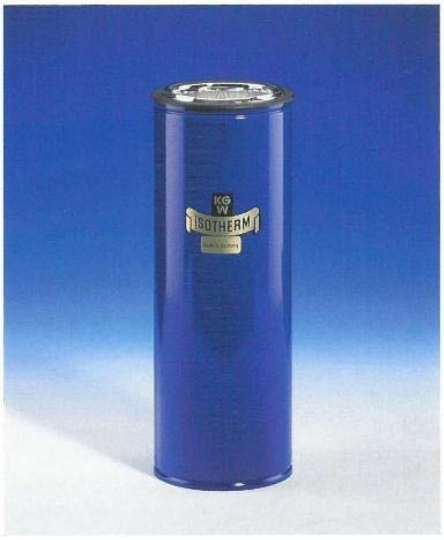


Figure 5.2 – Dewar container (source: https://tehnix.hr/en/)

The self-heating test should be performed with the optimal water content of the standard sample. If the sample material is too dry or too wet, the self-heating capacity is increased and the degree of decomposition is also increased.

To conduct the study, the container is loosely filled, tapping gently on the table, with compost to its rim, the thermometer probe is placed in the lower third of the container. The container remains open at room temperature, and the maximum temperature is usually reached after 2-5 days. Table 5.6 shows the degree of decomposition of the compostable material and, accordingly, the readiness of the products is calculated based on the maximum temperature of the material.

As a result of the test, the compost is rated as “fresh” or “finished” compost. Fresh compost is decontaminated material that is currently decomposing rapidly, or material capable of decomposing rapidly. Ready compost is a decontaminated, biologically stabilized compost.

Table 5.6 – Information on the degree of decomposition of the material and the readiness of the compost

Degree of decomposition	Maximum temperature, °C	Product condition
I	>60	Raw material for compost
II	50-60	Fresh compost
III	40-50	Fresh compost
IV	30-40	Ready compost
V	<30	Ready compost

Optimization of the composting process

The main important parameters and their influence on the course of the composting process:

- *nutrient supply* – the main important nutrients that must be available in sufficient quantities and in the correct ratio are carbon (C) and nitrogen (N);
- *oxygen supply* – to provide the decomposing material with a sufficient amount of oxygen, a constant supply of fresh air is necessary;

- *sufficient amount of moisture* – water is a carrier of nutrients and oxygen to microorganisms that carry out the composting process;
- *pre-treatment of the material* – grinding and mixing of the raw material at the beginning of the composting process will affect the pore volume of the decomposing material and, as a result, the content of oxygen and water, which compete with each other due to the use of pores (voids) between the particles of the compost pile. Because air and water are both necessary to bring oxygen to microorganisms, ensuring such conditions will reduce the amount of time spent in the compost heap, and accordingly the speed of obtaining ready compost will increase;
- *temperature* – most active microorganisms in the composting process are thermophilic (50-65°C) and mesophilic (25-45°C), the intensive decomposition process takes place in the thermophilic range, and the ripening process - in the mesophilic range;
- *pH value* – most microorganisms need a neutral pH value.

If the process of disintegration does not progress properly, then the solution to such a problem is always reduced to turning the edge.

Table 5.8 shows the list of the main violations of the composting process and the reasons for their occurrence with the corresponding corrective measures.

Table 5.7 – Main violations of the composting process and corrective measures to eliminate them

The main violations of the composting process	**Reason of occurrence**	**Corrective measures regarding elimination**
Insufficient heating freshly prepared side of compost (T<50°C)	1. Lack of moisture 2. C/N ratio is too high, lack of nitrogen 3. The raw compost material is not sufficiently mixed or chopped 4. The pH value is low 5. The air temperature is too low	1. Turn over and moisten 2. Add nitrogen aggregates and turn over 3. Turn several times and, if necessary, grind the material again 4. Add calcium carbonate ($CaCO_3$) and turn over 5. Increase the volume of the side, add fresh compost
Overheating of compost clamp (T>75°C)	1. C/N ratio too low, too much nitrogen 2. Accumulation of heat in the side	1. Add wood material (offcuts, straw...), turn often and moisten 2. Turn several times, moisten if necessary
Intense smell of ammonia in the primary intensive phase of decomposition (acute may occur, pungent smell of ammonia (NH_3), with strong evaporation may burn eyes)	1. Too much nitrogen (C/N ratio below 20:1) 2. The pH value is too high	1. Add high-carbon materials (sawdust or straw) 2. To lower the pH on the side by adding acidic materials or avoid any alkaline substances such as lime and wood ash
The compost is too dry (a little fume is released from the clumps, and dust emissions while flipping)	Too much moisture evaporates due to exposure to heat, sun or wind	Turnover and moisten the material
The compost is too wet (compost is sticky and dirty with an unpleasant smell,	1. Overwetting by rainwater 2. The edge was moistened very often and intensively	1. Turnover several times after the rain stops

The main violations of the composting process	Reason of occurrence	Corrective measures regarding elimination
when squeezed in a fist with water flowing from it)	3. Incorrectly formed mixture at the beginning of the decomposition process	2. Stop moistening, and turn often 3. Add dry material (for example, straw)
The appearance of unpleasant smell (appears rotten smell)	1. Insufficient aeration or ventilation 2. Overwetting of the side 3. Anaerobic processes begin and gas is formed	1. Turn it over and add dry ingredients 2. Add bulk material (for example, straw) 3. Cover the edge during draining (with a membrane, or film)
Delayed decomposition (after flipping does not rise temperature (T<50°C), the color of the compost does not change)	1. Adverse composting conditions 2. Mainly decomposed organic materials	1. Check and correct composting parameters (humidity, pH...) 2. Initiate the maturation phase

CONCLUSIONS AND RECOMMENDATIONS TO PART I

The system of management of municipal and commercial bio-waste, including waste from green areas and other biodegradable waste, includes a set of measures for their collection, transportation and treatment (recovery and disposal), including the creation of appropriate treatment facilities. The choice of technical solutions for bio-waste management (collection, transportation and treatment) depends on many factors. Treatment of bio-waste consists in its restoration and/or removal, including its preparation for such operations, and depends on the adopted technological scheme of bio-waste collection.

The growing awareness that the environment needs to be protected, as well as the increase in the cost of proper waste treatment, has led to changes in legislation, and composting is being implemented in many countries as one of the most common, simple and acceptable methods of bio-waste treatment. Various technological variants for composting have been developed; the most often used is an open system using composting in rows or edges. Composting material must be collected separately from other types of municipal waste and must be free of toxic substances or pollution - this is one of the most important conditions for obtaining a high-quality final product (compost). Important factors for bio-waste composting are its grinding, control over the moisture content during the decomposition process and regular and sufficient supply of the sides with oxygen. The product of decomposition is compost, which is rich in nutrients and is used as a fertilizer where soil fertility needs to be increased.

The feasibility of implementing a bio-waste composting system has the following main reasons:

- *economic*:
  - reducing the amount of waste stored in landfills, saving space and unnecessary waste treatment costs;
  - the final product is a useful substrate, rich in nutrients, which practically excludes the use of expensive fertilizers;
  - composting is the cheapest treatment method.
- *environmental:*
  - organic material is returned to the biological cycle, and not simply destroyed, as when using waste incineration methods;
  - prevention of pollution, mainly CO_2, which occurs during the burning or burial of bio-waste - the composting method excludes the occurrence of CO_2.
  - reducing the use of peat fertilizers because as a result of composting, a product is formed that replaces the peat used to improve the soil;
  - the level of nitrates in groundwater decreases in those areas where compost is used instead of chemical fertilizers.

According to the results of Stage I of the study “Evaluation of the Most Suitable Technical Solution for the Management of Organic Waste, Sorted Municipal and Commercial Green Waste in Uzhhorod“, part I “Evaluation of the Most Suitable Technical Solution for the Management of Organic Waste, Sorted Municipal and Commercial Green Waste” received the following:

- it was established that the most common methods of bio-waste treatment are aerobic composting and anaerobic fermentation, and the priority method of management of separately collected bio-waste (municipal and commercial waste from green spaces and biodegradable waste) for implementation in Uzhhorod is the composting method, which is explained by the presence of a large share of bio-waste in the composition of MW, the lowest level of capital investments and operating costs in comparison with alternative methods of waste treatment (waste incineration, disposal at MW landfills) and compliance with environmental safety requirements. The advantages and disadvantages of the existing technical solutions for the management of bio-waste through composting are revealed, and the variants for the implementation of the bio-waste management system in Uzhhorod are proposed, including, taking into account the results of a sociological survey of residents,

which at the initial stage can be started with a relatively simple method, for example, from centralized composting of municipal and commercial separately collected green waste (landscaping, garden waste, etc.) and similar waste (with a high degree of moisture and a minimum C/N ratio, therefore ideal for mixing with green waste) that require minimal pre-treatment and will yield compost of high quality, which can be used as a soil improver, suitable for use in agriculture and for other purposes;

- in order to solve the issue of bio-waste management in Uzhhorod, it is necessary to determine the appropriate territory and create a suitable enterprise where bio-waste treatment facilities will be located, therefore, the available places in Uzhhorod for appropriate technical solutions for the management of the generated bio-waste have been analyzed, namely, variants for the placement of bio-waste treatment facility (composting station) and a brief description of the characteristics of the planned facilities and structures;
- based on the volume of bio-waste generation in Uzhhorod the calculation parameters of the material balance of the composting station in Uzhhorod were determined, and approximate calculations of the main parameters (including the workload) of the composting station in Uzhhorod were made, and a comparative financial analysis of bio-waste management variants according to various technological schemes was carried out. The capacity of the composting station at the start of operation in 2025 may be 1,200 t/year and in 2030 – 1,600 t/year, depending on the chosen variant of the bio-waste treatment technology, the costs of composting will range from approximately 860.88 to 884.00 UAH/t (without taking into account the planned profit) and may be reduced when the volume of bio-waste treatment increases;
- the feasibility of implementing the proposed technical variants for management of bio-waste and implementing the construction project of a bio-waste treatment facility in Uzhhorod (composting station) has been established according to the results of the analysis of the current state of waste management in Uzhhorod, the method of its collection, the level of availability of separate collection, problems and peculiarities of management. It has been investigated that the issue of bio-waste management is unresolved, therefore, at the initial stage of the implementation of the bio-waste management system in Uzhhorod, the primary priority should be the introduction of relatively simple bio-waste treatment technologies – individual composting of bio-waste in private municipals by installing individual composters in the yards of municipals and centralized composting of municipal and commercial separately collected green waste (waste of landscaping, parks, gardens, etc.), part of food and similar waste, at least in the short term. In the medium and long term, a more practical variant for the treatment of bio-waste (for example, its biological stabilization with the help of MBT facilities) should still be applied;
- general concept of monitoring for composting station installations in Uzhhorod is proposed, taking into account European experience.

PART II.
ANALYSIS OF THE SECONDARY RAW MATERIALS MARKET

CHAPTER I. GENERAL CHARACTERISTICS OF THE STATE OF WASTE MANAGEMENT AND THE MARKET OF SECONDARY RAW MATERIALS IN UKRAINE

1.1 Legislative prerequisites in the field of waste management and the secondary raw materials market

The regulatory and legal field of Ukraine waste management, including the market of secondary raw materials, is quite extensive and consists of laws, several subordinate legal acts (resolutions of the Cabinet of Ministers of Ukraine, orders of ministries, standards, state building regulations, etc.).

The regulatory and legal acts of Ukraine in this area are:
Constitution of Ukraine[19];
Law of Ukraine "On Ratification of the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their member states, on the other hand"[20];
Code of Ukraine on subsoil[21];
Law of Ukraine "On Waste Management"[22];
Law of Ukraine "On Environmental Protection"[23];
Law of Ukraine "On Environmental Impact Assessment"[24];
Law of Ukraine "On Strategic Environmental Assessment"[25];
Law of Ukraine "On the Public Health System"[26];
Law of Ukraine "On Scrap Metal"[27];
Law of Ukraine "On Housing and Communal Services"[28];
Law of Ukraine "On Improvement of Settlements"[29];
Law of Ukraine "On Veterinary Medicine"[30];
Law of Ukraine "On Licensing Types of Economic Activities"[31];
Law of Ukraine "On Alternative Energy Sources"[32];
Law of Ukraine "On by-products of animal origin, not intended for human consumption"[33];
Law of Ukraine "On Local Self-Government in Ukraine"[34];
Order of the Cabinet of Ministers of Ukraine from November 8, 2017 No. 820 "On Approval of the National Waste Management Strategy in Ukraine until 2030"[35].

The Law of Ukraine "On Waste Management" is a framework in the field of waste and provides for the reform of waste management, which will contribute to the transition of Ukraine to models of circular economy and sustainable development. The law defines the legal, organizational and economic principles of activities related to the prevention of formation, reduction of the volume of waste generation, reduction of negative consequences from waste management activities,

[19] https://zakon.rada.gov.ua/laws/show/254%D0%BA/96-%D0%B2%D1%80#Text
[20] https://zakon.rada.gov.ua/laws/show/1678-18#Text
[21] https://zakon.rada.gov.ua/laws/show/132/94-%D0%B2%D1%80#Text
[22] https://zakon.rada.gov.ua/laws/show/2320-20#Text
[23] https://zakon.rada.gov.ua/laws/show/1264-12#Text
[24] https://zakon.rada.gov.ua/laws/main/2059-19#Text
[25] https://zakon.rada.gov.ua/laws/main/2354-19#Text
[26] https://zakon.rada.gov.ua/laws/show/2573-20#Text
[27] https://zakon.rada.gov.ua/laws/main/619-14#Text
[28] https://zakon.rada.gov.ua/laws/show/2189-19#Text
[29] https://zakon.rada.gov.ua/laws/main/2807-15#Text
[30] https://zakon.rada.gov.ua/laws/show/2498-12#Text
[31] https://zakon.rada.gov.ua/laws/show/222-19#Text
[32] https://zakon.rada.gov.ua/laws/main/555-15#Text
[33] https://zakon.rada.gov.ua/laws/show/287-19#Text
[34] https://zakon.rada.gov.ua/laws/main/280/97-%D0%B2%D1%80#Text
[35] https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80#Text

promotion of waste preparation for reuse, and recycling, as a result of which waste is processed into products, materials or substances for their use for a primary or other purpose, and restoration to prevent their negative impact on human health and the surrounding natural environment.

The law introduces the fundamental principles and provisions of European legislation in the field of waste management into national legislation; in particular, the introduction of the waste management hierarchy and the basic requirements for extended producer responsibility, a system of long-term waste management planning is introduced at the national, regional and local levels. Implementation of the National list of waste[36] contributes to the harmonization of the list of waste with the European one and will be used in the accounting and reporting system in the field of waste management.

The law envisages the introduction of a waste management information system, which will make it possible to significantly simplify the system of accounting and reporting, submission of declarations and implementation of permit procedures in the field of waste management. The introduction of a subsystem of open registers will provide access to information about generators and other owners of waste, the public. It is proposed to strengthen control over the collection and treatment of hazardous waste by strengthening the licensing requirements for such activities. The law establishes the procedure for the collection, removal and treatment of municipal waste, ensures the implementation of their separate collection and recycling, and provides requirements for the quality provision of waste management services and the charging of fees for such services. Ensuring the implementation of the above-mentioned provisions will make it possible to solve several nationwide problems related to the uncontrolled accumulation and burial of waste, the mass formation of spontaneous landfills, the total violation of environmental safety requirements in the field of waste management, and will lead to inflows of investments in the field of waste management. The law amends the Code of Ukraine on Administrative Violations[37], establishing a system of liability for offences in the field of waste management.

Adoption of the Law of Ukraine "On Waste Management" brings national legislation closer to the legislation of the European Union (EU), which will lead to a significant reduction in the amount of waste that will be sent to landfills and landfills and dumps, thereby improving the state of the environment and human health. As a result, the gradual introduction of best practices in waste management is expected; reducing the volume of waste disposal at landfills; attracting investments in the field of waste management and creating modern waste management infrastructure; reducing the number of waste management facilities that do not meet the requirements of the law; complying with environmental safety requirements during the operation of waste management facilities and reducing the level of social tension; increasing the volumes of collection, procurement, restoration and recycling of waste as secondary raw materials; creation of an information support system in the field of waste management, improvement of the procedure for keeping records of waste, informing about the location of places or objects of waste management, their impact on the state of the environment and human health. Adoption of the law serves as a basis for the legislative introduction of systems of extended producer responsibility to producers of products, because of consumption/use of which various types of waste are generated.

Adoption of the Law of Ukraine "On Waste Management" (coming into force on 09/07/2023) provides for the gradual development of new and bringing existing legal acts into compliance, including draft laws of Ukraine, acts of the Cabinet of Ministers of Ukraine and central executive authorities.

In Ukraine, the main circular economy program documents are the following:

- *National Waste Management Strategy until 2030* (envisages the implementation in Ukraine of the best European practices in the field of management of various types of waste and aims to identify and solve key problems of waste management in Ukraine; establish priority areas of activity for building an innovative model in Ukraine waste management; to determine ways and methods of improving the existing waste management infrastructure; to ensure the sustainable development of

[36] http://surl.li/mwvox
[37] https://zakon.rada.gov.ua/laws/show/80731-10#Text

Ukraine; to improve the quality of the services provided, as well as to reduce the administrative burden);

- *National Waste Management Plan until 2030*[38] (is a plan for the implementation of the National Strategy and establishes specific tasks and measures that will allow Ukraine to move to a new model of waste management by 2030, to a closed-loop economy, which is used by leading European countries. The implementation of the above measures is intended to adapt the national legislation in the field of waste management to the European one);

- *The main principles (strategy) of the state environmental policy of Ukraine for the period until 2030*[39] (principles for overcoming the consequences of environmental problems, including, by eliminating the causes of their occurrence, which are successfully working in EU countries, measures to reduce water and air pollution, as well as some changes in public administration due to the introduction of environmental norms and standards, fully complies with EU norms and standards in the field of ecology, as well as medium-term priority actions of the government);

- *Concept of Implementation of State Policy in the field of Climate Change for the Period up to 2030 and its Implementation Plan* [40] (determines the grounds for the development of draft laws and other normative legal acts in the field of climate change, established key directions of its implementation, which is designed to improve the state policy in the field of climate change climate, create prerequisites for Ukraine's transition to low-carbon development under the condition of increasing the welfare of the population, as well as economic, environmental and energy security);

- *Ukraine's Low-Carbon Development Strategy until 2050*[41] (envisages the transition of Ukraine's economy to a low-carbon development model by switching to renewable energy sources and mainly reducing emissions of greenhouse gases into the environment and was developed in order to fulfill Ukraine's obligations in accordance with the provisions of the Paris Agreement, the decision of the Conference Parties to the UN Framework Convention, as well as to fulfill the orders of the CMU, the goals are: forming a new energy system, increasing the amount of carbon absorption and retention, reducing emissions of greenhouse gases into the environment, and introducing the concept of ecological production in Ukraine through the use of “green” (ecological) technologies).

The implementation of these documents aims to improve legislation in the field of waste management; build effective schemes for the management of various waste streams; create a waste treatment infrastructure; to raise the level of awareness in this area of various interested parties (market players, authorities, the public, etc.). However, despite the large number of adopted program documents, a comprehensive system supporting the development of the circular economy has not yet been formed in Ukraine. The state of development of the branches of the “closed cycle” economy is still at a low level. In addition, these strategic documents provide for minimal interaction and cooperation of relevant departments.

In the international arena, special legislation regarding waste management was formed. The EU countries have defined the main legal aspects in the directives, which number more than ten, which is caused by the heterogeneity of the morphological composition of waste, the basic directive in this direction is the Directive 2008/98/EC on waste. The development of globalization has created conditions for the implementation of EU directives in the legislation of Ukraine.

Using the experience of developed European countries with a similar legal and institutional system it is necessary to develop an effective legislative and regulatory framework for the functioning of the circular economy in Ukraine, eliminating existing differences in the understanding and interpretation of some concepts. It is necessary to ensure maximum interaction and cooperation of relevant departments in the field of circular economy. In addition, taking into account the practical experience of the EU it is necessary to move to new, more effective business models (eco-design, repair, reuse, recovery and exchange of products and maximum prevention of waste generation).

[38] https://zakon.rada.gov.ua/laws/show/117-2019-%D1%80#Text
[39] https://zakon.rada.gov.ua/laws/show/2697-19#Text
[40] https://zakon.rada.gov.ua/laws/show/932-2016-%D1%80#Text
[41] https://mepr.gov.ua/wp-content/uploads/2023/07/LEDS_ua_last.pdf

The state of development of the circular economy in Ukraine can be assessed as very low or non-existent. The experience of introducing a circular economy model in leading European countries sets trends in the formation of a national economic development strategy. In today's conditions, Ukraine, taking the example of the EU countries, should implement specific changes that will facilitate the faster transition of its linear economy to a circular economy.

The introduction at the legislative level of the main European approaches and principles, including the five-level hierarchy of waste management and the principle of extended responsibility of the producer, will help producers to provide financial and technical support to local self-government bodies in organizing the separate collection of municipal waste and conducting educational and informational work with the population.

1.2 Pricing and the price on the market of secondary raw materials

The modern market system is better than others adapted to use the achievements of scientific and technical progress, intensification of production and, ultimately, to more fully satisfy the needs of consumers.

The market is one of the most widespread categories in economic theory and business practice and serves as a mechanism through which the balance of supply and demand is achieved. The main difference between the market of recycled materials and the commodity market because this market has peculiarities of origin and peculiarities of functional purpose.

The balancing of buying and selling in the market should be achieved with the help of such a tool as the price. If there is no balance between supply and demand, the market affects production through the price. An insufficient amount of some consumer goods on the market leads to an increase in their prices and vice versa, which, in turn, affects production, causing its expansion or decrease.

Therefore, the economy operating under market conditions develops according to market laws: cost, supply and demand, average profit, etc.

1.2.1 General information on pricing and determination of product prices

Pricing is a process of development, adoption and practical implementation of pricing decisions, depending on the goal pursued by the company in the market, different approaches to pricing are used, which are reflected in the pricing policy of the company.

The enterprise's pricing policy (price policy) is a set of measures for setting prices to achieve the enterprise's goal, which includes the development of a strategy, the choice of a pricing method and the adoption of management decisions on prices. Pricing policy consists of determining and maintaining the optimal levels and structure of prices within the product range of the enterprise, in timely changes in prices for goods and markets to achieve the maximum possible success in a specific market situation, and is almost the most important part of the general economic policy of the enterprise, because it contributes to better adaptation of the company to economic conditions.

The price takes a leading place in the mechanism of formation of market relations between economic entities and significantly affects the results of product sales and the effective operation of the enterprise (it directly affects the financial indicators of the enterprise, ensures the formation of profit and market share, determines the level of competitiveness of products, their perception by consumers and positioning from the point of view of consumer value, which is offered, is an indicator of the quality of the product, contributes to the establishment of mutually beneficial relations between enterprises and consumers, as well as with other market subjects, etc.). The correct setting of the price enables the enterprise to survive in difficult economic conditions and conduct effective activities, achieving its goal as best as possible.

The main mandatory elements of the product price are cost price and profit. In addition, the price may include: excise tax, value added tax, markups of supplier and sales organizations, trade allowances or discounts. When setting prices, the company must be aware of the close relationship

with consumers and competitors and, based on these factors, build its own pricing solutions for successful functioning in a competitive environment.

All prices are divided into two large groups: production and consumer.

Production prices are the prices at which products are sold and services are provided to other enterprises and organizations, they include:

Wholesale prices (enterprise prices and industry prices) are the prices at which state, collective and private enterprises are settled among themselves or with wholesale intermediaries for large batches of goods.

Purchase prices at which agricultural producers (cooperative, collective, state, farm, personal subsidiary farms) sell their products to state, cooperative, treatment, trading and other firms are also used in the procurement of products of fur breeding, fish farming, and recycled raw materials.

Estimated prices - prices and estimates used to determine the estimated cost of new construction, reconstruction of buildings and structures, their expansion and re-equipment.

Consumer prices - prices for goods and services sold to the population, which include:

Retail prices - prices at which the population buys goods in state, collective and private trade. Varieties of retail prices are prices for products of public catering establishments, tariffs for communal, municipal, transport, tourist and other services, housing prices.

The basis of the formation of wholesale and retail prices (and any prices in general) is the cost of production, which is the lower limit of the price.

The specificity of market pricing is that all costs associated with the production and sale of products do not directly determine the price level. The price level is significantly influenced by the market situation, which determines general approaches to pricing, namely the following factors:

- state regulation of prices;
- competition of manufacturers;
- ratio of supply and demand;
- purchasing power of money;
- product quality and others.

The method of pricing is a specific method, method, set of consecutive actions for determining and justifying the price of a specific product. The division of pricing methods into groups is quite conditional and depends on which factor dominates when determining the price and, accordingly, from which factor its justification begins (that is, demand-based methods mean that the base price of the product is set primarily on the basis of studying consumer demand, on costs - based on the calculation of average costs, on competition - taking into account the prices of competitors, etc.). The price obtained as a result of the application of any method is not necessarily final, and in many cases requires additional adjustment, in particular, other pricing methods may be applied to it, therefore such a price is a base or base price. The price determined based on demand can be adjusted using interconnected pricing and competition-based methods. In addition, it must be compared with costs and checked for profitability. Quite often, the price is determined simultaneously by several methods, and then the final price is selected.

Taking into account these factors, the market strategy adopted by the enterprise in order to establish the optimal price level, the following **pricing methods are used:**

1) **“costs+profit”**, in which the price, *Ц*, UAH, is calculated according to the formula:

$$Ц = С + П, \tag{1.1}$$

where *С* is the production cost, hryvnias;

П is the amount of profit in the price, hryvnias.

Profit is determined as a percentage of the cost price, the value of which is established based on considerations of product profitability and competitiveness. In the market economy, the scope of this method is limited.

2) **"obtaining the target rate of profit"**, which is focused on expenses and the target rate of profit. Businesses try to set a price, including the profit, which is planned as a percentage of the invested capital. At the same time, the concept of break-even is used, and when setting the price according to this method, the dependence of total costs and revenue on the volume of sales is taken into account, and the price, *Ц*, UAH, is calculated according to the formula:

$$Ц = В_{зм} + \frac{В_{пост} + П_{заг}}{N}, \quad (1.2)$$

where $В_{зм}$ – the amount of variable costs per unit of production, hryvnias;

$В_{пост}$ – constant costs for this product for a certain period (year), hryvnias;

$П_{заг}$ – the total amount of profit to be received for the same period from the sale of products, hryvnias;

N – the volume of product sales in natural units.

3) **"estimation of consumer value"** is based on the assessment of the consumer effect that the consumer has from using the product, and is associated with certain risks due to unjustified overestimation or underestimation of the price.

4) **"proportional pricing"** (or "according to the level of competition"), in which the price is set depending on the price level of competitors, that is, the price is a function of prices for similar products of competitors – $Ц = f(Ц_1, Ц_2, ... Ц_n)$, where n is the number of sellers of similar products.

5) **"expected profit"** – is used when the company plans to win a tender or competition for a contract at a lower price.

6) "**quick return of costs"** used for active sales of large volumes of products and quick return of spent funds due to the uncertainty of manufacturers in the long-term success of their products on the market.

Price belongs to the most important economic categories because it has a significant impact on all aspects of the economic activity of each enterprise and the entire country as a whole. With the help of the price, the costs of the enterprise are reimbursed, which are divided into wages of employees, materials, rent of premises, payment of taxes, etc. The price is a guide for buyers when choosing a product for purchase, with the help of prices, the relationship between supply and demand is regulated to a large extent. The price is the easiest to change, but finding and justifying its optimal level under certain business conditions is an extremely difficult and ambiguous task.

Market conditions of business require streamlining of the pricing system. It must comply with the laws of the market economy. The prevailing models of price setting in the market economy are cost and value pricing, which exist in parallel and are based on a deep and complete accounting of costs, to reduce them. In general, the application of pricing methods is a very individual process that depends on many factors (the goals of the company, the professionalism and awareness of managers, the market situation, etc.), so it is impossible to formulate any specific recommendations in this area.

1.2.2 Pricing on the market for recycled materials (in particular, compost)

The pricing strategy in market conditions, including the market for recycled materials, is based on three factors – costs, demand and competition. Enterprises in these conditions have wide opportunities in forming prices for goods and services. However, the state must regulate pricing processes with effective methods. In the field of waste management and the recycling market, it is primarily about supporting the production of low-profitable, but necessary goods for consumers through the system of state grants and subsidies, and promoting the purchase/sale of waste products (compost).

In addition, introducing new waste management systems and creating a recycling market is usually a complex process, as it requires the introduction of new technologies and new technical and administrative skills, which in turn requires new approaches to pricing, financing and reimbursement. The efficiency of secondary treatment depends on the quality of raw materials, and therefore on the primary sorting of waste. For these and other reasons, the effective implementation and operation of a new waste management system, including a recycling market, can benefit from technical assistance

from international organizations and/or experts who can train local staff and transfer their experience in supporting the development of local efficiency in management and provision of waste management services and organization of an efficient market for recycled materials.

In the market of recycled materials, on the one hand, there is a calculation of the economic value of the product, on the other hand, there is a price policy. At the same time, the price should at least cover the production costs; according to EU rules, the tariff must cover the "real cost".

Currently in Ukraine:

– methods of calculating product prices are far from international accounting standards;

– prices are often set based on a compromise between groups of influence, so they are rarely economically justified and efficient;

– current prices, which are the starting point of price policy, are social and far from EU practice;

– economically justified prices are difficult to determine in practice, especially given the goals they must meet (primarily: cost recovery). Currently, prices are often set on "non-economic" grounds (political or electoral considerations) and do not cover either the operating costs or the capital costs required to expand and improve production;

– when demand decreases, the price of products falls, which leads to their accumulation and further sale at inappropriate prices;

– prices change frequently, are set annually/seasonally, which makes it impossible to improve the quality of products in the medium or long term and is ineffective in terms of investment by the respective company in improving services.

As of 2023, **the market for compost** obtained as a result of the treatment of bio-waste as a recyclable material by the composting method in Ukraine has not been formed. At the first stage of the implementation of the bio-waste management system in the first year or two of operation of bio-waste treatment facilities, the obtained high-quality compost is provided to farmers and agricultural cooperatives free of charge to familiarize them with the advantages of its use and is used by communal enterprises of settlements for their own needs.

However, the bio-waste management system needs to be improved to increase its economic efficiency within the framework of increasing the efficiency of the overall waste management system. Based on this, it is necessary to develop local compost markets for the possibility of its realization at a price that will take into account all the costs of its production, and the possibility of receiving income from the sale of compost, which will not be equal to zero. The decision to provide services for the treatment of separately collected bio-waste from the population on a free basis leads to a missed benefit, considering that an approximately high-quality product from separately collected bio-waste (organic waste, sorted municipal and commercial green waste) is worth 5-10 euros per 1 ton.

In Ukraine, the market value, limitations in doses, frequency of application and areas of application of different groups of compost are established depending on the quality assessment according to the criteria of SOU ZhKH 03.09-014. So, as of 2023, according to expert estimates, the market value of compost by areas of application:

- **in agriculture** (for grain, fodder and technical crops) available only *for group 1* (used in doses adequate to standard fertilizers) and is approximately 620 UAH/t. For *group 2* (used at a dose of 4-5 t/ha per year based on the dry matter or no more than 15 t/ha once every 3 years) and *group 3* (used at a dose of 5-6 t/ha based on the dry matter once every 5 years with mandatory control of the background content of elements) is not installed;
- **in forestry, green construction and for land reclamation** (forest crops, green construction, land reclamation) is 620 UAH /t *for group A* (used in doses adequate to standard fertilizers) and 450 UAH/t *for group B* (used in a dose of 10-15 t/ha per year on the dry matter or no more than 50 t/ha once every 3 years), *for group B* (used in a dose of 10-20 t/ha of dry matter once every 5 years with mandatory control of the background content of elements) there is no market value.

To increase the price of compost, it is advisable to prepare compost according to the specific needs of the market by including different types of composted humus or other natural additives that

can improve the resulting compost. Composting and the creation of a compost market are especially effective in those areas where the content of organic substances in waste is significant and there is a need for fertilizers. The introduction of composting technology will reduce the cost of purchasing fertilizer for existing enterprises that are prospective consumers of compost as fertilizer, and the sale of its surpluses will provide an opportunity to obtain an additional source of income and stimulate the formation and growth of the compost market.

For the market of recycled materials in Ukraine to be successful, it is necessary to overcome the existing obstacles, including regarding the practice of setting the price, and constantly take into account the factors that influence its formation.

1.3 Factors affecting the formation of the secondary raw materials market

To solve the main economic problems, including waste management, the market system turned out to be the most effective and flexible. At the same time, the level of stability of the development of the market and its individual components depends on the nature of the influence of various factors and factors, among which the main ones affecting the market of secondary raw materials can be distinguished:

- application of economic tools that stimulate the use of recycled materials (tax benefits, subsidies, deposit return systems, etc.);
- absence or malfunction of the waste management system, namely, collection, sorting and storage of waste as secondary raw materials;
- the amount of recycled material received (certain volumes that can be used immediately);
- quality of collected secondary raw materials (presence of impurities, pollutants);
- costs for transportation of recycled materials;
- obstacles of a practical nature (for example, additional costs for treatment and cleaning resource-valuable material);
- current standards/technical conditions and other regulatory documents for secondary raw materials and products from them;
- bias of product manufacturers and consumers regarding the possibility of using recycled raw materials or products from them due to their low quality;
- lack of necessary information among potential consumers regarding the availability and possible ways of using the appropriate secondary raw materials.

Unfortunately, today in Ukraine, the policy on the market for the management of municipal waste and recyclables is imperfect.

Potentially, most of the waste can be involved in a new resource cycle, but for some types of waste there are barriers of a technological or economic nature (availability of treatment technologies, profitability, demand for secondary raw materials or products using them, etc.), so part of the waste currently does not find use as a recycled material, influencing the formation of the recycled material market.

It should be taken into account that in case of the need for additional cleaning and sorting of recycled raw materials, the costs of obtaining them increase, which affects the cost of recycled raw materials on the market.

There is a need to bring the tariffs for waste management to a justified level by including in the tariff for the removal of waste the costs of their sorting and treatment, and in the tariff for waste disposal - a significant increase in the environmental tax to stimulate the reduction of the volume of disposal of unsorted waste, including recycled materials.

The national system of collecting statistical data and monitoring market indicators has significant shortcomings, which leads to the emergence of significant discrepancies between the data of state authorities and expert organizations, which leads to the fact that actual calculations between consumers and subjects in the field of waste management are carried out according to the state regulations standards, and not by the volume of actually provided services. In addition, it is necessary

to note the lack of reliable information in the country on the amount and composition of municipal waste generated, transported and buried, since there is no systematic approach to accounting (weighing) waste at the indicated stages of their management of, and the calculations of indicators are carried out mainly according to the rules for the removal of municipal waste of waste per inhabitant (at the same time, these norms are individual for different settlements and may differ several times). There is an urgent need to create a system for monitoring and accounting for the volume and composition of the MW to develop an actual state policy in this area.

It is also necessary to increase the number of educational and informational programs regarding the harm to people and the environment caused by the unlimited consumption of goods, the waste of which pollutes the natural environment. In addition, consumers are not well informed about the possibilities of returning materials that can be reused or otherwise beneficial. In highly developed countries, positive experience has been accumulated in the organization and operation of an effective system of stimulating the rapid implementation of separate waste collection, which should be studied and implemented in Ukraine.

As of 2023, to deepen the level of treatment of recycled materials increase the number of secondary resources obtained and make the secondary raw materials industry in Ukraine effective and attractive for investors, it is necessary, to take into account the factors affecting the market of recycled materials (in particular, compost), to start with the improvement of the relevant legislation, implementation of information campaigns, gradually getting closer to setting prices at the market level, including for waste removal, and expanding the producer's responsibility.

1.4 Trends in the development of the market of secondary raw materials with the highlighting of the main problems

The market of secondary resources as one of the markers of the circular economy becomes an integral and important component of any economic system. Thanks to its operation, the use of primary resources is reduced through waste recycling, the energy efficiency of production is increased due to the use of waste as energy resources, and the amount of waste removal, in general, is reduced. The formation of the market of secondary raw materials in Ukraine is becoming more and more systematic, and the absolute indicators testify to the stable dynamics of its growth. Increased attention to secondary raw materials in the modern world is because every year it is gaining more and more importance in the overall resource balance of several industries. Therefore, the absence of a formed market for secondary raw materials in Ukraine restrains the use of reserves of these resources.

Secondary resources are suitable for the repeated manufacture of finished products from them, which implies their economic importance as a large reserve of saving material costs, prospects for improving the environment and an effective method of educating people to be thrifty. Modern development trends in the field of waste management are increasingly directed towards secondary resource use (recycling), which depends on the composition of waste and is associated with the presence of certain useful and valuable elements (paper waste, polyethylene, plastic packaging, food waste, glass, metal, plant waste, tetra pack packaging, etc.). In addition, the costs of management of (collection, transportation, sorting and treatment) of waste as a secondary raw material are several times lower than for the production and enrichment of primary materials, from which paper, textiles, polymer materials, glass, and various metals are contained in MW.

The main difference between the environment for the implementation of the waste management system and the market for recycled materials is that Ukraine currently has a peculiar alternative system of collecting and collecting secondary raw materials, different from the European one, which can be technologically defined as the primary stage of separate collection of waste, which is partially carried out by the population, that separates part of the waste from the total volume and hands over the received recycled material to collection points or uses it for its purposes. The rest of the procurement of separately collected recyclables is provided through contracts with enterprises that generate large waste streams in the production cycle. However, for the sorting and treatment of waste,

including recycling, to produce higher results, it is necessary to involve more citizens, state and local authorities, and businesses.

The classic way of removing waste from a container to a landfill today is inefficient and potentially dangerous due to several factors, including the fact that the landfill is a source of "landfill gas" that stimulates the greenhouse effect. The creation of new environmentally friendly technologies, progressive ways and methods of waste treatment will be facilitated by the mechanism of stimulating nature use on an innovative basis; therefore, there is a need for active state intervention.

For the waste management system (including waste treatment and reuse) to work, it is necessary to involve all possible subjects in cooperation, which, starting from the local level will help to reorient the consciousness of the citizens themselves, and then achieve the effect at the national level. At the moment, due to the rather passive position of citizens compared to EU residents, it is necessary to implement measures in this direction to stimulate the introduction of separate collection, and as a result of the development of the field of municipal waste management and the creation of an effective market for recycled materials. Also, the environmental awareness of the majority of Ukrainians is at a low level, therefore, for the high efficiency of the implementation of waste management activities, it is necessary to carry out active promotional activities, that is, incentive measures for initiative groups in the field of environmental development and safety, which are a tangible driver of relevant changes, which can bring considerable economic and social effect.

In general, in Ukraine, the need for waste treatment and the creation of a market for recycled materials is a topical issue and has two aspects:

– without an established waste treatment process, their volumes and, accordingly, the area of waste landfills for the disposal of accumulated waste will increase rapidly, polluting the environment and approaching an ecological disaster in the country where this is the most widespread method of waste treatment;

- waste treatment (including recycled materials) and the sale of the resulting products can be a profitable business, which is successful in many developed countries, because waste is a unique resource, the main feature of which is that its reserves are practically inexhaustible, as long as Humanity produces waste, and on average one person produces about 300 kg of waste per year.

Waste treatment is a good opportunity to start a profitable business with minimal capital investment. Additional value in the field of waste management appears when waste becomes a raw material for various industries, which is possible only under the conditions of high quality and cheap collection and sorting. Currently, secondary raw materials in Ukraine cannot compete with cheap foreign resources based on these two indicators, but they have potential. With the introduction of extended producer responsibility, the solution to the issue of building the waste collection and sorting infrastructure will begin, and under the conditions of comprehensive assistance at the state level, it is possible to develop an effective industry of recycling, which will bring additional funds to the country's budget and create jobs. Table 1.1 shows the main advantages and disadvantages of waste treatment activities.

Table 1.1 – Main advantages and disadvantages of waste treatment activities

No.	Advantages	Disadvantages
1.	A constant increase in the volume of production of "raw materials" for the implementation of activities	Bureaucracy and peculiarities of legislation
2.	The problem is highly relevant due to the deterioration of the ecological situation and the raising of this issue at the international level	Valuable equipment
3.	High prospects for development if it is possible to start operations with small volumes of "raw material" and capacities of the treatment facility	Competition, presence of monopolists
4.	The profitability of the activity is from 60 to 80%	Lack of waste sorting system and culture

Several obstacles hinder the development of the waste management system and, accordingly, the recycling market in Ukraine with the participation of private capital can be conventionally divided into:

- *administrative* – caused primarily by insufficient financing of the industry as a guarantee of investment return. Such obstacles include the imperfect regulation of tariffs and other payments related to waste, as well as the lack of economic incentives for the development of recycling. Barriers are also the lack of a clear division of responsibility between market participants, the lack of transparency of public-private partnership mechanisms, the lack of reliable data on waste, as well as the problems of technical regulation of the industry and environmental monitoring;
- *economic* – become an obstacle to new enterprises entering the market, as they negatively affect the transparency of the industry's functioning. Stakeholders cannot access the complete information needed to make effective decisions. Eliminating uncertainty requires high operational costs;
- *cultural and informational* – manifested in insufficient awareness of the importance of proper waste management in society, as a result of which the population's demand for services of appropriate quality is practically absent. It requires a change in attitude to the problem both on the part of the population and on the part of the authorities.

As of 2023, the main problem of applying **composting technology** in Ukraine - apart from the possibility of using limited types of waste (only waste of vegetable origin (bio-waste)) and the need to create a separate system for managing bio-waste (separate collection), is the lack of a market for the resulting compost or compost-like of the product, resulting in lost profit.

Gradually, the provision of separately collected municipal and commercial bio-waste treatment services will be expanded due to their presence in large quantities in the territory of the settlement and the expansion of their collection volumes. Therefore, it is important to develop markets for compost obtained as a result of treatment bio-waste as a recyclable material at waste treatment facilities (composting stations, mechanical-biological treatment facilities, etc.) for the possibility of its realization with income, the increase of which is possible provided that the quality of the compost meets specific market needs. The introduction of a centralized composting system and the creation of a local compost market in those areas where the content of bio-waste in the total volume of municipal waste is significant and there is a need to obtain fertilizers for use by local enterprises is particularly effective.

The use of secondary resources is an important ecological, scientific, and technical problem that requires its development. The continuous growth of the collection of secondary raw materials in Ukraine has been especially observed in the last 5-6 years. Forecast estimates indicate a gradual growth of the potential of secondary raw materials in the coming years, taking into account the available resource reserves of secondary raw materials in Ukraine. However, only 15-20% of revenue in this area has been mastered. In Europe, the process of obtaining profits is quite developed, and in Ukraine, this area is just beginning to develop. In EU countries, about 85% of waste is processed a second time, while in Ukraine the system of separate waste collection is still mostly at the initial stage of implementation. The indicators of the market of secondary raw materials in economically developed countries are much higher than in Ukraine, which indicates a high state of development of technologies, equipment and, in general, material and technical support of the relevant treatment enterprises, which affect a high percentage of the creation of secondary resources. To ensure the profitability of Ukrainian recycling enterprises, it is also necessary to develop this direction.

Today, a certain structure of the recycling market has been formed in Ukraine, but its development is at a slow pace. The consistent implementation of the measures of the National Waste Management Strategy and the National Waste Management Plan, which set the task of transitioning to the principles of a circular economy (in particular, the formation of effective waste management schemes with a priority for their recycling in each region of the country; the creation of a waste treatment infrastructure based on the principles of self-sufficiency and proximity; establishment of

tariffs for waste management based on full cost coverage, etc.). The development of the secondary raw materials market in Ukraine is a rather complicated process. Its practical support should be recycling technology in the field of municipal waste treatment since it is the initial stage of further treatment of waste as recycled raw materials to create a new product. A prerequisite for the construction of an effective waste recycling system in Ukraine and the further application of recycling technologies is the introduction of an effective system of separate waste collection based on an improved and clearly defined waste classification at the legislative level. The introduction of priority measures in Ukraine, which are the basis of recycling, will make it possible to increase the efficiency of the recycling market.

Solving the tasks of optimizing the organization of the secondary resource use system as an infrastructural and production link of the national economy should methodologically be based on a comprehensive approach and include research on the territorial location of existing enterprises; identifying features of the formation of the resource base of secondary raw materials; determination of existing disparities and inconsistencies in the resource-production model. The main factors shaping the marketing of recycled materials include price policy, market conditions, market infrastructure, demand and supply of recycled materials, institutional support, budget constraints of consumers and factors of cyclical and economic growth.

The problem of the recycling market in Ukraine has not been sufficiently studied, it faces many issues on the way of its development, however, some measures can increase the turnover of this market and thereby affect the improvement of the country's economy and the efficiency of the development of the recycling market itself, which depends on the state of the economy as a whole. The correct use of secondary raw materials in various branches of industry as a source of additional material resources, a factor in reducing capital costs and production costs is important for the further development of the country's economy.

1.5 Main strategies for waste management in European countries and their impact on the economy of Ukraine

A package of Directives on waste management, which includes measures to help stimulate the EU's transition to a circular economy, strengthen global competitiveness, promote sustainable economic growth and create new jobs, with the assumption that the transition to a circular economy will increase the EU's GDP by 2030 by 17%, approved by the EU Commission in December 2015. The given EU action plan establishes a specific program of measures for the development of the circular economy, which covers the entire cycle: from production and consumption to waste management and the market for secondary raw materials, and determines time limits for the implementation of the described actions. The proposed measures involve “closing” the product's life cycle through recycling and reuse, which will benefit both the environment and the economy.

In most of the developed countries of the world, the policy of dealing with hazardous waste is aimed at curbing the volume of their production and increasing the depth of treatment. Thus, in the EU countries, the management of MSW is based on the construction of the most ecologically safe system of management of MSW flows. The priority is not disposal of waste at landfills, but separate collection and treatment. Most of the MSW is processed, used (returned to treatment plants as recycled material) or used as fertilizer, and most of the final waste after sorting, which could not be sorted, is incinerated to generate energy that is used to heat homes and generate electricity. Waste incineration plants are widely used in countries with high population densities (Sweden, Germany, Japan, Switzerland, Belgium, etc.). However, the operation of these plants in comparison with waste treatment enterprises and landfills requires significantly higher capital and operating costs.

In Denmark, Sweden, Belgium, the Netherlands, Germany, and Austria, less than 5% of MSW is landfilled, 35% is recycled; 15% is used for composting and biogas production and 50% of MSW residues are incinerated in most developed countries. Local self-government bodies determine the tariffs for the removal of waste materials independently. Often in EU countries, a two-rate tariff applies: for sorted waste – lower, for unseparated – higher (sometimes double). There is an effective

system of fines. The majority of the EU population does not refuse to sort and prefers deep separation, thus the separated waste goes to recycling points, for some of the types you can get paid.

In the EU countries, at the national level, it is recommended to focus efforts on the implementation of state regulation of the field of waste management on more rational use of resources in the production of products to minimize the volume of waste generation at all stages of the life cycle, changing the behavioral stereotypes of consumers in the direction of moderate consumption of goods and services, and modernizing old landfills of waste by new requirements and the development of environmentally safer and cheaper methods of management of waste as the most promising areas of regulation.

In 2015, the European Commission identified as a priority the departure from the so-called linear EU economy and its transformation towards a closed cycle economy (circular economy), where natural resources and goods made from them should serve as long as possible and at the end of their life cycle transform into secondary raw materials, and not become waste. The idea of a closed cycle economy is proposed by analogy with a natural ecosystem, which is an excellent example of the natural sustainability of a system where the concept of waste is absent in principle – all "waste" produced serves as food for others, creating a stable cycle of matter and energy. A priority issue for the circular economy is waste management, including the prevention of their formation. An important part of the circular economy is the market of secondary raw materials.

An important priority of the European Commission in recent years has become the strategy of effective management of bioresources, or bio-economy, the main sectors of which are agriculture, forestry, fish farming, and to a large extent the food industry. Occupying a relatively small share in the structure of EU GDP, they are sectors of the economy that provide the basic natural needs of EU citizens, therefore their proper management is extremely important for the sustainable development of the EU.

The most ambitious priority of the EU's sustainable development strategy in recent years has become the strategy of the European Green Deal[42], which involves not just proper protection and preservation of the environment, but a complete transformation of the EU economy with the aim of turning Europe into the first climate-neutral continent, where the negative impact of man on the natural environment and climate planets minimized. In particular, by 2050, the total emissions of greenhouse gases should be equal to zero, and the entire economic system will be as friendly as possible to the natural environment.

The action plan for the circular economy, which provides for the transformation of sustainable products into the norm in the EU, will eventually lead to a decrease in the demand for industrial products due to the extension of the period of use of goods. Given this and the promotion of the use of secondary raw materials, it is possible to predict a proportional decrease in the demand for raw materials.

Initiatives in the agricultural sector and the transition to a sustainable EU food system will probably increase the requirements for agricultural and food products - this may become an additional trade barrier and negatively affect Ukrainian exports. On the other hand, the popularization of organic products in the EU will create new market opportunities for producers.

The circular economy action plan in the EU aims to create a coherent policy for sustainable goods and services, mainly to prevent the generation of waste in the process of their production. In addition, the EU seeks to create an effective market for secondary raw materials, the strengthening of which in the EU will lead to a reduction in the export of secondary raw materials to Ukraine, which will affect treatment industries that are currently dependent on the import of such raw materials - the volume of forced imports for the functioning of existing treatment enterprises is 400,000 volume/year At the same time, the EU's intention to completely abandon the export of waste and introduce a powerful European market for recycled materials can contribute to the emergence of such a market in Ukraine, which, in turn, will create conditions for the separate collection, sorting and treatment of waste in Ukraine.

The Cabinet of Ministers of Ukraine for the first time identified the transition to the principles of circular economy as a priority task in 2017. The introduction of circular economy ideas in Ukraine is an important step in the activation of European integration processes because the idea of a circular economy is new for Ukraine and it lags far behind the EU countries in the development of this direction.

[42] https://commission.europa.eu/document/daef3e5c-a456-4fbb-a067-8f1cbe8d9c78_en

CHAPTER II. ANALYSIS OF THE SECONDARY RAW MATERIALS MARKET IN UKRAINE

On average, about 76% of primary production waste, about 18% of secondary production, almost 2% of agricultural waste and about 2% of municipal waste (MW) are generated in Ukraine every year. Despite the insignificant share of MW in the structure of waste, they affect the state of the environment in settlements and act as a source for obtaining secondary raw materials.

2.1 Analysis of waste collection and secondary raw materials (volume of generated waste, volume of recycled waste, volume of use of secondary raw materials)

2.1.1 State of the field of municipal waste management in Ukraine[43]

As of 2023, in Ukraine, at the legislative level, the executive bodies of village, settlement, and city councils are responsible for solving municipal waste (MW) management issues, setting tariffs for the MW management service, and organizing the separate collection of useful MW components (recyclables). Appropriate work is also being carried out to create market conditions and develop a competitive environment in the field of waste management and the provision of services by business entities involved in the removal of hazardous waste.

According to the data obtained[44] in the settlements of Ukraine for the year 2022, almost 80% of the population is covered by services for the removal of solid waste, which generated almost 39 million m³ (or more than 7 million tons), which buried in 5.7 thousand landfills and dumps in total with an area of almost 8,000 hectares, of which 163 units are overloaded landfills (2.8%), do not meet environmental safety standards – 693 units, (12%), require passporting – 34% of their total number. The need for construction of new waste landfills is 290 units, for reclamation – 2,197 landfills, removal of unauthorized landfills – 14.7 thousand with a total area of 0.6 thousand ha.

In 2022, about 9.9% of MW was processed and disposed of, of which: 1.66% was incinerated, and 8.24% went to recycling points and waste treatment lines.

By the requirements of the Association Agreement with the EU, Ukraine must implement Directive No. 2008/98/EU on waste, according to which it is obliged to achieve by 2030 the rate of recycling of 50% of waste through separate collection. In 2022, separate collection of solid waste will be implemented in 1,440 settlements in Ukraine, for the effective implementation of which it is planned to purchase containers and garbage trucks for the current year at the expense of regional and local budgets, from environmental protection funds, at the expense of the program of projects of local initiatives and funds of enterprises. In addition, 10 waste sorting complexes, 1 waste incineration plant, and 1 waste transfer station are being built in settlements.

There are 31 waste sorting lines in 26 settlements: in Vinnytsia, Murovani Kurylivtsi village, Illintsi, Kalinivka, Kozyatyn and Ivanivtsy village, Vinnytska oblast; Lutsk, Kryvyi Rih, Neresnitsa Zakarpatska oblast, Zaporizhia, Ivano-Frankivsk, Bila Tserkva, Obukhiv, Pereyaslav, Kyivska oblast, Kropyvnytskyi, Busk, Sambir, Novoyavorivsk, Stryi (2 lines), Chervonograd and Zolochiv, Lvivska oblast, Sumy, Plebanivka and Malashivtsi villages, Ternopilska oblast, Bogodukhiv, Kharkivska oblast, Kyiv (5 sorting lines). Disposal of MW by incineration is carried out at an incineration plant in Kyiv.

On 55 landfills there is a leachate collection system, including at 50 landfills there is a leachate decontamination system, at others storage tanks are arranged, from where leachate is periodically transported to treatment facilities.

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[43] The state of the field of household waste management in Ukraine was analyzed based on data provided by regional military administrations without taking into account information on temporarily occupied territories, as well as most of the eastern and southern regions of Ukraine, which due to military aggression by the russian federation did not have the opportunity to provide complete information on statistical data in this area, since part of the territories were occupied for some time or are still occupied or are currently in hostilities, which makes it impossible to collect data in these territories

[44] https://mtu.gov.ua/news/34323.html

On 18 waste landfills, a biogas extraction system has been installed (biogas is flared at landfills in Kremenchuk, Konotop, Sumska oblast, Kharkiv) and cogeneration plants are in operation (Vinnytsia; Lutsk; Uzhhorod, Zhytomyr, Rybne village, Ivano-Frankivska oblast, Boryspil, Pidhirtsy village, Obukhiv district, Hlyboke village, Boryspil district and Rozhivka village, Brovarsky district, Kyivska oblast, Kyiv city, Kropyvnytskyi, Vesnyane village, Mykolaivska oblast; Odesa; Kremenchuk, Rivne; Kharkiv, Khmelnytskyi; Cherkasy).

Thus, today Ukraine is experiencing a crisis in the field of municipal waste management. Due to the imperfection of the monitoring system, it is difficult to obtain objective information about the amount of waste and its morphological composition, and due to a lack of funding, it is impossible to carry out the reconstruction and modernization of existing waste management facilities and to build new ones. According to statistics, most of the generated waste is removed to specially designated places and objects, buried in landfills and landfills, but there are also cases of dumping of waste in unauthorized places. The cost of communal services does not cover costs in this area, as a result, the communal sector is unable to provide high-quality services for the management of municipal waste to the population. Given the low solvency of the population and its detachment from waste issues, the indicators of separate collection and sorting of solid waste remain low – the separate collection is implemented in a fragmented, unsystematic manner, covering the central parts of settlements, where shopping centers and points of acceptance of secondary raw materials are concentrated.

2.1.2 Available volumes of waste in Ukraine

The development of the modern stage of civilization leads to a rapid increase in the volume of waste generation – every year in Ukraine, their volume increases by an average of 20%.

Table 2.1 shows the main indicators of waste generation and management in Ukraine. Table 2.2 shows the generation of waste by categories of materials. Table 2.3 shows the waste management according to disposal operations.

During 2014-2020, the average annual rate of decrease in the volume of waste disposal was 4.94%, the volume of incineration was 0.34%, while the volume of waste that ended up in specially designated places grew by 1.2% annually. In 2020, 4.61% of the total volume of collected waste was sent for recycling, which is more than 95% more than the corresponding indicator of 2014, but several times lower than similar indicators of EU member states.

As of 2023, the popular way of management of waste remains its removal for burial in landfills and dumps, creating a critically low level of waste treatment. This can also be explained by the current tariffs for the disposal of MW, which are regulated by the state and local self-government bodies - they are significantly lower than the cost of sorting and treatment by specialized enterprises. It is economically unprofitable for companies that collect and dispose of MW to sort and send MW for recycling - therefore, at the end of the reporting period, the majority of waste remains unutilized and only a small part of the waste is used for energy or utilized for further treatment. For comparison: in EU member states in 2020, about 40% of waste was disposed of and processed, 31.3% was sent to landfill, and 0.48% was incinerated.

Table 2.1 – Main indicators of waste generation and management in Ukraine

Indicator of waste generation and management	2010	2015	2020
Formed, thousand tons	**425,914.2**	**312,267.6**	**462,373.5**
including from economic activity	419,191.8	306,214.3	456,423.8
Waste generated per person, kg	9,285	7,288	11,074
Collected and received municipal and similar waste, thousand tons	9,765.5	11,491.8	12,634.9
Imported, thousand tons	4.1	3,4	2.7
Total burned, thousand tons	1,058.6	1,134.7	1,008.0
including for the purpose of obtaining energy	840.3	1086.3	902.2
Recycled (R2-R11), thousand tons	145,710.7	92,463.7	100,524.6

Indicator of waste generation and management	2010	2015	2020
Prepared for disposal (R12-R12K), thousand tons	–	1,940.5	2,641.3
Removed to specially designated places or objects (D1, D5, D12), thousand tons	313,410.6	152,295.0	275,985.3
including to specially equipped landfills (D5)	207,445.1	31,142.8	25,815.3
Removed by other removal methods (D2-D4, D6, D7), thousand volumes	24,318.0	55,248.1	46,768.1
Neutralized (D8, D9), thousand tons	–	2616.0	464.8
Placed in dumps, thousand tons	87.4	14.4	–
Exported, thousand tons	281.3	675.4	257.8
Removed due to leakage, evaporation, fires, thefts, thousand tons	1,367.6	6.5	–
Accumulated waste during operation at waste disposal sites at the end of the year, million tons	13,267.5	12,505.9	15,635.3
calculated per 1 km² of the country's territory, tons	21,984.2	21,692.8	27,115.9
per person, kg	289,236	291,888	374,457

Note: in 2010, the indicator "recycled" includes volumes of waste prepared for disposal, the indicator "accumulated waste during operation at waste disposal sites at the end of the year" includes volumes of waste temporarily placed in specially designated places or facilities. Data on waste disposal in specially designated places or facilities for 2010 are listed: waste dumped into surface water bodies and pumped to depth, which are classified as other methods of waste disposal, were removed. Codes for recycled (R) and disposal (D) operations are listed by the list approved by the State Statistics Service order No. 24 of 23.01.2015

Table 2.2 – Generation of waste by categories of materials in Ukraine, thousand tons

Waste category by materials	2015	2020
Total	**312,267.6**	**462,373.5**
Used solvents	31.6	2.4
Waste acids, alkalis or salts	384.9	392.7
Waste oils	15.5	19.3
Chemical waste	913.4	663.2
Sediment of industrial effluents	3,209.9	3,462.1
Sludge and liquid waste of sewage treatment plants	249.8	860.6
Medical and biological waste	0.9	1.1
Waste of ferrous metals	3,396.7	2,491.9
Waste of non-ferrous metals	30.1	24.3
Mixed waste of non-ferrous and ferrous metals	9.6	10.3
Glass waste	22.3	21.0
Paper and cardboard waste	111.0	140.8
Rubber waste	22.9	19.9
Plastic waste	42.9	40.8
Wood waste	683.1	750.1
Textile waste	8.0	21.9
Waste containing polychlorodiphenyls	0.5	0.2
Waste equipment	14.4	5.0
Waste vehicles	3.1	1.0
Accumulators and battery waste	7.2	4.2
Animal waste and mixed food waste	897.0	405.4
Waste of plant origin	7,742.3	6,101.8
Animal excrement, urine and manure	4,938.0	3,314.7
Municipal and similar waste	6,789.2	6,672.0
Mixed and undifferentiated materials	7,380.9	6,906.3

Waste category by materials	2015	2020
Sorting remnants	35.6	35.1
Normal sediment	397.6	334.1
Mineral waste of construction and demolition of objects	897.5	873.2
Other mineral waste	235,700.2	404,649.4
Combustion waste	13,896.0	10,845.7
Soil waste	788.2	1332.8
Empty rock from dredging works	23,125.1	11,947.5
Solidified, stabilized or vitrified waste; mineral waste generated after treatment	522.2	22.7
Note: the categories of waste by materials are given in accordance with the international statistical classification EWCStat Ver.4, adapted to national conditions		

Table 2.3 – Waste management by disposal operations in Ukraine

Disposal operation	Operation code	2010	2015	2020
Total disposed of	–	**145,710.7**	**92,463.7**	**100,524.6**
Disposal / regeneration of solvents	R2	330.6	65.3	111.2
Recycling / disposal of organic substances that are not used as solvents	R3	2,773.2	443.2	320.0
Composting of organic waste	R3 A	147.4	651.1	549.8
Fermentation of organic waste	R3 B	295.8	86.7	63.5
Recycling of paper and cardboard	R3 C	–	24.0	0.3
Recycling / utilization of metals and their compounds	R4	9,564.4	6,515.8	5,356.2
Recycling / utilization of other inorganic materials	R5	110,658.2	58,958.1	43,068.9
Regeneration of acids and bases	R6	33.6	0.4	2.1
Recovery of components used to reduce pollution	R7	6,125.2	137,18.7	36,553.7
Recovery of catalyst components	R8	0.0	0.0	0.0
Re-distillation of used petroleum products or their other reuse	R9	99.3	29.0	13.5
Soil treatment that has a positive effect on agriculture or improves the ecological situation	R10	9,244.5	10,763.3	13,501.3
Use of waste obtained from any of the above operations	R11	6,438.5	1,208.1	984.1
Everything is prepared for disposal	–	–	1,940.5	2,641.3
Exchange of waste for further disposal or disposal	R12	–	34.9	2,578.4
Waste sorting	R12 A	–	163.1	32.3
Mechanical and biological treatment of waste at MBP installations	R12 B	–	57.6	15.3
Dismantling unusable vehicles	R12 C	–	0.0	0.0
Collection and preliminary treatment of scrap metal and waste containing metals	R12 K	–	1,684.9	15.3
Note: 1) waste utilization is the use of waste as secondary material or energy resources. 2) operation codes are given by the list of waste disposal and disposal operations, approved by the State Statistics Service of Ukraine order No. 24 of 23.01.2015				

Depending on the resource value of the waste and other factors, *resource-valued waste* (is a competitive recyclable material from the point of view of modern ecological, technological and other conditions and requirements), *potentially resource-valuable waste* (has a close prospect of its possible use as a recyclable material, based on their properties and composition, development trends the country's resource needs, market conditions, technological progress, etc.) and *waste with an uncertain resource value shortly* (currently, under existing technologies, they cannot be processed and used as recycled materials, and can be considered promising under certain conditions of technological development). According to the specified features, the listed waste has its level of use as a secondary resource on the recycling market, and part of the waste is currently not used.

To reduce the load on landfills, improve the environmental situation, improve the waste management mechanism and increase the percentage of waste used in the field of secondary resource use (such as recycled materials), a separate group of specific waste, bio-waste, which includes the so-called “green waste” (fallen leaves, waste from cutting green fences and lawns, trees, keeping green areas clean) and separate fractions of food waste. In the process of introducing a separate collection system, this bio-waste needs to be more carefully separated from the main volume of waste, which is fundamentally important, because, firstly, it should not enter the recycling system of other types of waste as secondary raw materials (to significantly increase the quality of their further sorting), secondly, these wastes have a significant resource potential and serve as a good source for obtaining products as a result of their appropriate treatment - compost, which determines the urgency of finding ways to process them.

2.1.3 Assessment of the impact of the state of waste management on the secondary resource utilization industry and the market for recycled materials

As shown by the trends in the development of the sphere of management of MW, the activation of market relations accelerated the turnover and contributed to the expansion of the range of products. These processes have led to an increase in the volume of solid waste, which contains waste that requires specific methods of management, including the effective implementation of recycling systems. Statistics on waste management show a critical situation related to the low level of treatment of the received waste. A significant increase in the amount of waste and its improper management leads to the deterioration of the state of environmental, economic and social security in the respective territories.

Policy and legislation of the EU and countries on waste management in many parts of the world place increasingly high demands on providers of these services, namely on municipalities and their associations, demanding high rates of recovery and recycling for a wide range of materials and goods, high rates of redirection of the biodegradable fraction of waste, advanced treatment processes, long periods of care for existing and planned landfills, etc. In addition, this level of service must be provided at the lowest possible cost, as the public will not be able to withstand significant increases in waste collection fees, and municipalities are increasingly being required to benchmark their operations to ensure the most efficient provision of waste removal services.

The current practice of waste management in Ukraine is focused on the collection, removal and disposal of MW in landfills and dumps, most of which do not meet the requirements of environmental safety, as well as in spontaneous landfills. Responsible waste management is a key issue for the entire recycling industry in Ukraine. Recycling is the process of converting waste into material that can be reused, is a key element of the circular economy and one of the main stages of waste management. The determinant for recycling is the availability of high-quality secondary raw materials, so waste accumulated at the landfill due to its mixed structure is not suitable for further treatment. Waste treatment will develop only if there is access to quality raw materials. Currently, there is a shortage of recycled materials on the domestic market, among other things, due to the poor quality of the received recycled materials as a result of low-quality sorting.

The field of waste management is of particular interest in terms of its potential to optimize services, as waste management systems with a large number of secondary flows usually require more

transport and this sector, even if only waste collection services are concerned, already absorbs a significant part of the municipal budget, allocated to waste management. Optimizing waste collection using new tools offered by spatial modelling methods and geographic information systems can provide significant cost savings.

The average tariff for waste management in the country is 167 UAH /m³ (including disposal – 68 UAH/m³), and the average tariff for waste management for the population is 143 UAH/m³ (including burial – 61 UAH/m³). Given that waste disposal remains the cheapest of all types of waste management, it does not create incentives for economic entities and local authorities to process it. As a result, the level of waste treatment in Ukraine is critically low, and at the same time, small volumes of recycled materials are obtained from waste, which leads to a periodic shortage of high-quality sorted raw materials for treatment at treatment enterprises and a low level of their loading (up to 40%), due to which enterprises are forced to import raw materials necessary for treatment. The absence of a tariff for waste treatment has led to the fact that in fact, 50% of the recycling market in Ukraine is shadow.

Because the sphere of secondary resource use in Ukraine is at the stage of active formation, and in previous years it happened largely spontaneously, this led to the emergence of several imbalances both in the territorial (regional) and the production relation. Contradictory approaches to the problem of regulating the waste management of secondary raw materials can harm the formation of a full-fledged market for secondary raw materials. The field of secondary resource use requires both an analysis of the specifics and features in the regions of Ukraine, as well as optimization (improvement) of the modern regional waste management system, taking into account specific local problems and resources, including purposeful regulation of the specified area by the regional authorities in the context of comprehensive support this type of entrepreneurship in all its branches.

Due to the lack of an effective system of separate collection, as a result of insufficient consideration of the importance of the secondary resource potential of waste and the imperfection of economic mechanisms for stimulating the use of waste as a secondary raw material, insufficient awareness and lack of proper marketing, underestimation of social (for example, the creation of additional jobs) and environmental factors, in Ukraine every year millions of tons of resource-valuable materials are lost, which are contained in waste and can be used as material and energy resources, which indicates negative trends in the recycling market. The market of recycled materials in Ukraine has several peculiarities; it develops mainly based on self-regulation and private entrepreneurship with state support.

The problems of circulation of production waste, their treatment, consumption and related issues of the use of secondary raw materials constitute one of the main problems of the ecology and economy of Ukraine. The relevance of the problem consists in the preservation of primary (natural) resources, which are replaced by secondary ones; in reducing the negative impact on the environment due to the use of secondary resources, as well as in the release of land resources currently used for landfills and landfills, and in reducing the cost of some types of industrial materials.

In this area, effective solutions are needed, taking into account national characteristics, for the development and improvement of the effectiveness of the waste management system and the minimization of negative consequences as a result of the accumulation of a large amount of waste. The urgency of creating a more modern system of waste management, taking into account such components as ensuring full coverage by the collection system, maximum possible treatment, timely removal of waste, the introduction of environmentally safe methods and technologies of waste management, creation of appropriate infrastructure will lead, among other things, to the creation of a balanced and efficient market of secondary raw materials.

2.2 Operators of the market of secondary raw materials

The operators of the market of secondary raw materials are enterprises whose activities are related to the procurement and treatment of recycled materials, which can be divided according to their specific activity as follows:

- *harvesting* – enterprises that carry out operations for the collection and harvesting of certain types of waste as secondary raw materials, as a result of the activity, the recycled raw material and the final product of treatment have the same classification, the activity is related to the removal of waste from individuals or legal entities, their further accumulation, including sorting, and transferring them to treatment enterprises;
- *treatment*:
  - independent enterprises – carry out operations on the treatment of certain types of waste, which are mainly purchased from procurement enterprises or receive waste for treatment, the result of which is another type of recycled raw material or finished products;
  - enterprises as part of industrial complexes (technological divisions) – use secondary raw materials;
- *procurement and treatment* – enterprises that combine the activities of procurement and treatment of secondary raw materials, which process a part of the harvested raw materials in-house, and sell a part to other consumers.

In Ukraine, a certain system of procurement and treatment enterprises, which are engaged in the treatment of resource-valued waste, has developed and is developing. The sector of the secondary resources market consists of enterprises of various forms of ownership, which are classified according to the activity profile, features of specialization regarding secondary raw materials, and territorial features (territory coverage).

Depending on the specialization and for the joint solution of problems in the market of secondary resources, enterprises unite in associations. Large associations mostly include companies from Kyiv and other regions of Ukraine.

In particular, the management of recycled materials (wastepaper, secondary textile and polymer materials, polyethylene, plastic packaging, broken glass, used tires, used metal containers, etc.) is carried out by: "Ukrvtorma"[45] (about 100 specialized and procurement enterprises, located in all regions of Ukraine), "UkrPapyr"[46] (more than 30 enterprises, including 18 producers of paper and cardboard, 13 distributors of cardboard and paper products, 2 collectors and suppliers of waste paper, etc.); "Glass of Ukraine"[47] (almost 60 Ukrainian and foreign enterprises working in the glass industry, including plants related to the treatment of broken glass, scientific organizations, etc.); Ukrainian packaging and ecological coalition (Ukrpek)[48]; Ukrainian Association of Secondary Metals, "Ukrecoalliance"[49] (association of 15 enterprises in the field of waste management services) and others.

The market for compost from municipal waste is still being formed because settlements and communities are more likely to choose small composting sites than centralized large bio-waste treatment facilities to reduce logistics costs and solve the problem of proximity to private development, and then use the compost during landscaping exclusively own territories, without sale. Most enterprises in the field of waste management are just starting work in the direction of using the method of composting collected bio-waste with the possibility of receiving income. The first municipal composting station[50] in Ukraine is the only practical example of composting part of municipal waste financed from the municipal budget of organic food and garden waste (bio-waste) in Lviv (LKP "Green City"). The composting station started working in test mode in January 2020, and since June 2020 it has been operating at full capacity of 30,000 tons per year. Currently, in Lviv, containers for the separate collection of bio-waste are located at almost all container sites (more than 1,200 units), and more than 50 contracts have been concluded with commercial organizations for the acceptance of organics. Waste is removed as it accumulates - usually once every two days. Bio-waste is collected by a separate car and brought to the composting station, where it is processed into

[45] http://ukrvtorma.com.ua/general
[46] https://ukrpap.com.ua/
[47] https://sklo.kiev.ua/?mid=2
[48] https://www.facebook.com/ukrpec
[49] http://ukrecoalliance.com.ua/
[50] https://zelenemisto.info/projects/kompostuvannya-organichnyh-vidhodiv/

compost. Everyone can buy it for the needs of their farm. In addition, soil mixture made based on compost is used for landscaping. 50 tons of finished products from the station's processed waste were sold for the first time through the state procurement system PROZZORO, and after receiving the relevant certificates, it is planned to sell the compost through a trade network. The city budget provides funds for expanding the capacity of this station to 120,000 tons per year.

A practical example of composting part of commercial waste (pure organic raw materials from the markets), which is a profitable activity, is in the city of Lutsk (Pasternak-bio company[51]), which, to attract a larger audience of customers, developed soil mixtures with bio humus content and various packaging. It was developed as a liquid organic fertilizer – extracted from biohumus for root irrigation and for spraying plants. Thus, the range of products is designed both for transplanting a small indoor pot and for growing fruit plants in open ground or greenhouse conditions.

In addition, various enterprises of the agricultural complex receive goods for agriculture in industrial conditions – fertilizers on an organic basis, – enterprises that compost/ferment and sell waste of their production (manure, cow manure, chicken droppings, mushroom compost, etc.). Plant waste (weeds, leaves, spoiled vegetables and fruits), as well as feces, some types of garbage, meat production waste, etc., are used to make compost. Composting is a vital aspect of sustainable agriculture that plays a critical role in maintaining soil health and fertility. Composting technology is just beginning to be used in agriculture. Composting is usually practised on large farms, but small-scale composting operations can also make a significant contribution.

As of 2018, the cost of one ton of compost did not exceed 200-250 UAH in most farms that started composting; today the price of unpackaged compost on the domestic market is about 1,000 UAH.

LLC "IPK Poltavazernoprodukt" (part of the structure of Astarta agro-industrial holding[52]) started implementing a composting project using a trailed aerator (which was a continuation of the experience of the Dobrobut agricultural firm), the goal of which is to reduce the annual storage of thousands of tons of manure for reducing the impact on the environment and reducing the need to apply mineral fertilizers and herbicides[53].

The team of the "Family Dairy Farms" project[54] to increase the efficiency of activities and search for new tools for generating profit, decided to implement the composting project based on the industrial farm of PSP "Ukraine" (Rivnenska oblast, Rivnenskyi district, Zdovbytsia village) with a capacity of more than 18 thousand tons of manure per year. The implementation of composting technology will allow for a reduction in the cost of fertilizers for the network of family farms of the project (169 family farms from 11 regions of Ukraine), and the implementation of surplus-ready compost will provide an opportunity to obtain an additional source of income. Compost is sold in bulk from 20 tons on self-delivery terms at a price that depends on the volume of compost.

LLC "Agrotandem-Plus" (Gubinykha township, Novomoskovsk district, Dnipropetrovska oblast) is engaged in the production of compost for mushroom cultivation. The volume of products produced is about 450-600 tons per month for 4,100 UAH per ton (phase 2 in briquettes).

Research in the field of secondary resource utilization and the analysis of raw material-production relations formed at that time testify to the ambiguity of the situation that has developed with certain types of waste as recycled raw materials. At the same time, certain critical problems need to be solved.

As of 2023, the problem of the treatment industry in Ukraine lies not in the insufficiency of treatment enterprises, which are currently more than enough, but in their need for significant volumes of secondary raw materials, which are currently insufficient. Quite significant capacities for waste treatment were created in the hope of establishing a system of recycling raw materials and their large volumes. More than 1,500 different types of enterprises are involved in the field of waste collection and

[51] https://www.facebook.com/pasternakbio/?locale=ru_RU
[52] https://astartaholding.com/
[53] https://agroportal.ua/news/novosti-kompanii/v-astarti-zapustili-proyekti-z-kompostuvannya
[54] https://smf.org.ua/

procurement as secondary raw materials and their recycling in Ukraine. However, there are no official statistics on this type of entrepreneurial activity, and the corresponding information is rapidly changing. However, these expectations did not coincide with the possibility of obtaining recycled materials, which led to the emergence of excessive and idle capacities in the field of treatment of most types of waste. Due to this situation, the state/enterprises are forced to purchase the necessary volumes of secondary raw materials abroad - the existing shortage of raw materials on the domestic market is covered by its import. Thus, existing treatment enterprises import up to 30% of recycled materials from the total amount of treatment, and many of them, even taking into account imported raw materials, are only 50% loaded. Until the beginning of 2022, enterprises that processed secondary raw materials imported about 30% of cardboard and paper raw materials from the total amount of treatment, 22% – glass scrap and 10% – polyethylene. The practice of importing secondary raw materials is also characteristic of some EU member states (Netherlands, Czech Republic, Denmark, Sweden and Poland), which have powerful treatment and waste incineration plants. Unlike the EU member states, in which secondary treatment of a significant part of the generated waste is carried out, in Ukraine, due to the limited development of the treatment sphere, a low level of waste treatment is observed.

The functioning of enterprises engaged in the treatment of secondary raw materials in Ukraine depends to a large extent on the efficiency of the work of enterprises in the field of waste management and the organization and coverage of separate collection of solid waste in the regions, a sufficient number of reception points for secondary raw materials, as well as waste management facilities (incinerators and waste treatment plants, waste sorting lines, composting stations). Under the condition of effective organization of a separate collection of MW, it is possible to extract up to 50% of useful components from them (such as paper and cardboard, scrap glass, secondary polyethylene and polymers, textile materials, and bio-waste). However, under the modern system of waste management in Ukraine, this raw resource is lost. Since the current state of the existing waste collection system does not allow to fully load the production capacities of treatment enterprises, they are forced to resort to the import of secondary raw materials.

Regarding the functioning of bio-waste management facilities, aerobic waste treatment technologies are moderately sensitive to the stability of the supply of raw materials (bio-waste). The sensitivity of technologies has an economic nature – the deterioration of the financial and economic indicators of the functioning of specific bio-waste treatment facilities due to a decrease in the efficiency of the use of technical means and staff workload. Anaerobic treatment technologies are extremely sensitive to the stability of the supply of raw materials (bio-waste). The sensitivity of technologies has a technological nature – it can lead to a violation of the technological parameters of the object's functioning. As a result, there may be a deterioration in the financial and economic indicators of the functioning of specific bio-waste treatment facilities.

There is also an acute problem of the profitability of points of reception of recycled materials-procurement enterprises that collect recycled materials to obtain income, which found themselves in a difficult situation, faced with a large amount of imported already sorted recycled materials (in particular, plastic and waste paper) from the EU, which is sold two to three times cheaper than the Ukrainian one, due to its large surplus in the EU countries. It is more profitable for treatment enterprises to buy cheaper recycled materials, which is why the operating points and collection points have to reduce the cost of their raw materials, which, in most cases, leads to a significant loss and the closing of the point, or to look for additional ways of maintaining life activities, such as grants or charitable support.

Currently, the priority is to establish a collection system, not treatment, since there are underutilized capacities for each type of waste (except wastepaper) due to a lack of recyclable materials. At the same time, when compared with prospective volumes of resources, the question of increasing treatment capacities will inevitably arise - both at existing enterprises and at new treatment facilities.

The target indicators for the implementation of the National Waste Management Strategy were determined based on existing statistical indicators, as well as based on expert evaluations in case of lack of relevant data or imperfection of the used statistical methodology. In the process of

implementation, the specified indicators can be reviewed for clarification. The proposed targets for the creation of **bio-waste composting facilities** in Ukraine as of the end of 2023 are 150 units and by the end of 2030 – 500 units.

Prospective for the creation of new treatment enterprises are the regions where the conditions for a stable supply of raw materials for enterprises have been created, that is, a system for the collection of recycled materials has been established. The choice of location requires a more detailed study of the issue, taking into account the forecast volumes of the collection of recyclable materials and the logistical component. By reforming, changing activities, etc., the system of collecting secondary raw materials with traditional methods of collection (through the population, a network of points for collecting secondary raw materials) will deteriorate in parallel with the increase in the socio-economic development of society and will be replaced by more developed forms characteristic of civilized countries.

At the regional level, new enterprises will be created, which will be integrated into municipal systems with support (and equity participation). For a few more years, the traditional network of recycling collection points will remain, but due to insufficient economic profitability of this form, its use will decline. Sources of financing for the field of MW management will change steadily. Special municipal funds, targeted budget subsidies and commercial capital will join the means and capabilities of the waste management system operator, and revenues from the sale of products from secondary raw materials will become a more prominent source of investment. Thus, the circle of participants and entrepreneurship in the relevant recycling market will expand, thanks to which it will become more and more competitive.

2.3 The main consumers of the market for the sale of secondary raw materials (in particular, compost)

Consumers on the market of secondary resources can be both enterprises that use recycled materials for the production of their products, and the population – due to the demand for products and products from secondary materials.

Consumers of services and products of the waste treatment enterprise are:

1. Municipal bodies and enterprises, the main task of which is the liquidation of the municipal landfill and ecologically clean treatment of the collected waste, the need for reclamation of disturbed lands, including covering (reclamation) of the landfill and overlapping of layers of waste.
2. Enterprises (pulp, wood treatment, glass, and others) that are interested in removing their waste and cannot afford to store waste on their territory, and the state imposes significant fines for unauthorized dumping, which are aimed at reducing costs due to waste removal for less than their current treatment costs.
3. Enterprises (consumers of recycled waste - paper, leather, polymer waste, construction waste, glass, rubber products, etc.) that will buy secondary raw materials for industrial and individual purposes for carrying out activities.
4. Individual consumers (retail sale).

The main potential consumers in **the compost market** are primarily representatives *of the agricultural industry* (state agricultural enterprises, economic societies, cooperatives, private farms, farms, auxiliary agricultural enterprises of non-agricultural enterprises and municipals, which include personal auxiliary farms of rural and municipal populations) and *forestry* (forestry enterprises "Forests of Ukraine", "military" forestry farms and forestry farms of the agro-industrial complex).

However, increasingly, *municipalities and territorial communities in Ukraine are interested in composting technologies, which are part of a full-fledged waste management system that includes waste generators, transporters, and the city administration,* including the consumers of commercial compost are *the balancers of green spaces at the objects of green improvement farms* of state and communal forms of ownership. Because these enterprises can use compost from fallen leaves in their activities to maintain green spaces, it is advisable to locate equipped areas for composting fallen leaves on their territory.

In addition to the use of the obtained compost as fertilizer for the locality's own needs and for use as roofing material for the landfill site, there is a potential market for the sale of compost to enterprises of neighbouring territorial communities and, in the long term, for projects in other regions of Ukraine, including reclamation of landfills and careers.

Such an example is the transfer of LKP "Green City" (Lviv) for an experiment on the use of 80[55] tons of compost from bio-waste, which was formed from food and garden waste on the territory of the composting station[56].

The advantages of using composting are:

- reduction of operating costs for storage and application of humus;
- saving on mineral fertilizers;
- reduction of costs for the purchase of plant protection products;
- increasing soil fertility;
- solving environmental problems of enterprises of the agrarian sector and green economy.

A distorted view of the soil can lead to unbalanced conditions that limit the potential of the crop. In turn, the development of agriculture is impossible without the balance and diversity of microbiota in the soil. Traditional agriculture in Ukraine, based on nitrogen, phosphorus and potassium, is not efficient, as nutrients are lost as a result of evaporation. Thus, the soil loses its fertility during traditional farming through several processes (water runs off, increasing erosion, the soil becomes less porous, air penetration into the soil is limited, without oxygen, microorganisms that help the roots extract nutrients die). Humus does not allow nutrients to be lost, therefore soil in agriculture with a large amount of humus has the following advantages (improves water infiltration; humus in the soil retains moisture that exceeds four times its weight; humus formation allows excess moisture to seep in; the air is available to microorganisms; plant residues are processed; the soil is porous). A key element of humus-based soil fertility is the ability of humus compost to restore or enhance soil biological activity and nutrient recycling. All these factors should be included in the agriculture of Ukraine.

Practice shows that bio-waste composting is the most ecologically and economically justified treatment of organic matter produced in a settlement, but its implementation in every community requires extensive preparatory and educational work.

Among the special measures in the National Waste Management Strategy, development of the direction of composting of the organic component of municipal waste (bio-waste) is provided, namely, it is established that:

(a) in the field of municipal waste, normative legal acts should be adopted aimed at introducing composting of the organic component of municipal waste in private municipals in rural areas, as well as sub municipal areas of cities;

(b) in the field of agricultural waste, the introduction of composting of waste generated in small agricultural holdings should be encouraged.

Must be carried out:

in terms of composting plant waste:

- development of regulatory documents related to the quality of compost and the quality of raw materials for composting;
- development and establishment of requirements for applying compost to the soil, including soil quality control;

in terms of composting agricultural waste of animal origin:

- stimulation of composting of waste generated in small farms and rural settlements by spreading knowledge and relevant information;
- development of requirements for the quality of compost and raw materials for composting;
- development and establishment of requirements for applying compost to the soil, including soil quality control;

[55] https://zahbug.com/

[56] https://zaxid.net/lkp_zelene_misto_dlya_eksperimentu_peredalo_80_t_kompostu_privatniy_agrokompaniyi_n1506666

in terms of animal excrement treatment:

- organization of collection of surplus animal excrement at the places of their formation with redistribution to places of shortage of fertilizers or at composting and anaerobic fermentation facilities;
- determination of the mechanism for stimulating the use of animal excrement as a raw material for composting and anaerobic fermentation, where direct application to the soil is not possible and/or permissible.

Agroholdings are interested in obtaining high-quality compost in a short time – either by purchasing it on the compost market or by introducing its production because it is the health of the soil and the content of useful substances in a form available to plants.

In addition to the annual reduction in the storage of thousands of tons of bio-waste, the impact on the environment is reduced and the need to apply mineral fertilizers and herbicides is reduced.

Community involvement is a key aspect of sustainable agriculture and is particularly important when it comes to practices such as composting, which can benefit not only individual farms as a real farm investment in the future but also the environment as a whole. It is important to work closely with other local farms to offer their compost as a resource to improve soil health and yield, which will not only benefit the farmers who use the compost but also help create a more sustainable and interconnected local food system in the country. It is worthwhile to engage in composting both for the domestic needs of the farm and sale, given the existing interest of exporters ready to buy Ukrainian compost.

Expanding the level of coverage of composting will have a positive effect on the price policy of the compost market – such fertilizer will become much cheaper and more accessible to consumers (especially small farms) when the volume of its production increases.

2.4 Basic measures of implementation of the circular economy in the field of waste management

In today's conditions, the most important challenge on a global scale is the depletion of natural resources and large-scale pollution of the environment. The solution to this problem is the achievement of sustainable development. The implementation of the circular economy contributes to the transformation of the economic system into a more sustainable and ecologically clean one, at the same time, it makes it possible to preserve primary resources, create new jobs and increase the competitiveness of both an individual enterprise and the entire country. The promotion of Ukrainian enterprises to circular economy models is an important stage on the way to European integration. At the same time, the introduction of circular business models in Ukraine is associated with certain risks and difficulties for enterprises, in connection with which it is necessary to study the current state and trends of the development of the circular economy at Ukrainian enterprises.

In practice, the idea of a circular economy is to reduce waste to a minimum, which means keeping waste within the production cycle as long as possible. Reusing waste, and extending the life cycle can create additional value for the enterprise, as well as provide competitive advantages. The main activities within the framework of the circular economy include reuse (reusing), repair, renewal and recovery (recovery), treatment (recycling) of existing materials and products, as well as preventive actions to reduce the volume of waste. The main idea is that what was previously considered “waste” can be turned into a valuable resource.

Implementation of the principles of circular economy.

- reducing the amount of waste by encouraging individual and corporate responsibility;
- waste treatment for their maximum and best use while balancing tariffs and services;
- use of the most ecological waste treatment technologies.
- transformation of the field of waste management from waste disposal to its use as a secondary resource.
- eliminating the need for landfills and landfills.

In Ukraine, there is a need to intensify the treatment, recovery and reuse of waste by enterprises with the help of circular economy business models, despite several advantages and disadvantages for business. In the short term, the use of business models of the circular economy is associated with a high level of costs and a low level of awareness of both consumers and partners, competitors, and suppliers, as well as with imperfections in legislative regulation. However, in the long term, the use of circular models leads to positive effects in both environmental and economic aspects and can provide the enterprise with a sustainable competitive advantage.

Most of the factors of the external environment that will have an impact on enterprises that decide to use circular economy business models in Ukraine generally have a favorable effect on such implementation.

The above causes the need to analyze the specifics and features of secondary resource use in the regions of Ukraine, as well as to optimize (improve) the modern regional waste management system, taking into account specific local problems and resources. In a more general plan, there is a task in purposeful regulation of the specified sphere by the regional authorities in the context of comprehensive support of this type of entrepreneurship in its entire links. The sphere of waste management is an infrastructural link of the region's economy (landfills, waste treatment enterprises, waste sorting complexes, etc.), but the products of treatment/waste treatment become part of the resource base and thus move into the production sphere – as their component. Solving the tasks of optimizing the organization of the secondary resource use system as an infrastructural and production link of the national economy should methodologically be based on a comprehensive approach and include research on the territorial location of existing enterprises; identifying features of the formation of the resource base of secondary raw materials; determination of existing disparities and inconsistencies in the resource-production model.

The development of a national environmental strategy and the transition to a bio-economy require a large-scale and comprehensive approach, using the most complete range of parameters, rather than relying on local initiatives. Changing the parameters requires a different level of material and technical solutions, which can be differentiated into four levels:

- *strategic decisions* – related to the number, location and potential of enterprises - waste carriers, waste processors, waste storage and disposal sites;
- *commercial solutions* – aimed at finding waste treatment products as recyclable materials, subcontracting waste recycling processes and distribution of finished products. This is the creation of a structure of trade relations between the treatment company and its suppliers, distributors and customers;
- *operational decisions* – on the issue of the terms of production from resource-valuable raw materials and distribution, translation of trade relations into separate flows of goods and determination of the speed of rotation of inventory in warehouses.
- *functional solutions* – related to the management of material and technical resources for waste recycling.

Today, it is important to use marketing tools when conducting educational work among the population regarding institutions that organize additional sorting, sale or treatment of waste, that is, collection points and recycling (treatment) enterprises. At the same time, there is a need to create such a management mechanism for the waste management program that would combine market patterns and the regulatory influence of state administration. This mechanism should ensure flexible and effective regulation of the processes of using limited financial resources and contribute to solving a complex of extremely urgent tasks of preserving and developing the economic and intellectual potential of the city, region, and country.

CHAPTER III. IMPLEMENTATION OF THE COLLECTION AND TREATMENT SYSTEM OF BIO-WASTE

Considering that an important issue regarding any waste is its treatment, and the removal of bio-waste from the total amount of waste (including waste from green areas and food waste) increases the useful life of the waste landfill several times and minimizes the burden on the environment, and the availability of bio-waste as a resource potential as a recycled raw material with the implementation of a certain treatment technology, the implementation of a planned and regular system of separate collection of municipal and commercial bio-waste, the arrangement of reception points and container sites following the requirements of current legislation and the creation of a bio-waste management facility with the possibility of selling the received treatment products.

The possible prospect of increasing the volume of waste from green areas, obtained in the process of caring for them both in the general territories of settlements and individual homesteads of residents, aims to ensure the implementation of an effective system for the removal and treatment of waste from green areas and the introduction of modern methods of treatment and organization of the general bio-waste management system.

The bio-waste management system must ensure the implementation of the measures of the National Waste Management Plan and the directions of the National Waste Management Strategy, taking into account the features of the economic and social development of communities based on European standards. Therefore, the issue of bio-waste treatment and consumption of the products of their treatment concerns important social, economic and environmental relations that require comprehensive regulation.

3.1 Determination of steps for implementation and operation of the proposed system of collection and treatment of municipal and commercial bio-waste

3.1.1 Collection and transportation

The presence of a large volume of biodegradable waste (waste from green areas, food waste) leads to their excessive accumulation and the need for removal by residents and, as a result, to the contamination of other solid waste and separated secondary raw materials, to which they are added, further, when they get into to landfills – worsens the ecological and sanitary condition of landfills, since the biological decomposition of organic components of landfills is the main reason for the formation of leachate and biogas, which are harmful migrations into the surrounding natural environment. Therefore, it is important to separate bio-waste, which can make up to 40% (by mass) according to the morphological composition of the municipal solid waste, from the total volume of solid waste by implementing *separate collection* and *separate transportation* to the waste management facility. Accordingly, this requires the implementation of other methods of treatment such as waste disposal at landfills. The methods used must be convenient and effective.

3.1.2 Bio-waste treatment

Currently, there is an urgent need to implement modern bio-waste treatment technologies in settlements, including municipal and commercial waste from green spaces and part of bio-waste from mixed waste.

For the implementation in settlements, based on the main characteristics of the most common methods of bio-waste treatment, based on the available amount of generation and composition of bio-waste components, the priority method of management of separately collected bio-waste (municipal and commercial waste from green spaces and biodegradable waste) that has the property subject to anaerobic or aerobic decomposition, is a method of composting, which is explained by the presence of a large share of bio-waste in the composition of MW, the lowest level of capital investments and operating costs in comparison with alternative methods of waste treatment and compliance with

environmental safety requirements. The introduction of composting will significantly reduce the amount of waste to be disposed of at landfills and obtain the target product - compost. To produce high-quality compost that can be used as a soil conditioner, suitable for use in agriculture and for other purposes, the method requires separately collected material to avoid contamination of the final product.

3.1.3 Implementation of the proposed bio-waste composting system

All stages of the implementation of the bio-waste management system should include **stimulation and encouragement** by local self-government bodies of residents to separate collection and composting of bio-waste and the parallel implementation of powerful informational work with the population, including through the formation of public opinion[57] on environmentally safe management of waste, to increase the level of public awareness regarding environmentally safe management of MW and increasing the efficiency of implementation of new modern MW management technologies in populated areas of Ukraine. Studying the opinion of the population and creating the conditions for the formation of a favourable attitude of citizens is necessary for the sustainable existence of the system of dealing with MW; the results are a change in people's behaviour and their support for changes in the sector.

It is important **to assess the behavioral aspects** of residents to form appropriate measures, including educational campaigns on environmentally responsible waste management at the municipal level. A high level of potential involvement of the population in future innovations in waste management will speed up the implementation of bio-waste management systems, which are aimed at reducing their content in waste, namely: support for the introduction of separate collection of bio-waste, creation of a facility for their treatment, readiness to use the resulting product (good quality compost) in the municipal's own needs. It is necessary to create simple and clear rules of conduct for citizens regarding waste management in municipals, which should contain simple provisions aimed at minimizing the total generation of waste, the proper collection of waste by type and the necessary sources of additional information, contact details of special enterprises in the field of waste management.

At the initial stage of implementing a bio-waste management system, its treatment can be started with a relatively simple method, for example, with **centralised composting** of municipal and commercial separately collected green waste (waste from landscaping, gardens, etc.) and similar waste that requires minimal pre-treatment and will produce high-quality compost. In addition, some residents of individual buildings (houses of the private sector) with a plot of land can organize **individual composting** waste from green plantings (fallen leaves, mowed grass and branches after pruning trees in the autumn and spring period) in one's yard according to the established Bio-waste composting rules[58].

Given the low density of separately collected green waste, it is economically impractical to transport it to a remote treatment facility, for example, to a regional waste landfill, therefore variants for centralized composting of separately collected green waste involve **the creation of a treatment facility (composting station)** in within the settlement, where they will be delivered and crushed. The resulting raw materials will then be formed into compost rows and left to decompose into final compost through natural processes supported by periodic turning. The final product will have a high potential for use in crop production and horticulture.

In the process of operation, depending on local conditions, efficiency indicators are set for the composting station, **typical efficiency indicators** are as follows:

- *cost indicators* (total operating costs, per ton of processed input bio-waste, per ton of compost produced, total fuel consumption for the composting station and total personnel costs);

[57]"Methodical recommendations for the formation of public opinion regarding environmentally safe management of household waste" (approved by the Order of the Ministry of Regional Development, Construction and Housing of Ukraine dated 01.02.2010 No. 38

[58]Rules for composting bio-waste by its generators on homestead, summer cottage and garden sites // https://zakon.rada.gov.ua/laws/show/z1271-23#Text

- *process indicators* (tonnage of incoming bio-waste by type, tonnage of compost at the exit, difference in weight between the tonnage at the entrance and at the exit, the intensity of the operation of the station (hours of operation/working hours of the shift), the rate of compost production (monthly tonnage of produced compost), the number of hours at breakdown and maintenance and compost shipment rate (monthly tonnage));
- *monitoring indicators***.**

For residents of individual buildings it is proposed to introduce a separate collection of bio-waste by installing individual composters in the yards of municipals, the number and parameters of the equipment are determined by the owners of municipals, based on their needs. By 2030, due to the encouragement of residents of the private sector, the expected increase in the removal of bio-waste will be approximately 5% of the total volume of municipal waste generation. Another part of the bio-waste generated in the private sector will enter the municipal waste collection system in a special container with mixed waste.

According to the decision of the governing bodies of dacha or horticultural cooperatives (societies) to organize centralized composting of bio-waste generated on the common territories of such cooperatives (societies) to obtain compost and use it for the improvement of their territories, **composting points may be formed**, which must meet the requirements of the law on the protection of the natural environment and on ensuring the sanitary and epidemic well-being of the population. To stabilize and optimize the composting process, compost ripening and improve its ecological characteristics, it is necessary to add additives (ash, sand, limestone powder, bentonite (clay), dry mixture (branches of trees (bushes), dry grass, leaves, etc.), enzymes, emulsifiers), which are introduced at the beginning or during the composting process in a maximum volume of 10-15% of the mass of bio-waste.

To ensure the operation of a small composting point, it is not necessary to carry out any investment and operational costs, provided that the composting point will be located on the territory of an existing agricultural enterprise or cooperatives (societies). For small volumes (up to 20-25 tons of bio-waste annually), a concreted area of about 100 m² (8×12 m) is sufficient, where one worker will be responsible for grinding the input materials and regularly turning the sides (combining this activity with another). Such small composting points can be installed in all large rural settlements, for smaller settlements with smaller volumes of bio-waste generation; the optimal solution will be the implementation of composting in individual composters.

Composting is especially effective in those areas where the content of organic substances in the waste is significant and there is a need for fertilizers.

The waste that will be composted in the first stages of the implementation of the system is green (leaves, young cuttings, garden waste from municipals) and separately collected food waste (mainly kitchen waste and food scraps, which are usually fine-grained with a high degree of moisture and minimum C/N ratio, therefore ideal for mixing with green waste).

The main condition for obtaining commercial compost is the need to separately collect compostable waste and exclude its mixing with other types of municipal waste. Improperly collected bio-waste containing plastic, glass or metal is not suitable for composting. It is possible to carry out additional treatment of bio-waste before composting to separate impurities and pollution; grinding; separation of metals, obtaining the optimal C/N ratio and the necessary structure, etc. to improve the quality of bio-waste, which will satisfy the high requirements for the purity of the compost. Combining different fractions of bio-waste allows for reducing the amount of ammonia released in the first stages of composting - leaves (high in carbon, low in nitrogen) can be combined with food waste (high in nitrogen). Composting of mixed MSW can be used as a preliminary phase before waste disposal.

Homestead composting is a bio-waste treatment method that helps transform available green waste into valuable compost that can be applied directly to the soil for the municipal's use while reducing the total amount of waste that needs to be collected, and as a result, it can help reduce the costs of waste collection and its subsequent centralized treatment.

Composting in individual composters can begin to be carried out in pilot municipals in small settlements, and parallel, in large settlements and districts, it is possible to organize the collection of separately collected bio-waste (waste from green areas and part of food waste), performing it according to the planned schedule during the spring and autumn seasons, mostly once or twice a week with prior notification of the population about the days of such collection. The collection and delivery of such materials to bio-waste treatment facilities should become the responsibility of the general waste collection operator.

Initially, composting of bio-waste should be carried out using separately collected green waste generated only on the locality's territory. In the future, it is necessary to gradually expand the list of waste accepted for composting by adding separately collected other municipal and commercial waste that is most suitable for composting and to create an opportunity to accept bio-waste from other settlements in neighbouring communities. In this way, the generated bio-waste will be transformed into a safer and more stable product.

For further reporting at the regional level regarding the fulfilment of the target indicators defined by the National Waste Management Strategy, it is necessary to establish a system of accounting (calculations) for bio-waste that will be composted.

3.2 Development of the concept of compost consumers and advice on the marketing strategy of the enterprise

3.2.1 Concept of compost consumers

The main trends in the world market, which determine the basis of the functioning of the industry of waste management in general and composting in particular, are set by the developed countries of the world, in particular the EU, the USA, and others. Thanks to this, the predictability of the volumes of service provision (in particular, compost production) is achieved, the necessary control and monitoring are carried out, and the safety and quality of products are guaranteed. At the same time, the organizational structure of production, and land relations are regulated, the latest technologies and modern equipment are used, and qualified personnel work at enterprises.

Although compost from bio-waste is currently not widely distributed on the Ukrainian market, experts note that today it is a fully balanced fertilizer with the necessary indicators of nutrients and biologically active substances that plants and soil need.

The concept of compost consumers is based on the awareness of the importance of an ecological attitude to waste and the desire for sustainable consumption. Compost consumers value efficient management of waste and natural resources. It is assumed that the following components should be the main aspects of this concept:

1) environmental awareness;
2) phased bio-waste management system;
3) responsible consumption;
4) education and dissemination of eco-information;
5) support for sustainable development.

When forming the concept of compost consumers, it is important to rely on the principles of reforming the implementation of environmental policy and guaranteeing the provision of environmental rights of citizens, which have become one of Ukraine's obligations under the Association Agreement with the EU. A clear example is the Convention of the UN European Economic Commission “On access to information, public participation in the decision-making process and access to justice in matters relating to the environment”, which was adopted on June 25, 1998 in Aarhus (Denmark)[59]. Ukraine became one of the first countries to sign this Convention. The Aarhus Convention defined **three basic environmental rights,** which are considered important factors in the formation of democracy:

[59] https://zakon.rada.gov.ua/laws/show/994_015#Text

1) public access to environmental information;

2) public participation in the decision-making process on environmental issues;

3) public access to justice on issues related to the environment.

Thus, the formation of ecological awareness of citizens should also take place through communication with compost consumers, who understand the negative impact of bio-waste and other organic materials on the environment. The consumer must demonstrate a desire to minimize their footprint by resorting to natural innovations such as composting.

Effective communication between compost consumers and citizens regarding environmental information requires balance, accessibility, and interaction. It is necessary to use simple and understandable language, providing specific examples of the impact of their actions on the environment. It is important to emphasize positive changes that everyone can make, contributing to the formation of a responsible attitude towards the environment. The use of various communication channels, such as social networks, websites, lectures and information campaigns, will ensure a wide level of outreach and create a favourable atmosphere for the exchange of ideas and action.

Compost consumers, together with the local government, should actively implement composting practices to reduce the amount of bio-waste and ensure the recovery of natural resources. The practice of bio-waste composting should include two main stages: composting in municipals (individual) and composting at a specially equipped site - composting station (centralized).

The compost consumer must understand the organizational scheme of composting in the settlement and be aware of the appearance of different groups of commercial and technical compost. Information on the quality and characteristics of compost should be available and referable.

Consumers can be divided into certain groups according to the groups of commercial compost:

a) consumers who buy commercial compost *on a contractual basis in large quantities*, who usually use compost in their economic activities (enterprises);

b) consumers who buy compost *on a retail basis* usually use compost at home (citizens).

The formation of responsible consumption is an approach to the choice of goods and services aimed at maximizing the positive impact on social, environmental and economic aspects. Consumers should pay attention to the responsible consumption of compost, which also includes awareness of the volume of their consumption and the impact on the production of excess resources. Consumers who choose minimalism and recycling demonstrate a commitment to a sustainable lifestyle. This approach helps to promote more equitable and balanced development while contributing to the creation of a friendly environment for present and future generations.

Bio-waste composting is an important component of a sustainable lifestyle and environmental protection. Organic materials such as fruit and vegetable scraps, coffee grounds, leaves and other biodegradable waste can be used to produce high-quality compost. This natural fertilizer enriches the soil with necessary nutrients, improving its structure and ability to retain moisture. In addition, compost helps reduce the volume of waste that goes to landfills, thereby helping to reduce methane emissions that occur when organic materials decompose in landfills and landfills.

It is important to understand that composting is a simple and affordable way for citizens to make their contribution to the preservation of the environment. Encouraging bio-waste composting contributes to the formation of an environmentally conscious community working to create a healthier and more balanced environment for all.

Education and dissemination of eco-information among consumers can be carried out with the help of various initiatives:

a) *information campaigns* – conducting educational campaigns that provide information about environmental problems, the impact of consumers on the environment and the positive effect of making changes in their lifestyle;

b) *cooperation with educational institutions* – cooperation with schools, universities and other educational institutions to include environmental topics in curricula and create environmental education programs;

c) *organization of events and working groups* – conducting various eco-events, such as lectures, workshops, seminars and working groups, among different groups of citizens to discuss environmental issues, exchange experiences and determine ways to improve the situation;

d) *use of social networks and media* – creation of an active online presence where useful information, articles, facts and other content that contributes to understanding environmental issues are shared;

e) *development of applications and interactive resources* – creation of applications, interactive websites and other resources that provide consumers with tools to measure their environmental footprint and offer recommendations for reducing it;

e) *support of sustainable consumption* – promotion of the use of environmentally friendly and renewable resources, popularization of the use of products with eco-packaging and support of companies and consumers that adhere to the principles of sustainable development;

g) *creation of awards and incentives* – implementation of programs, awards and incentives for consumers who take steps to reduce their impact on the environment (discounts on goods or the opportunity to participate in initiatives, etc.).

Implementation of these measures will contribute to raising the level of environmental awareness among consumers and creating sustainable and environmentally responsible consumer behaviour.

The concept of compost consumers is marked not only by the act of composting itself but also by a general awareness and commitment to an ecologically appropriate lifestyle.

3.2.2 Advice on the marketing strategy of the enterprise

Most of the strategic decisions made by any company are in the field of marketing, including the creation of a new product, the development of a new market niche, the selection of suppliers, partners, consumers, and other decisions are made within the framework of the marketing strategy – the basis of the company's actions in specific market conditions that determine how to apply marketing to expand target markets and achieve effective results.

Formation of the enterprise's marketing strategy

The formation of effective marketing strategies is the most important component of the development strategy of the enterprise as a whole, one of the most essential and difficult stages of the marketing process. The main purpose of the marketing strategy is to mutually agree on the marketing goals of the enterprise with its capabilities, and consumer requirements, to use the weak positions of competitors and its competitive advantages; the success of the entire enterprise, and its competitiveness depends on the adequacy of the marketing strategy. Its choice depends on many external and internal factors, the most important of which are: factors characterizing the state of the industry and conditions of competition in it, and factors characterizing the competitive capabilities of the enterprise, its market position and potential. The strategy can be considered as a comprehensive plan for realizing the purpose of the enterprise. In its form, the strategy is one of the management documents, in terms of its content; it is a set of actions to achieve the company's goals.

In the new economic conditions, the problem of forming effective marketing strategies for market penetration is urgent. In the conditions of the formation of market relations in Ukraine, an integral part of which are competitive relations, the problem of strategic planning of the competitive behaviour of the enterprise, which would make it possible to achieve success in the long term, is becoming more and more urgent. Most Ukrainian enterprises approach the choice of a competitive strategy more spontaneously, according to the circumstances, than as a process of strategic planning. As a result, the strategic course is often changed, which leads to the impossibility of achieving high financial results and ensuring the further development of activities. The absence of many Ukrainian enterprises in the process of planning and forming an activity strategy, in particular a competitive strategy, leads to their uncompetitiveness on the market and their successive disintegration in the future.

In the process of forming the company's marketing strategy, it is possible to highlight:

– *input elements* – factors, the analysis of which precedes the development of a marketing strategy, that is, factors of the marketing environment and the goals of the enterprise;

– *output elements* are strategic decisions regarding the marketing complex of components, which includes four components – product, price, sales and promotion.

The marketing strategy of the enterprise is subordinated to the corporate strategy of its activity. The main goal of any commercial enterprise is to make a profit. Businesses can increase their profits in two ways: by adding value to their products so that consumers will pay more for them or by reducing the cost of creating value (i.e. production costs). There are two main strategies for improving the company's profitability – the strategy of differentiation and the strategy of reducing costs.

Formation of marketing strategies is one of the most essential and difficult stages of the marketing process. The implementation of marketing analysis for the further development of goals, development of strategies, leads to the best results. This is quite a difficult thing in the conditions of constant changes in the factors of the external and internal marketing environments, the accumulation and consideration of data on all the results of the company's activities, it is important to conduct it on a dynamic basis. Compliance with the basic requirements for marketing analysis (accuracy, consistency, systematic implementation) allows you to have the necessary information for monitoring or adjusting the marketing strategy at each time point.

When forming a strategy, first, it is necessary to take into account: what stage of the life cycle the industry is at; its industry structure; the essence and power of five competitive forces (suppliers of the most important resources, buyers, competition between sellers within the industry, substitutes, potential sellers of this product), the scope of competitors' activities.

The choice of marketing strategy is carried out in several stages. First, the competitive advantages of the enterprise are revealed. To assess the possibilities of the enterprise's successful entry into the market, the data of the analysis of the external and internal environment are compared and, based on them; the characteristics of the given enterprise are compared with the characteristics of competitors, as well as with the expectations of consumers and partners. The company determines its strengths and weaknesses, which helps it to highlight the areas in which it can achieve success; evaluates the opportunities and threats of potential markets, which helps determine the factors that are necessary for success in the market. Comparing potentially successful areas and important factors for success gives the company an idea of its competitive advantages and makes it possible to develop strategies. The first step in developing a market strategy involves defining a market coverage strategy: describing the target groups of potential consumers. Based on the results of analyzes of potential groups of consumers, a market coverage strategy is determined. To work in selected market segments, it is necessary to formulate a basic development strategy. The first step is the formation of the marketing concept of the product that the consumer will receive.

Next, a basic marketing strategy is developed – a long-term plan for the enterprise, it should not be written in detail, because it can be refuted by some unforeseen events in the external environment. Therefore, the basic long-term strategy is not something that is determined once and for all and never changes. It should be regularly adjusted and clarified depending on the changes that occur in the market and the results of the enterprise's activities. When developing a basic strategy, the management decides on the degree of globalization of the company's activities, taking into account such factors as the volume of the local market, the intensity of competition in it, the degree of globalization of competitors' activities, the availability of resources and competitive advantages at the company.

The development of an effective marketing strategy for the company's activities on the market directly depends on the clear and correct formulation of the goals and objectives of this company in each of the individual target market segments.

The company changes its strategy if:

a) for a sufficiently long time, it does not ensure the achievement of satisfactory indicators;

b) competitor companies have drastically changed their strategy;

c) other external factors for the enterprise's activity have changed;

d) prospects for taking measures that can significantly increase the company's profits have opened up;

e) new customer preferences have changed or emerged, or trends toward possible changes in this industry have been outlined;

f) tasks set in the strategy have already been solved and fulfilled.

The main priority strategic goals of the enterprise are as follows:

- ***consumer orientation*** – considering that the goal is to make a profit, the company's activities should be aimed at maximizing the benefit and satisfaction of consumers, who are the main source of obtaining funds through the sale/sale of products;
- ***economic efficiency*** – the enterprise must ensure the most efficient and rational use of resources, for which measures are developed and taken to use the least amount of resources, complying with the requirements of quality and service standards, all costs and investments are clearly analyzed and calculated before spending funds;
- ***stable environmental situation*** – the enterprise must strive for a sustainable ecological situation, which is expressed in an effort to minimize the negative impact of the enterprise's activities on the environment by fully complying with all relevant laws and other normative legal acts of Ukraine and by promoting the increase of environmental awareness of its customers and stakeholders;
- ***management of the improvement process*** – the enterprise must constantly resort to improving the efficiency of its activities by cooperating with partners and other enterprises/organizations to improve both planning and actual implementation of activities, allocation of resources and use of assets;
- ***transparency and accountability*** – the enterprise must guarantee openness and responsibility in the process of decision-making, planning and provision of services and effective involvement of stakeholders. The goal is to create a system of regular reporting on the achieved results with the provision of widely available information and clear communication of all decisions made to interested parties. In addition, for consumers to clearly understand what improvements need to be implemented at the enterprise and the cost of their implementation, a comparison of the enterprise's performance with other similar enterprises should be carried out;
- ***loyalty, respectful attitude*** – the company must provide equal access to its services. For stakeholders to be able to participate in enterprise planning, the different needs of stakeholders must be respected and taken into account. It is important to create equal opportunities for your employees, including avoiding any kind of gender discrimination.

The general marketing strategy of the enterprise in the field of waste management

The main strategic goals of the enterprise in the field of waste management, taking into account European requirements, are as follows:

- ***compliance with EU standards in the field of waste management*** – the EU policy in the field of waste management is aimed at promoting the development of a circular economy by extracting high-quality resources from waste as much as possible. The European Green Deal is aimed at stimulating growth by transitioning to a modern, resource-saving and competitive economy. Several EU waste laws will be reviewed as part of this transition. The Waste Framework Directive is the EU legal framework for the treatment and management of waste in the EU. It introduces an order of preferences in waste management, which is called the “waste hierarchy”;
- ***compliance with the principles of the circular economy*** – the circular economy model is based on the desire to avoid waste. The circular economy is based on the idea that there is no such thing as waste. To achieve this goal, products are designed for a long service life (using high-quality materials) and optimized for the cycle of disassembly and reuse, which makes it easier to process, transform or renew. Ultimately, these compressed product cycles distinguish the circular economy model from recycling, where large amounts of embedded energy and labour are lost. The ultimate goal is to preserve and increase natural capital by controlling finite stocks and balancing the flows of renewable resources;

- ***implementation of a financially stable system of covering the costs of the enterprise for sustainable development*** – the main task of the enterprise is the provision of services for the management of solid waste and the operation of facilities for the management of solid waste. According to the Law of Ukraine, this activity must be regulated by the state by setting tariffs. One of the principles of state regulation of the activities of natural monopoly subjects is their self-sufficiency. Tariffs are one of the main factors that ensure self-sufficiency. Therefore, the enterprise's tariff policy affects its financial situation, and considerable attention should be paid to this issue;

- ***professional development and motivation of personnel*** – regularly (annually) assess the training needs of the company's employees and annually draw up and revise the training plan (which includes training at the workplace, attendance at specially organized training, training at professional development courses, and, if possible, exchange of experience with others similar companies both in Ukraine and abroad. One of the main and priority tasks of the enterprise is the organization of such a personnel motivation system, under which the employee will have a sincere desire to work effectively. The system includes:

1. *Material motivation* (rewards based on work results (individual, collective), material incentives for employees, availability of a social package)
2. *Intangible motivation* (career growth, professional growth and development, additional training at the expense of the company, verbal or written thanks from the manager for the work performed, public recognition of the personal contribution of the employee, awarding the title of "best employee", the opportunity to participate in the management of the enterprise, flexible work schedule, corporate family holidays, etc.)
3. *Personal responsibility and control* (a set of key performance indicators of personnel and their "binding" to department heads and specific performers)

- ***ensuring compliance with environmental requirements and reducing the negative impact on the environment*** – the long-term goal for the PV industry is to achieve waste treatment standards adopted in the EU, partly already mandatory within the framework of the Association Agreement between the EU and Ukraine, which will require
  - ensuring environmentally safe management of waste (in particular, compliance with requirements for waste disposal facilities);
  - the practical implementation of the hierarchy of management of MW, which prioritizes MW prevention and MW recycling over incineration and disposal;
  - full implementation of the "polluter pays" principle;
  - step-by-step achievement of goals for separate waste collection and recycling of waste fractions that are best recycled; 60% – separate collection and 50% – recycling of the total amount of MW are among the most important goals;
  - 55% recycling rate of packaging and packaging waste according to the EU packaging directive 94/62/EC and 70% recycling rate of construction waste according to the EU waste directive 2008/98/EC.

- ***modernization of equipment with the help of new investments*** – thanks to investment projects of obtaining new technological equipment and installations, which will help to implement the best EU practices in the field of management of MW. Constant search and attraction of investors, successful implementation of projects to create a positive reputation among investors. Open discussion and approval of the portfolio of new investment projects by the local self-government body.

- ***improvement of interaction with interested parties*** - establishment of trust, mutual respect, mutual understanding - intangible assets, the development and growth of which depends on the joint efforts of both company employees and representatives of other interested parties, during the interaction, development of the Plan for interaction with interested parties;

- ***entry into new markets*** – readiness to provide services in all potentially possible models, determination of the optimal model for the enterprise, which should be offered to consumers and to which they should be encouraged.

The above measures will allow the enterprise to:

- to save funds from the city budget by reducing the amount of waste transportation to landfills and directing them to solving strategically important issues of the settlement;

- to make a profit from the sale of compost and the provision of bio-waste treatment services;
- improve and expand the operation of the composting station;
- improve waste collection services and provide the infrastructure and services necessary for the separate collection of recyclable materials and bio-waste;
- financial motivation of individuals and legal entities to actively participate in the bio-waste sorting process.

The company's marketing strategy for the sale of compost

The main goal of ecological marketing is to make compost safe and ecological, in connection with which it is necessary to solve the following tasks:

- increasing environmental awareness among consumers;
- development and promotion of the idea of ecological compost;
- promotion of environmentally friendly compost on the market;
- formation of environmental needs on the market;
- greening of production and its demonstration.

The basis of this ecological marketing strategy is the concept of "ecological shortage", "ecological need", "ecological product", and "ecological service". This concept differs in that specific goods (compost) and services (environmental) appear here, and the manufacturing enterprise must orient its production and marketing activities to their satisfaction from the very beginning. This type of environmental marketing should be "environmental", so an important point of the strategy is the expanded concept of human need for environmental safety. It is also important to study the mechanisms of the formation of ecological needs and their dependence on the level of socio-economic development of the region (tourism emphasis).

The main directions of the marketing strategy of compost implementation are as follows:

- **PR and the creation of a positive image of the company that implements compost** – for the company to appear environmentally responsible in the eyes of consumers, it is necessary to demonstrate openness and social importance through advertising and communication with the audience. The eco-symbol of the enterprise should be a favourite of children, for example, the cat Chepuryk or the dog Uzh. The main actions of communication with the audience should take place, respectively, through the eco-symbol of the enterprise;
- **increasing the loyalty of the public** – for this, the company develops various ways of solving environmental problems, which are meant to attract potential consumers and the public to the consumption of compost and strengthen trust in it;
- **involvement of influencers and bloggers** - potential citizens trust the opinion of influential people more than advertising, so interaction with popular singers, actors, bloggers and other celebrities helps not only to increase the demand for eco-products but also to create a community of environmentally responsible consumers. We also recommend using the company's eco-symbol when engaging influencers and bloggers;
- **implementation of "green" or safe methods of compost production** – this approach involves demonstrating the safe operation of the enterprise, that is, the enterprise must comply with the provisions of the ISO 9000 and ISO 14000 standards. Communication with consumers and the public must take place through social networks, websites or mobile applications. The enterprise must demonstrate the safety of production through a declaration of compost quality monitoring (results of chemical, bacteriological, sanitary and hygienic analyses), inspection conclusions, etc. The enterprise must show its social importance through communication – the introduction of ecologically important technologies, facts about the safety of compost, and examples of safe use of compost.

In addition to the areas considered, the company should dynamically organize events, conduct promotions, and create communities, support innovations, and finance solutions to socially important problems together with the eco-symbol.

CONCLUSIONS AND RECOMMENDATIONS TO PART II

According to the results of Stage 2 of the study "Evaluation of the Most Suitable Technical Solution for Management of Organic Waste, Sorted Municipal and Commercial Green Waste in Uzhhorod", part II "Analysis of the secondary raw materials market" (in particular, compost), the following was obtained:

- the general state of the waste management system and the market of secondary raw materials in Ukraine are characterized. The main legislative prerequisites of the field and the normative-legal field of Ukraine in the field of waste management are sufficiently extensive and consist of laws, several secondary legal acts and basic program documents. The framework law in the field of waste foresees the reform of the field of waste management, which will contribute to the transition of Ukraine to models of circular economy and sustainable development;
- according to the basic principles of pricing, it is established that the price belongs to the most important economic categories, because it has a significant impact on all aspects of the economic activity of each enterprise and the entire country as a whole, and the market conditions of business require the regulation of the pricing system. The prevailing models of price setting in the market economy are cost and value pricing, which exist in parallel and are based on a deep and complete accounting of costs, to reduce them. The application of pricing methods is a very individual process that depends on many factors (the goals of the company, the professionalism and awareness of managers, the market situation, etc.);
- the efficiency of recycling depends on the quality of raw materials, therefore on the primary sorting of waste, that is why the bio-waste management system needs to be improved in order to increase its economic efficiency within the framework of increasing the efficiency of the overall waste management system, the introduction of new waste management systems and the creation of a market for recycled materials is usually difficult process, because it requires the introduction of new technologies and new technical and administrative skills, which in turn requires new approaches to pricing, financing and reimbursement;
- the market value, limitations in doses, frequency of application and areas of application of different groups of compost are established depending on the quality assessment according to the criteria of SOU ZhKH 03.09-014. As of 2023, according to expert estimates, the market value of compost is estimated at UAH 620/t (by areas of application – in agriculture *for group 1* and in forestry, green construction and land reclamation *for group A*), for other groups it is not determined;
- in order to deepen the level of treatment of recycled materials and increase the amount of secondary resources obtained and make the secondary raw materials industry in Ukraine effective and attractive for investors, it is necessary, taking into account the factors affecting the market of recycled materials (in particular, compost), to start with the improvement of the relevant legislation, the introduction of information campaigns, gradually get closer to setting prices at the market level, including for the removal of waste, and expand the producer's responsibility;
- the main problem of applying composting technology in Ukraine – apart from the possibility of using limited types of waste (only waste of plant origin (bio-waste)) and the need to create a separate system for management of bio-waste (separate collection), is the lack of a market for the resulting compost or compost-like product, which leads to lost profit;
- the use of secondary resources is an important ecological and scientific and technical problem that requires its own development. The continuous growth of recycling in Ukraine has been especially observed in the last 5-6 years, and according to forecasts, it is expected in the following years, taking into account the available resource reserves for recycling. At the same time, revenue generation in this area has been mastered by only 15-20% for

comparison – in European countries, the process of revenue generation is quite developed, about 85% of waste is recycled a second time;

- the priority task is the transition to the principles of the circular economy, the introduction of ideas of which in Ukraine is an important step in the activation of European integration processes due to the fact that the idea of a circular economy is new for Ukraine and it lags far behind the EU countries in the development of this direction;
- based on the assessment of the existing market of secondary raw materials in Ukraine (in particular, compost) through the analysis of the collection of municipal waste and secondary raw materials, the established volumes of waste generated and disposed of, and the general use of secondary raw materials – as of 2023, a crisis situation is observed in the field of municipal waste management – according to In 2022, about 9.9% of municipal waste was processed and disposed of, of which: 1.66% was incinerated, and 8.24% went to recycling points and waste treatment lines. The cost of communal services does not cover costs in this area, as a result of which the communal sector is unable to provide high-quality services for the management of municipal waste to the population, indicators of separate collection and sorting of solid waste remain low – separate collection is implemented fragmentarily, unsystematically, covers the central parts of settlements, where shopping centers and points of acceptance of secondary raw materials are concentrated;
- bio-waste in the process of implementing a separate collection system requires a more careful selection from the main volume of waste, which is fundamentally important, because, firstly, it should not enter the recycling system of other types of waste as secondary raw materials (to significantly increase the quality of their further sorting), secondly, these wastes have a significant resource potential and serve as a good source for obtaining products as a result of their appropriate treatment – compost, which determines the urgency of finding ways to process them;
- in Ukraine, a certain system of procurement and treatment enterprises, which are engaged in the treatment of resource-valued waste, has developed and is developing. The sector of the secondary resources market consists of enterprises of various forms of ownership, which are classified according to the activity profile, features of specialization about secondary raw materials, territorial feature (territory coverage) (they are operators of the secondary raw materials market and processors of secondary raw materials in Ukraine);
- the market for compost from municipal waste is still forming because settlements and communities more often choose small composting sites than centralized large bio-waste treatment facilities to reduce logistics costs and solve the problem of proximity to private development, and then use the compost during landscaping exclusively own territories, without a sale. Most enterprises in the field of waste management are just starting work in the direction of using the method of composting collected bio-waste with the possibility of receiving income;
- the primary task is to establish a collection system, not treatment since there are underutilized capacities for each type of waste (except waste paper) due to the lack of recyclable materials. At the same time, when compared with prospective volumes of resources, the question of increasing treatment capacities will inevitably arise – both at existing enterprises and at new treatment facilities. Prospective for the creation of new treatment enterprises are the regions where the conditions for a stable supply of raw materials for enterprises have been created, that is, a system for the collection of recycled materials has been established. The choice of location requires a more detailed study of the issue, taking into account the forecast volumes of the collection of recyclable materials and the logistical component;
- it is important to use marketing tools when carrying out educational work among the population regarding institutions that organize additional sorting, sale or treatment of waste, i.e. collection points and recycling (treatment) enterprises. At the same time, there is a need to create a management mechanism for the waste management program that would combine market patterns and the regulatory influence of state administration. This mechanism should

ensure flexible and effective regulation of the processes of using limited financial resources and contribute to solving a complex of extremely urgent tasks of preserving and developing the economic and intellectual potential of the city, region, and country;

- the bio-waste management system must ensure the implementation of the measures of the National Waste Management Plan and the directions of the National Waste Management Strategy, taking into account the features of the economic and social development of communities based on European standards. Therefore, the issue of bio-waste treatment and consumption of the products of their treatment concerns important social, economic and environmental relations that require comprehensive regulation. All stages of the implementation of the bio-waste management system should include stimulation and encouragement by local self-government bodies of residents to separate collection and composting of bio-waste and, in parallel, powerful informational work with the population;
- even though compost from bio-waste is currently not widely distributed on the Ukrainian market, experts note that today it is a fully balanced fertilizer with the necessary indicators of nutrients and biologically active substances that plants and soil need. The concept of compost consumers should be based on the awareness of the importance of an ecological attitude to waste and the desire for sustainable consumption, compost consumers should value the effective management of waste and natural resources, the concept of compost consumers is marked not only by the act of composting itself, but also by a general awareness and commitment to ecologically appropriate way of life;
- the main goal of ecological marketing is to make compost safe and ecological, in connection with which it is necessary to solve the tasks related to - increasing environmental awareness among consumers; development and promotion of the idea of ecological compost; popularization of environmentally friendly compost on the market; formation of environmental needs on the market; greening of production and its demonstration; In the compost implementation strategy, the enterprise should dynamically organize events, hold promotions, create communities, support innovations, and finance the solution of socially important problems together with the eco-symbol.

The development of the recycling market in Ukraine is hindered by numerous factors:

- *normative and legal*, which are due to the incompleteness of the formation process and the imperfection of normative and legal support in the field of waste management;
- *financial and economic*, which are caused by an imperfect system of tariff regulation in the field of waste management, as well as the lack of economic incentives for the development of the field of waste treatment;
- *administrative*, which negatively affect the transparency of the functioning of the field of waste management due, in particular, to the lack of transparency of public-private partnership mechanisms, the lack of a clear division of responsibilities between market participants, the problems of environmental monitoring and technical regulation of this field, as well as the lack of reliable data on the specifics of the generated waste;
- *socio-cultural* which are manifested in insufficient public awareness of the problem of proper waste management and the importance of effective waste management.

The primary tasks for overcoming the four main obstacles to the development of the recycling market in Ukraine are:

1) completion of the process of formation of regulatory and legal support in the field of waste management by supplementing the framework law with sectoral by-laws that make it possible to effectively regulate the waste management process;

2) implementation of mandatory separate collection of waste;

3) implementation of extended producer responsibility in close cooperation with local self-government bodies;

4) increasing control and responsibility in the field of waste management by significantly increasing fines and zero tolerance for violators;

5) increasing the level of awareness of the population regarding the culture of waste management at the municipal level, as well as educational activities;

6) development and implementation of regional and local waste management plans, which should become practical road maps for stimulating the development of the field of waste management;

7) practical implementation and application of the waste management hierarchy;

8) renewal and development of infrastructure facilities in the field of waste management;

9) ensuring data transparency in the field of waste management.

To create an effectively functioning recycling market in Ukraine according to the rules of a market economy, which would perform its inherent functions, the prerequisites tested by world practice must be recreated, which include:

- *the presence of subjects of market relations*, who, being economically and legally independent, can enter into equal partnership relations regarding the purchase and sale. This can be achieved by transforming existing property relations into various forms – individual, private, joint-stock, state, cooperative, mixed;

- *equivalent exchange of goods*, because there should be no economic aid, benefits, etc. in the market;

- *competition*, which provides all economic entities with the opportunity for free entrepreneurial activity: the freedom to choose buyers, suppliers, any counterparties, forces entrepreneurs to use the most advanced equipment and technology, thereby contributing to the reduction of production costs, increasing the efficiency of the economy;

- *free pricing* , which, as an element of competition and the main mechanism of the control and regulatory function of the market, contributes to the combination of interests of subjects of economic life, stimulating them to rationally use the elements of production;

- *real information about the market in its subjects* , in particular, objective information about the socially necessary quantity, assortment and quality of goods and services supplied to it.

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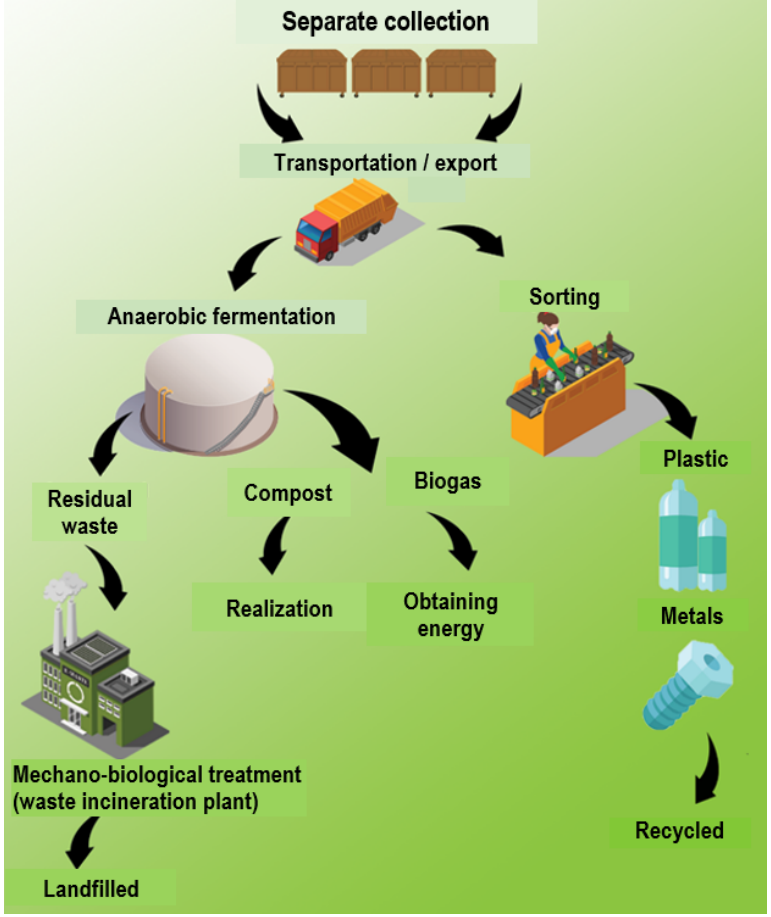
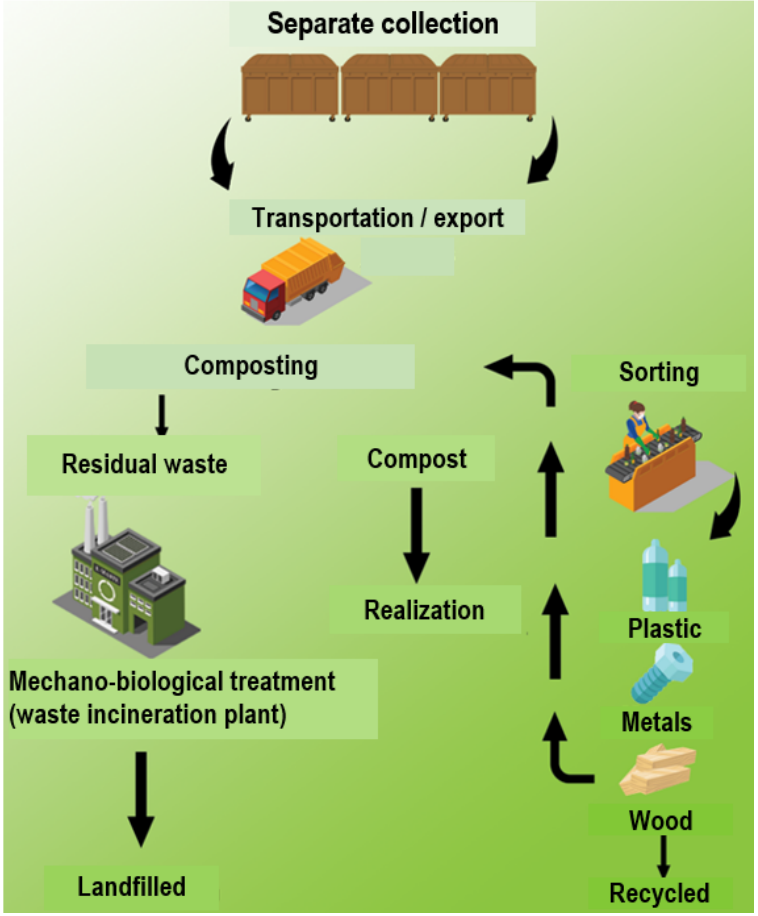
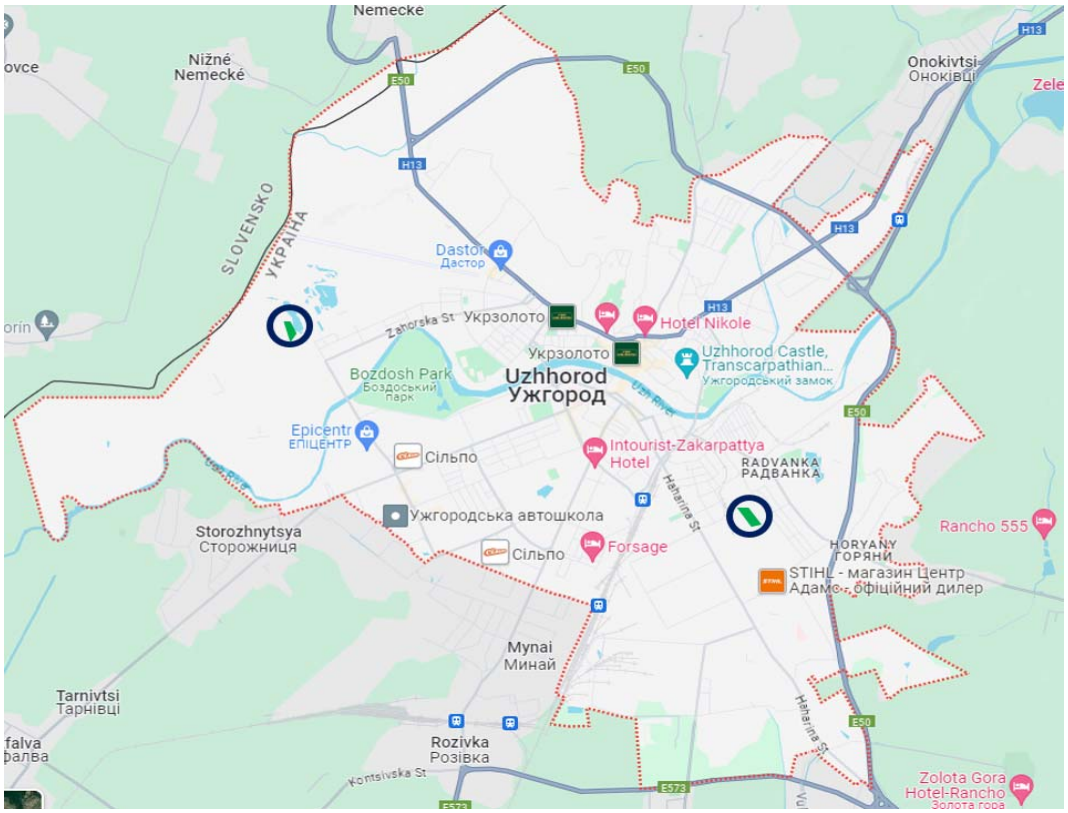
ANNEXES

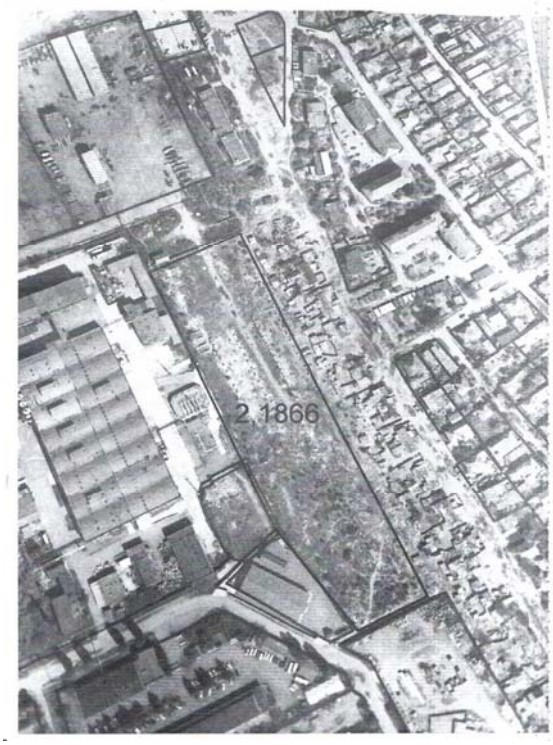
ANNEX A. BIO-WASTE MANAGEMENT VARIANTS FOR UZHHOROD

Variant "Anaerobic treatment of separately collected bio-waste"	
Technological scheme	**Description**
	**Collection**: mobile containers according to DSTU 8476:2015 and – especially for small volumes – bags or bags are suitable for bio-waste collection. **Transportation:** garbage trucks with rear or side loading usually carry out the removal of collected bio-waste. The model of the garbage truck is selected taking into account the actual local conditions. The same vehicles carry out the removal of bio-waste to anaerobic treatment facilities. The shorter the waste transportation distance, the higher the efficiency of the entire system. For the collection and transportation of large volumes of bio-waste (tree and shrub trimmings, garden and food waste), roller containers can also be used, as well as trailers with a movable bottom. **Treatment:** bio-waste is delivered to anaerobic treatment plants, where it is subjected to dry or wet fermentation. During the anaerobic process, organic substances decompose without access to oxygen and release biogas, which can be used to generate energy. Before anaerobic treatment, inert and other non-biodegradable fractions and secondary raw materials are mechanically separated from the mass of waste. In addition to the biogas production plant, there should be a composting plant or an additional plant for biological waste treatment (only the biological stage of mechanical-biological treatment) at the output of the process, as there is a need to process semi-solid waste suitable only for disposal at a landfill. Additional technologies are used to remove and/or use residual waste - for example, ash waste from composting can be used to build a high-quality cover at landfills

Variant “Composting of separately collected bio-waste”	
Technological scheme	**Description**
	**Collection**: mobile containers according to DSTU 8476:2015 and – especially for small volumes – bags or bags are suitable for bio-waste collection. **Transportation:** removal of collected bio-waste takes place, as a rule, by garbage trucks with rear or side loading. The model of the garbage truck is selected taking into account the actual local conditions. The same vehicles carry out the removal of bio-waste to the composting site. The shorter the waste transportation distance, the higher the efficiency of the entire system. For the collection and transportation of large volumes of bio-waste (tree and shrub trimmings, garden and food waste), roller containers can also be used, as well as trailers with a movable bottom. **Treatment:** Bio-waste is taken to a composting site to produce commercial compost that can be used to improve soil in agriculture or other areas. When sorting the material before and after composting, inert fractions and residual secondary raw materials are removed from the waste. Depending on the size of the composting site and other local conditions, open or closed composting technologies may be used. In addition to compost, as the main commercial product, this process produces residual waste that is treated by a mechanical-biological method or a thermal method (alternative variant). Residual waste from composting can be used to build a high-quality cover at landfills

ANNEX B. RECOMMENDED LOCATIONS OF THE PLANNED BIO-WASTE TREATMENT FACILITY (COMPOSTING STATION) IN UZHHOROD





Variant No. 1

Variant No. 2

Figure B.1 – Recommended locations of the planned bio-waste treatment facility (composting station) on the territory of Uzhhorod