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

REPORT

“Assessment of Technical Capabilities, Financial Analysis and Feasibility Study for Justification of the System for Separate Collection of Secondary Raw Materials”

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")

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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. 10 from 31.05.2023)

Project Manager:
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ABSTRACT

Report: 165 p., 2 parts, 81 tables, 24 figures, 7 annexes, 75 references.

MUNICIPAL WASTE, SECONDARY RAW MATERIALS, RESOURCE-VALUED COMPONENTS, BIO-WASTE, WASTE MANAGEMENT SYSTEM, SEPARATE COLLECTION, RECOVERY, SORTING, MECHANICAL BIOLOGICAL TREATMENT, COMPOSTING STATION, CLAMP, COMPOSTING, MSW LANDFILL, UNDERGROUND CONTAINERS, FEASIBILITY STUDY

Provision of the service "Assessment of Technical Capabilities, Financial Analysis and Feasibility Study for Justification of the System for Separate Collection of Secondary Raw Materials" within the framework of the project "Contribution to the sustainable management of municipal waste in Uzhhorod" (hereinafter – the Assessment) is carried out based on Contract No. 10 from 31.05.2023 (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 analysis 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 assessment is carried out considering European approaches to waste management, based on the provisions of the European Directives on waste management, as well as on the provisions of national legislation, their updates and modifications.

The purpose of the Assessment is to assess the technical capabilities, financial analysis and feasibility study (FS) of the system for separate collection in Uzhhorod on an innovative basis, the implementation of strategic planning, which will involve the implementation of several measures aimed at reforming and improving the waste management system in Uzhhorod, selection of the optimal waste management system (identification of the infrastructure for collection, separate collection, processing, treatment and disposal of waste; provision of information on planned technologies and methods of waste management) and practical measures necessary for the implementation of technical capabilities, financial analysis and justification of the separate collection system.

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. 10 from 31.05.2023, SE "NDKTI MG", Kyiv, 35 Metropolitan Vasyl Lypkivskyi str.

INTRODUCTION

Elements and principles of FS

"Assessment of Technical Capabilities, Financial Analysis and Feasibility Study for Justification of the System for Separate Collection of Secondary Raw Materials" (hereinafter – Assessment) 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:

- Framework Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives;
- 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);
- Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC;
- 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 Uzhhorod-2030", approved by the Decision of session No. 1382 from 18.01.2019.

The feasibility study is based on official information and the results of calculations and actual studies.

The purpose of the project is to assess the technical capabilities, financial analysis and feasibility study (FS) of the system for separate collection in Uzhhorod on an innovative basis, the implementation of strategic planning, which will involve the implementation of several measures aimed at reforming and improving the waste management system in the city, selection of the optimal waste management system (identification of the infrastructure for collection, separate collection, processing, treatment and disposal of waste; provision of information on planned technologies and methods of waste management) and practical measures necessary for the implementation of technical capabilities, financial analysis and justification of the separate collection system.

Expected results

The main tasks of FS in research are the following:

- 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 facility (for example, compost quality).

At **Stage 1** of the calendar plan of the Contract for the provision of the service “Assessment of Technical Capabilities, Financial Analysis and Feasibility Study for Justification of the System for Separate Collection of Secondary Raw Materials” Part I “Development of a Feasibility Study (FS) for the Separate Collection of Secondary Raw Materials in Uzhhorod” is being developed, in which in accordance with official information, data obtained by conducting actual research, and provided initial data:

- analysis of international experience in the municipal waste management (MW) and in Ukraine was carried out;
- an analysis of the existing practices of separate waste collection and methods of processing (treatment) of waste in Ukraine (briquetting, composting, incineration, etc.) was carried out, their advantages and disadvantages were indicated;
- analyzed the risks of implementation of various projects of construction (location) of a facility for treatment (sorting) of secondary raw materials (various variants for MSW processing, including mechanical biological treatment (MBT)) in Uzhhorod;
- adopted system of collection of solid waste in Uzhhorod;
- possibilities/variants of installation of container sites (KS) of closed type and with underground containers were analyzed, taking into account the location of underground networks in Uzhhorod;
- calculations of the approximate loading of cargo vehicles with underground containers in Uzhhorod were carried out;
- studied the possibilities (acceptability) of the implementation of the construction project of the facility for the treatment (sorting) of secondary raw materials (various variants for the processing of solid waste, including MSW) for Uzhhorod;
- technological schemes of various variants for the operation of the object of treatment (sorting) of secondary raw materials (various variants for processing solid waste, including solid waste) for Uzhhorod are given;
- scheme of the location of the planned facilities and structures of the facility for the treatment (sorting) of secondary raw materials (various variants for processing solid waste, including MSW), namely collection, landfill, processing, utilization (recovery), disposal, and transportation routes in Uzhhorod;
- consolidated estimates of the cost of implementation of various projects of construction (location) of a facility for treatment (sorting) of secondary raw materials (various variants for recycling of waste materials, including MBT) for Uzhhorod are provided;
- general assessment of the impact on the environment of various projects of construction (location) of the object of treatment (sorting) of secondary raw materials in Uzhhorod was carried out.

At **Stage 2** of the calendar plan of the Contract “Assessment of Technical Capabilities, Financial Analysis and Feasibility Study for Justification of the System for Separate Collection of Secondary Raw Materials”, Part II "Feasibility Study of the Most Suitable Technical Solution for Organic Waste, Sorted Municipal and Commercial Green Waste Management in Uzhhorod” is being developed, in which, in accordance with official information, data obtained by conducting actual research, and provided initial data:

- an analysis of possible technical solutions for bio-waste management (including organic waste, sorted municipal and commercial green waste) was carried out;

- the main selection criteria, conditions and peculiarities of implementation by stages of the bio-waste management system, including the selection of the bio-waste treatment method, are given;

- the basics of the bio-waste composting process as the simplest method of bio-waste treatment are provided;

- an evaluation of the main technical characteristics of various variants of the system of centralized treatment of bio-waste by the method of composting, which are the most feasible for implementation and implementation in Uzhhorod, was carried out, their main advantages and disadvantages were identified, and general recommendations for implementation in the Uzhhorod were provided;

- the availability of available places for the location of the bio-waste treatment facility by the composting method in Uzhhorod was studied, the location conditions and a description of the characteristics of the planned facilities and structures on the site were provided;

- a comparative financial analysis of three technological options for bio-waste processing, which can be implemented within the territorial community of Uzhhorod, was carried out, namely:

a) stabilization of the organic fraction by composting in rows covered by a membrane with a metal frame;

b) aerobic stabilization in tunnels;

c) aerobic stabilization of the organic fraction in the clamps with natural aeration and the possibility of involving neighboring communities in the project was considered.

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.

Bulky waste means municipal waste that cannot be placed in containers up to 1.1 cubic meters in size.

Waste disposal means any operation, which is not waste recovery even where the operation has as a secondary consequence the reclamation of substances or energy.

Waste recovery means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or the wider economy.

Material recovery means any recovery operation, other than energy recovery and the reprocessing into materials that are to be used as fuels or other means to generate energy. It includes, inter alia, preparing for re-use, recycling and backfilling.

Waste means any substance or object which the holder discards or intends or is required to discard.

Construction and demolition waste means waste generated by construction and demolition activities.

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

Non-hazardous waste means waste, which does not have hazardous properties.

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

Waste disposal means the 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 following 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, and 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.

Medical waste means waste generated as a result of medical care or veterinary practice, examinations and research in the field of health care, and veterinary medicine, including scientific or research works.

Hazardous waste means waste which displays one or more of the hazardous properties.

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 before 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,

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

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.

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 following the procedure established by law.

Renovation waste means substances, materials, objects, and products that were formed during conversion, redevelopment or ongoing repairs in a residential building, a separate apartment or a public building.

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 reprocessing of organic material but does not include energy recovery and the reprocessing into 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 processing 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 following legislation.

Thermal treatment of waste means a technological process of thermal treatment of waste, which corresponds to the rules of technical operation of the relevant installation.

Waste management means a set of measures for the collection, transportation, and treatment (recovery, including sorting, and disposal) of waste, including supervision of such operations and subsequent care of waste disposal facilities.

Waste incineration plant means any stationary or mobile technical unit and equipment intended for the thermal treatment of waste, with or without recovery of the heat generated during combustion, for removal by incineration with the help of oxidation, as well as other thermal treatment processes, such as pyrolysis, gasification, plasma process, if the substances formed as a result of heat treatment are subsequently burned.

Installation of co-incineration of waste means any stationary or mobile technical unit intended for the production of energy or the production of material products, which uses waste as a conventional or additional fuel or in which waste undergoes thermal treatment for removal by incineration with the help of oxidation, as well as other heat treatment processes, such as pyrolysis, gasification, plasma process, if the substances formed as a result of heat treatment are subsequently burned.

Waste producer means a natural person; a legal entity, because 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.
DEVELOPMENT OF A FEASIBILITY STUDY (FS) FOR THE SEPARATE COLLECTION OF SECONDARY RAW MATERIALS IN UZHHOROD

CHAPTER I. ANALYSIS OF INTERNATIONAL AND UKRAINIAN EXPERIENCE IN SOLID MUNICIPAL WASTE MANAGEMENT

1.1 Analysis of international experience in municipal waste management

In the European Union (EU) countries, the municipal waste management (MW) is an important topic from the point of view of ecology, sustainable development and environmental protection. The EU pays great attention to the reduction of waste generation, its secondary use and optimal ways of utilization (recovery). Here are some aspects of the MWM in the EU countries:

1) **Separate collection of waste**. Many EU countries are implementing a system of separate waste collection. This means that citizens are obliged to sort waste into different types (paper, plastic, glass, metal, organic waste (bio-waste), etc.) to facilitate their further use and treatment.
2) **Return of secondary resources**. Collection and recycling of secondary resources such as paper, glass, plastic and metal are important. This allows for the reduction of the need for new raw materials and energy for production.
3) **Ban on some types of waste**. The EU is implementing a ban on certain types of plastic, such as single-use plastic cutlery and plastic food containers, to reduce environmental pollution.
4) **Regulation of waste volumes**. Some countries set limits on the amount of MSW that can be landfilled. This encourages citizens and enterprises to reduce the volume of waste generation.
5) **Economic and social incentives**. Some countries use deposit systems on bottles and containers to encourage recycling and reduce waste loading.
6) **Environmental education campaigns**. The EU actively supports environmental education campaigns and programs aimed at raising citizens' awareness of effective waste management.
7) **Promotion of innovation and research**. The EU funds research and innovation projects aimed at developing new methods of waste processing and efficient disposal technologies.

In general, waste management in the EU countries is based on a hierarchical system - prevention (reduction), recycling, secondary use and effective utilization (recovery) of waste to preserve natural resources and reduce the impact on the environment, and final disposal of waste.

The long-term objectives of the EU are outlined in the form of Directives and Regulations:

Directive 2008/98/EC on waste;

Directive 1999/31/EC on the landfill of waste;

Regulation (EC) No. 1013/2006 on shipments of waste;

Regulation (EC) No. 2150/2002 on waste statistics;

Directive 2004/35/EC on environmental liability concerning the prevention and remedying of environmental damage;

Regulation (EU) 1272/2008 on classification, labelling and packaging of substances and mixtures;

Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators;

Directive 2012/19/EU on waste electrical and electronic equipment (WEEE);

Directive 94/62/EC on packaging and packaging waste.

The framework **Directive 2008/98/EC** defines the list of waste, the classification of waste management operations establishes requirements for the management of hazardous waste (HW), implements a ban on mixing HW, introduces their labelling, formulates the necessary documents for transporting HW through the territory of EU countries.

In addition, Article 11 makes it mandatory to ensure the separate collection of glass, paper and cardboard, metal, polymers, and by 2025 textiles, as well as preparation for reuse and recycling. Article 22 establishes the need for a separate collection of bio-waste and ensuring its further processing.

The directive sets targets, according to which 55-60% of waste must be prepared for reuse and treatment by 2025, and 60-65% by 2030.

Directive 1999/31/EC defines three classes of waste disposal sites: landfills for hazardous waste, landfills for inert waste and landfills for non-hazardous waste. The directive also defines several conditions for placement, equipment, supervision, control, and tightness, as well as measures to prevent and protect against any threat to the environment.

Measures regarding the management of MW in the EU countries can be presented in the form of the so-called Lansink's Ladder:

1) Prevention of waste generation (prevention) – measures to prevent the generation of waste to optimize the design processes of resource extraction, production of goods (eco-design) and waste generation.
2) Re-use (preparing for re-use) – creation of a network of enterprises, and organizations for checking, cleaning or determining the suitability of products or their components for re-use without prior processing.
3) Recycling (recycling) – utilization (processing) of waste with the return to the production cycle of various materials contained in the waste.
4) Composting (other recovery) – aerobic treatment of biodegradable waste;
5) Combustion with energy recovery (e.g. energy recovery).
6) Disposal (disposal)– burying them in specially equipped places and disposing of them at facilities that comply with environmental standards, only in case of lack of possibility to perform the previous stages of the hierarchy.

Formation prevention includes a wide range of tools at different levels: at the state level – economic incentives, tariff formation, benefits, and eco-design of packaging materials; at the local level – benefits for separate collection, fines for non-fulfilment of separate collection conditions, implementation of eco-education, implementation of educational events, competitions, implementation of separate collection methods in educational processes.

Re-use includes the deployment of a system of separate collection of resource-valuable components of municipal waste (secondary raw materials), which is carried out in EU countries with the help of containers, waste reception points, and waste collection centers for their repair with the purpose of reuse, and centers for the collection of used goods for reuse. In the EU, such centers and points have been created for many separate components of waste: blankets, organic waste (bio-waste), hazardous waste, bulky waste (BW), waste paper, waste electrical and electronic equipment (WEEE), etc.

Treatment, composting, incineration for energy, landfill. In world practice, as well as in the practice of the EU countries, more than 20 technological methods are used for treatment waste, each of which has 5...10 (individual – up to 50) varieties of technologies, technological schemes, and types of structures. According to the technological principle, the methods are divided into biological, thermal, chemical, mechanical, and mixed.

The following methods have become the most popular:

- landfills;
- heat treatment with energy (thermal or electrical);
- processing (usually mechanical and biological processing, sorting);
- composting (production of commercial compost).

Table 1.1 shows the MW indicators of production by country in kilograms per capita.

Fig. 1.1 shows the amount of MSW processed in the EU countries for the period from 1995 to 2021 by technological treatment methods, in kg per capita. The following waste management methods are common in the EU countries: landfill, incineration, material recycling, composting, etc.

The data covers the period from 1995 to 2021 for 27 EU member states. For candidate countries, coverage is as follows: Bosnia and Herzegovina (since 2008), North Macedonia (since 2008), Albania (since 2013), Serbia (since 2011) and Turkey. United Kingdom data covered up to 2018.

Table 1.1 – Generation of municipal waste per capita from 1995 to 2021 in EU countries

Municipal waste generated, in selected years, 1995-2021
(kg per capita)

	1995	2000	2005	2010	2015	2020	2021	Change 2021/1995 (%)
EU	*467*	*513*	*506*	*503*	*480*	*521*	*527*	*12.9*
Belgium	455	471	482	456	412	729	755	66.0
Bulgaria	694	612	588	554	419	408	445	-36.0
Czechia	302	335	289	318	316	543	570	88.8
Denmark	521	664	736	758	822	814	769	47.6
Germany	623	642	565	602	632	641	620	-0.5
Estonia	371	453	433	305	359	383	395	6.4
Ireland (1)	512	599	731	624	557	644	644	25.7
Greece (2)	303	412	442	532	488	524	524	72.8
Spain	505	653	588	510	456	464	472	-6.6
France	475	514	529	534	516	538	565	18.8
Croatia	220	262	336	379	393	418	447	103.6
Italy	454	509	546	547	486	487	495	9.1
Cyprus	595	628	688	695	620	609	633	6.5
Latvia	264	271	320	324	404	478	461	74.5
Lithuania	426	365	387	404	448	483	480	12.7
Luxembourg	587	654	672	679	607	790	793	35.0
Hungary	460	446	461	403	377	403	416	-9.5
Malta	387	533	625	623	641	643	611	57.6
Netherlands	539	598	599	571	523	533	515	-4.6
Austria	437	580	575	562	560	834	835	90.9
Poland	285	320	319	316	286	346	362	27.3
Portugal	352	457	452	516	460	513	513	45.6
Romania	342	355	383	313	247	290	302	-11.8
Slovenia	596	513	494	490	449	487	511	-14.3
Slovakia	295	254	273	319	329	478	497	68.5
Finland	413	502	478	470	500	611	630	52.6
Sweden	386	425	479	441	451	431	418	8.3
Iceland	426	462	516	484	588	614	659	55
Norway	624	613	426	469	422	604	799	27.9
Switzerland	602	659	664	711	728	706	704	16.9
United Kingdom (3)	498	577	581	509	483	463	:	:
Bosnia and Herzegovina	:	:	:	340	352	352	:	:
Montenegro (4)	:	:	:	494	530	486	515	:
North Macedonia	:	:	:	381	441	441	459	:
Albania	:	:	:	:	491	369	311	:
Serbia	:	:	:	363	259	427	442	:
Türkiye	441	465	458	410	424	415	416	-6
Kosovo (5)	:	:	:	:	252	255	270	:

(1) 2020 data instead of 2021.
(2) 2019 data instead of 2020 and 2021.
(3) 2018 data instead of 2020.
(4) 2012 data instead of 2010.
Note: data presented in italic are estimated.
(5) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence
Source: Eurostat (online data code: env_wasmun)

Although more waste is generated in the EU every year, the total amount of MSW sent to landfills has decreased. Thus, the total volume of MSW taken to landfills in the EU decreased by 67 million tons, or by 55%, from 121 million tons (286 kg per capita) in 1995 to 54 million tons (121 kg per capita) in 2021. This corresponds to an average annual decline of 3.0 %. As a result, the landfill rate (the proportion of waste sent to landfill as a proportion of waste generated) in the EU has fallen from 61 % in 1995 to less than 23 % in 2021[2].

[2] Eurostat https://ec.europa.eu/eurostat/data/database?language=ru&etrans=uk

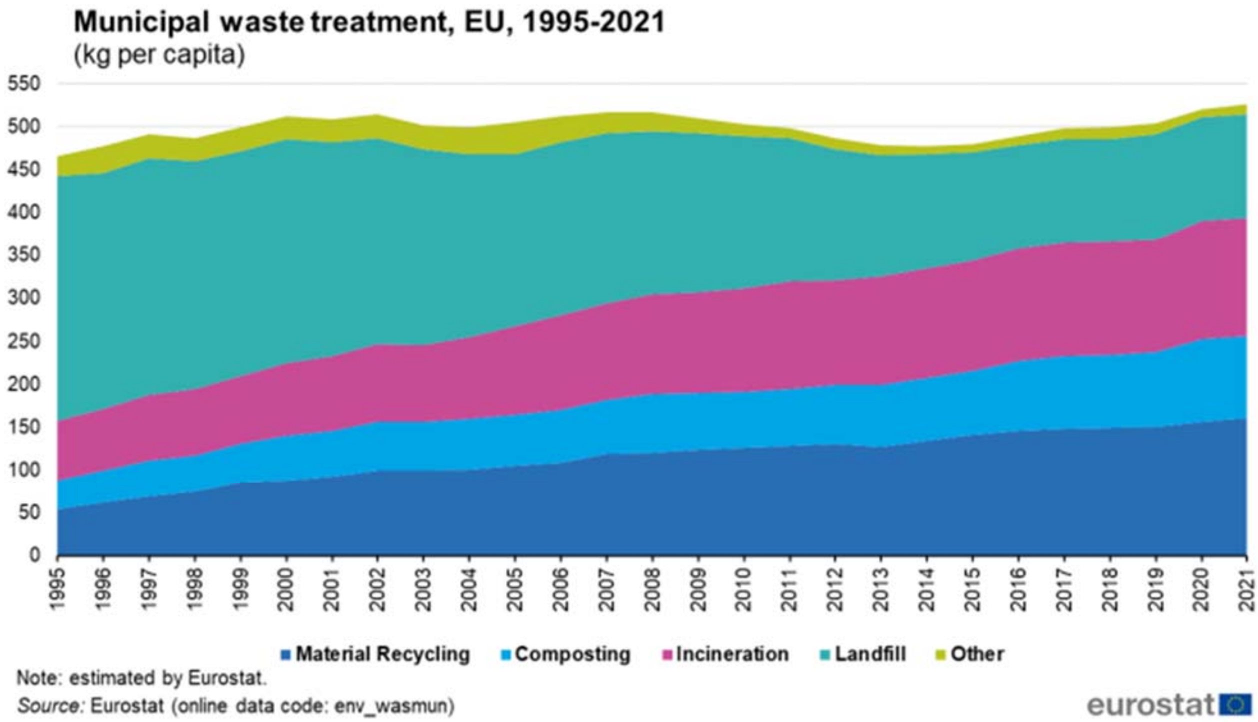

Figure 1.1 – Municipal waste treatment by methods, EU, 1995-2021

Council Directive 1999/31/EC on the landfill of waste provides that EU member states are obliged to reduce the amount of biodegradable fractions of MSW entering landfills to 10% by 2035. The reduction was calculated based on the total amount of municipal bio-waste generated in 1995. The Directive led countries to adopt different strategies to avoid sending the organic part of MSW (bio-waste) to landfill, namely composting (including fermentation), incineration and pre-treatment such as mechanical-biological treatment (MBT) (including stabilization).

As a result, the amount of processed waste (sorting and composting) increased from 37 million tons (87 kg per capita) in 1995 to 115 million tons (257 kg per capita) in 2021, with an average annual rate of 4.3 %. The total share of recycled MW increased from 19 % to 49 %.

The incineration of MSW is also steadily increasing, although not as intensively as recycling and composting. Since 1995, the amount of MSW incinerated in the EU has increased by 32 million tons, or by 106 %, and in 2021 was 62 million tons. Thus, the amount of incinerated MW increased from 70 kg per capita to 138 kg per capita[3].

1.2 Analysis of experience in municipal waste management in Ukraine

1.2.1 State of the field of municipal waste management in Ukraine

According to the available data[4], in 2022, almost 39 million m³ of municipal waste, or more than 7 million tons, was generated in the settlements of Ukraine, which is landfilled in 5.7 thousand landfills and MW landfills with a total area of almost 8 thousand hectares.

Collection of municipal waste

Almost 80% of the population of Ukraine is covered by municipal waste removal services.

In 2022, about 9.9% of MSW was treated and disposed of which: 1.66% was incinerated, and 8.24% went to recycling points and waste processing lines.

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

[4] Ministry of Development of Communities, Territories and Infrastructure of Ukraine // https://mtu.gov.ua/news/34323.html

Municipal waste landfills

The number of overloaded landfills is 163 units (2.8%), and 693 units (12%) do not meet environmental safety standards.

Work on certification and reclamation of landfills was carried out improperly. From 2,197 units of landfills that require certification, in 2022, 258 units were certified (requires certification of 34% of landfills from their total number).

From 2,197 units of landfills that need reclamation, 258 units have been rehabilitated.

The need for the construction of new landfills is 290 units.

Due to an improper system of municipal waste management in the settlements of Ukraine, as a rule, in the private sector, in 2022, 14.7 thousand unauthorized landfills covering an area of 0.6 thousand hectares were discovered, of which 12.4 thousand were liquidated in 2022 with an area of 0.36 thousand ha.

Business entities that provide municipal waste removal services

Appropriate work is being done to create market conditions and develop a competitive environment. Thus, in 2022, 983 organizations, including 214 private properties (21.7%), provided services in the field of waste management.

The number of people working in the field of waste management is almost 16,000.

The total number of specially equipped vehicles is more than 3.4 thousand units. The average rate of wear and tear of special vehicles in 2022 was 60%.

Financing of municipal waste management

The average tariff for waste management in the country is 167 UAH/m^3, including 68 UAH/m^3 for disposal. The average tariff for waste management for the population is 143 UAH/m^3, incl. for burial – 61 UAH/m^3.

According to expert estimates, the volume of implementation of services for the removal of hazardous waste in 2022 is more than 5.9 billion UAH.

The volume of paid services is 5.4 billion UAH.

1.2.2 Implementation of modern methods and technologies in the field of municipal waste management in Ukraine

The Law of Ukraine "On Waste Management"[5] (coming into force on July 9, 2023) provides the reform of waste management, which will contribute to Ukraine's transition to circular economy and sustainable development models.

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 manufacturers of packaged goods to provide financial and technical support to local self-government bodies in the organization of separate collection of waste, and conducting educational and informational work with the population.

A separate collection of MSW has been implemented in 1,440 settlements in Ukraine (not including information on temporarily occupied territories, as well as oblasts where hostilities are taking place).

There are 31 waste sorting lines in 26 settlements: in Vinnytsia, the village Murovani Kurylivtsi, t Illintsi, Kalinivka, Kozyatyn and the village Ivanivtsy Vinnytsia oblast, Lutsk, Kryvyi Rih, village Neresnitsia Transcarpathian oblast, Zaporizhzhia, Ivano-Frankivsk, Bila Tserkva, Obukhiv, Pereyaslav, Kyiv Oblast, Kropyvnytskyi, Busk, Sambir, Novoyavorivsk, Stryi (2 lines), Chervonograd and Zolochiv, Lviv oblast, Sumy, village Plebanivka and village Malashivtsi, Ternopil oblast, Bogodukhiv, Kharkiv oblast, Kyiv (5 sorting lines).

Thermal disposal of waste (incineration) is carried out only at the waste incineration plant in Kyiv.

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

In addition, 10 garbage-sorting plants, 1 garbage incineration plant, and 1 garbage transfer station are being built in settlements.

To provide high-quality services for municipal waste management and to cover the entire population with this service, almost 31,000 containers for the collection of solid waste, of which more than 4,600 containers for separate collection of solid waste, and 61 specially equipped vehicles were purchased. By the end of 2023, it is planned to purchase containers for over 108 million UAH and garbage trucks for 180 million UAH at the expense of oblast and local budgets, from environmental protection funds, at the expense of the project program of local initiatives and funds of enterprises.

There is a leachate collection system at 55 landfills including a leachate decontamination system at 50 landfills, and storage tanks have been installed at others, from where leachate is periodically transported to treatment facilities.

Biogas extraction system has been installed at 18 landfill sites and cogeneration plants with a capacity of 0.5 to 2.0 MW·h are in operation. At the landfill in Kremenchuk, Konotop Sumy oblast, and Kharkiv, biogas is flared.

Cogeneration plants (degassing) are operated at landfill sites in settlements: Vinnytsia, Lutsk, Uzhhorod, Zhytomyr, village Rybne Ivano-Frankivsk Oblast, Boryspil, village Pidhirtsi, Obukhiv district, village Hlyboke Boryspil district and village Rozhivka, Brovarsky district, Kyiv oblast, Kyiv, Kropyvnytskyi, village Vesnyane Mykolayiv oblast, Odesa, Kremenchuk, Rivne, Kharkiv, Khmelnytskyi, Cherkasy.

1.3 General state of waste management in foreign countries and Ukraine

Currently, a large number of countries, including Ukraine, face the task of implementing the process of gradual transformation from simple storage of generated waste to its management. Most of the technical, organizational and legal provisions regarding waste management adopted in foreign countries contributed to the significant progress of technologies and techniques of waste treatment, which allow not only to improve the state of the environment but also to receive additional funds and raw materials from waste treatment.

In recent years, EU countries have gained experience in waste management and over time have improved methods of waste management, and adjusted methods of management to the peculiarities of the territory. Countries such as Switzerland, Sweden and Germany have practically abandoned landfills and are investing in waste management technologies such as sorting, incineration and recycling. Romania, Poland, the Czech Republic, Latvia, Hungary and Lithuania are among the countries that dispose of most of their waste in landfills and mostly do not use recycling, incineration and waste sorting.

Table 1.2 shows the data on the general state of MW management by types of treatment in foreign countries and Ukraine.

Table 1.2 – General state of waste management (2022[6])

Countries	Total mass of MW	Landfilling on landfills	Thermal treatment	Processing	Composting
	thousand tons	%	%	%	%
Austria	4,833	4.0	36.3	25.5	30.9
UK	31,131	27.8	26.5	27.3	16.4
Greece	5,585	80.7	0.0	15.6	3.7
Denmark	4,279	1.3	54.4	26.9	17.4
Estonia	470	6.5	47.2	26.5	4.6
Ireland	2,693	38.2	15.9	30.8	5.8

[6] Eurostat // https://ec.europa.eu/eurostat/data/database?language=ru&etrans=uk

Countries	Total mass of MW	Landfilling on landfills	Thermal treatment	Processing	Composting
	thousand tons	%	%	%	%
Spain	20,217	55.1	12.3	15.5	17.0
Italy	29,655	31.5	19.3	26.1	16.4
Netherlands	8,890	1.4	47.7	23.7	27.1
Germany	50,064	0.3	33.7	46.6	17.2
Norway	2,175	2.8	52.8	26.1	16.1
Poland	10,330	52.6	15.1	21.1	11.2
Portugal	4,710	49.0	20.7	16.2	14.1
Slovenia	892	23.3	0.2	29.0	6.9
USA	227,604	53.8	11.7	26.0	8.5
Ukraine	**7,000**	**90.1**	**1.66**	**8.24**	**0.02**
France	33,703	25.8	35.0	22.1	17.2
Croatia	1,637	80.0	0.2	14.4	2.1
Czech Republic	3,261	56.0	18.5	22.6	2.9
Sweden	4,246	0.6	49.5	33.4	16.5
Japan	44,874	1.3	77.6	20.3	0.3

As evidenced by the data in the table 1.2, in the field of waste management, the following have become the most widespread:

- *landfilling on landfills*

In general, the generally accepted storage of municipal waste in landfills creates a number of problems.

According to statistical data in the EU from 1995 to 2021, there is a very clear trend towards a decrease in the number of landfills of MSW, as countries are steadily moving towards alternative methods of waste management.

At the same time, in Ukraine, the dominant technology for MW management remains their disposal in landfills. In comparison, some EU countries such as Austria, Denmark, Estonia, the Netherlands, Sweden, Germany and Norway have landfill rates of less than 5%.

- *treatment (including composting)*

In many European countries (France, Italy, Germany, the Netherlands, etc.), waste treatment plants that use the technology of aerobic bio-thermal composting are operated. According to this technology, MW is included in the cycle of substances in nature, neutralized and turned into compost a valuable organic fertilizer that is used, for example, for urban landscaping and as biofuel for greenhouses. In the process of composting waste, conditions are created that are detrimental to most pathogenic microorganisms, helminth eggs, and fly larvae. Technological measures make it possible to normalize the content of trace elements in the compost, including salts of heavy metals. These plants are equipped with special equipment for grinding and distributing MW by fractions, separators for ferrous and non-ferrous metals, glass, polymers, etc. A complete set of both the main and auxiliary equipment of such factories is serially produced by their machine-building enterprises. Waste treatment plants in Western European countries, where only organic (vegetable) waste (bio-waste) enters the plants due to separate collection, produce compost, including for agriculture.

In Ukraine, the availability of guaranteed consumers of compost (organic fertilizer or biofuel) is limited; in most cities, compost is used as an organic component of the soil during landscaping of green areas around homes, parks and squares. As for the use of compost in growing crops, it is limited. Often, the waste treatment plant receives a large amount of materials that significantly deteriorate the quality of compost, due to the imperfect organization of separate collection of solid waste and separation of the organic part of solid waste.

- *thermal treatment of waste*

Plants for the production of energy from waste "Waste to Energy") have found wide application in countries with high population density (Germany, Japan, Switzerland, Belgium, etc.) and until recently were considered almost irreplaceable even for industrial cities of Ukraine. However, the operation of such plants, in comparison with waste processing enterprises and landfills, requires significantly higher capital and operating costs. In addition, the processes of gas purification, as well as the utilization and disposal of toxic ash and slag, which are formed during the burning of solid waste in a significant amount (up to 30% of the dry mass of waste), are plant and unreliable.

Ukraine has the experience of operating waste incineration plants only in large cities (Kyiv, Kharkiv, Dnipro) which revealed many shortcomings: the actual capacity for domestic waste was at the level of 60-70% of the design capacity, thermal energy was not used effectively, the plants were a source of environmental pollution since they did not have a perfect gas purification unit and as a result of non-compliance with the technological mode of burning, toxic substances entered the atmosphere, the ash of the waste incineration plant is a toxic substance and requires special methods of disposal. Currently, only the plant in Kyiv is operating.

Most of the mentioned shortcomings are not present at waste-to-energy plants in the USA, Japan, Canada, and Western European countries. In these countries, the issues of gas purification, as well as the utilization and disposal of toxic ash and slag, which are formed during the burning of large quantities of hazardous waste, have been resolved. Almost all foreign plants for the production of energy from waste have equipment for the utilization of heat, they take scrap ferrous metal.

The experience of the EU regarding the rejection of landfilling of waste in landfills and the use of new methods and practices of waste management is quite relevant for Ukraine, given the fact that the waste management system is in an unsatisfactory state. In Ukraine, there are no proven domestic technologies, design and construction documentation for waste-to-energy plants and waste treatment plants, and serial production of equipment plants has not been mastered. The low level of pre-sorting of solid waste and their further treatment leads to an increase in the accumulation of waste in landfills and to an increase in the need to create new landfills due to the overflow of existing ones, which is dangerous both for the environment and for the population.

Considering that it is quite difficult for Ukraine to adopt the international experience of integrated waste management due to the existence of its methods and practices in each country, which may differ from the needs and characteristics of our country, it is expedient at the initial stages of the development of the waste management system and its effective work to adopt experience in separate collection and sorting of waste, gradually adjusting and improving methods and practices and developing its waste management system for the existing features of the territory of Ukraine.

CHAPTER II. ANALYSIS OF EXISTING PRACTICES OF SEPARATE WASTE COLLECTION AND METHODS OF PROCESSING (TREATMENT) OF MUNICIPAL WASTE IN UKRAINE

Technologies and technical processes serve as the basis of modern municipal waste management. These include, first of all, the processes of recycling, utilization and treatment (preparation, extraction of recycled materials, stabilization, pre-treatment of waste), thermal treatment of waste with or without obtaining energy as a combination of utilization and pre-treatment (incineration), as well as necessary processes storage and layer-by-layer burial of residual waste at the MW landfill.

In the European waste management system various technological possibilities and treatment processes should optimally complement each other and, as a result, lead to effective waste management.

2.1 Separate collection of waste

Separate collection of waste precedes the stage of waste treatment. Models of separate collection are formed depending on the accepted model of waste management, which is determined by the oblast waste management plan in the oblast. Models of separate collection of municipal waste (MW) may include:

– separate collection of valuable components (paper, cardboard, plastic, glass, metal, packaging, wood, textiles, etc.);
– separate collection of bio-waste;
– separate collection of hazardous waste (HW) as part of the municipal waste;
– separate collection of waste electrical and electronic equipment (WEEE);
– separate collection of bulky waste (BW);
– separate collection of repair (construction) waste (CDW);
– separate collection of other waste.

The separate collection ensures the efficiency of the entire processing process.

Methods and means, technological schemes, stages of implementation of the separate collection of MSW components, their transportation and processing are chosen to take into account their morphological composition, the annual volume of MSW formation, the need for secondary energy and material resources, organic fertilizers, economic factors and other requirements. The provisions of the Methodology are used for the separate collection of MW and its phased implementation[7].

The solid waste collection system includes the mandatory implementation of a planned and regular system of solid waste collection and the arrangement of container sites following the requirements of current legislation, including DSanPin "State sanitary standards and rules for maintaining the territories of populated areas"[8].

In addition to the container system for the collection of hazardous waste, the following should be created:

– **specialized municipal waste reception points** (by the National Waste Management Strategy[9]), which can accept only those wastes for which there are available technologies and existing enterprises for their treatment, and with appropriate justification – perform additional functions;

– **waste collection points for reuse and recycling** for the collection and possibility of reuse of furniture, municipal appliances, clothes and other goods that were in use. These points can be created as a component of the volume-spatial plan of specialized communal waste collection points (for those settlements where they have already been created) with a separate room, or separately, first of all, in oblast centers;

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[7] Methods of separate collection of household waste // https://zakon.rada.gov.ua/laws/show/z1157-11#Text
[8] https://zakon.rada.gov.ua/laws/show/z0457-11#Text
[9] National waste management strategy in Ukraine until 2030 // http://surl.li/kgyjj

– **waste collection centers for their repair with the purpose of reuse –** it is recommended to provide primarily for WEEE and it is expedient to organize them as an additional block to specialized communal waste collection points in oblast centers.

A containerless method is used for waste collection in those areas of settlements where the possibility of passing garbage trucks and their maneuvering is limited, by using bags (black or with appropriate markings).

The organization of separate collection of waste allows for a significant reduction for waste to be disposed of (disposal), to improve the ecological situation and to receive funds from the sale of secondary raw materials. Therefore, separate collection of waste is one of the most promising ways to solve the waste problem.

To improve the efficiency of the separate collection of all types of waste, it is recommended to hold permanently public and educational actions on the collection of individual components with the involvement of residents of the settlement, the creation of information resources in social networks to popularize eco-education and basic actions of residents regarding waste management, the creation of an educational space to popularize basic knowledge about the best practices of waste management and developing public educational (reference) materials describing the actions of residential regarding waste management.

Further treatment of separately collected secondary raw materials is environmentally acceptable, energy- and resource-saving production, leading to the saving of the most valuable, and at the same time, strategically important materials. The implementation of separate waste collection allows not only to reduction of the damage caused to the environment by waste, to financially support communities but also to obtain valuable secondary raw materials for industry, the natural sources of which are not limitless.

2.2 Waste treatment methods

Waste treatment measures should be fundamentally oriented towards the selection of components suitable for removal from the flow of waste intended for disposal, unusable waste and their processing, which would allow obtaining the greatest benefit from raw material or energy properties. Other goals of waste treatment are to remove potentially hazardous substances from the residual waste stream destined for landfill and neutralize or at least isolate them, reduce the volume of the residual waste stream, and stabilize it so that environmental hazards during storage at the MW landfill are reduced to a minimum.

The preparation (pre-treatment) of waste for further reliable disposal can also be accompanied by the recovery of recyclable materials and the use of energy contained in the corresponding waste. Waste treatment measures are integrated stages of the management system, but can also be considered and carried out as independent processes in combination with other operations within the framework of management.

The most common methods are composting, mechanical-biological treatment (MBT) and waste incineration.

2.2.1 Bio-waste composting (bio composting)

Composting of bio-waste (bio composting) is the method used for the production of technical humus substrates from suitable organic and inorganic materials, which are in biological waste, using their biological decomposition. The method is aimed at significantly reducing the volume of bio-waste, which is usually taken to landfills or incinerated, as well as reducing the reaction potential of waste from other biological processing processes (for example, fermentation processes (anaerobic fermentation)). Composting plants are used all over the world.

Composting of mixed MW can be used as a preliminary phase before waste disposal. Composting is part of the process of mechanical and biological treatment (MBT) of waste. It is more appropriate, however, to use composting as part of an integrated concept of waste treatment and disposal, which involves separate collection and various waste recovery and treatment measures. Compost suitable for use as fertilizer can only be obtained from separately collected bio-waste. Table 2.1 shows the list of waste most suitable for the composting method.

Table 2.1 – Types of waste most suitable for bio-waste composting

Type of waste	Features of use
Food and green waste (garden, backyard)	–
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 processing 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

Composting is an aerobic process in which oxygen reacts under certain conditions with organic materials to produce CO_2, water and humic compounds. The consumption of oxygen is the highest at the first stage of the process, at the following stages it decreases somewhat. Due to 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 lead to the drying of the material and its sanitization, until the end of the process, the temperature slowly decreases.

Table 2.2 shows the input and output materials of the composting method and the approximate energy balance of the method

Table 2.2 – Input and received output materials of the composting method

Input materials	Source materials
Bio-waste	waste and impurities (10-20% of sifted waste of input materials)
	compost (35-40% of finished compost)
	biogas and a small amount of process water (up to 40-55% – mass loss due to decomposition, water evaporation and gas release)

The energy consumption of intensive decay systems is approximately 15-65 kW/t, with mechanical equipment consuming about 10 kW/t. During composting, mechanical operations (aeration) are the most energy-intensive. Depending on the intensity of processing, their energy consumption can reach from 2 to 15 kW/t.

Aerobic decomposition produces 0.6-0.8 g of water and 25.1 kJ of thermal energy per gram of organic matter.

During biological processing, significant volumes of CO_2 and other (greenhouse) gases are released. However, unlike burning or depositing untreated waste, composting binds a significant amount of carbon in the substrate, which prevents its rapid release into the atmosphere.

The range of composting technologies is extremely wide and ranges from simple to technically planted and precisely controlled. There are two fundamentally different *composting systems*:

- *open* (clamp composting);
- *closed* (shop composting (in flat clamps), tunnel composting, boxes/containers, compost drums).

Table 2.3 shows the difference between the systems.

Table 2.3 – 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 - rapid decay process
Disadvantages	- frequent problems with an unpleasant smell - a long process of rotting - 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 rotting, and open systems are used for the final decomposition and ripening of compost.

Since only organic compounds can be decomposed, and harmful substances from other waste fractions can enter the final product, the starting materials should be collected separately and no harmful substances should be allowed to be present in them. Additional processing of raw materials before composting allows for improved quality but does not ensure separation from mixed MW fractions that meet high requirements for compost purity. Preliminary mechanical processing may include the following operations:

- separation of impurities and pollution;
- grinding;
- separation of metals.

These mechanical types of preliminary treatment are similar to the operations carried out within the framework of MBT.

In addition, preliminary mechanical processing allows obtaining the optimal C/N ratio and the required structure of the composting material by combining different bio-waste. For example, leaves (high in carbon, low in nitrogen) can be combined with food waste (high in nitrogen). This allows to reduce the amount of ammonia released in the first stages of decay.

The productivity of the plants ranges from 300 to 100,000 tons/year (the vast majority is about 3-10,000 tons/year). The throughput capacity of tunnel plants is generally higher compared to container systems. The tunnel systems operate cost-effectively while processing 3,000 tons of waste per year.

When composting, it should be guided by international standards for composting. Table 2.4 shows the main technical requirements for the composting method to obtain a good initial product.

Table 2.4 – Basic technical requirements for the composting method

Parameter	Requirements
Quality of incoming material (waste)	1) waste must be collected separately and must not contain components that emit harmful substances; 2) the structure of the material should provide good aeration; 3) the C/N ratio should be from 20:1 to 40:1 with adequate humidity; 4) moisture content 50-60%; 5) the C/N ratio of 25:1-30:1 is optimal for rapid composting (higher ratios are acceptable, however, too high a concentration of nitrogen in the starting material is not permissible, since in this case almost all the nitrogen contained in organic substances will be transformed under the action of microorganisms on ammonia. At pH>7, a high concentration of ammonia leads to its unwanted emission into the atmosphere)

Parameter	Requirements
Temperature mode	To destroy pathogens and weed seeds during composting, the input material must be exposed to a temperature of at least 55°C, if possible, continuously for 2 weeks or a temperature of 65°C (in closed installations 60°C) for 1 week
Purification of technological waters	Process water, if it is not treated in the process itself, must be treated at local water treatment facilities in accordance with the requirements of Directive 91/271/EEC on the treatment of urban wastewater before being discharged into surface water bodies
Quality of the source material	To ensure the stability and safety of matured compost, it must meet the following quality requirements: - C/N ratio – significantly less than 1:25 (for agricultural use); - no reheating above 20°C; - volume reduction - at least by 60% based on the source material; - low content of heavy metals in accordance with international standards

Table 2.5 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 2.5 – Special characteristics and basic requirements for the application of the bio-waste composting method

Special characteristics and application requirements	
Necessity of preliminary processing	separate collection of waste, 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 source material	obtained compost can be used mainly in agriculture, horticulture, and landscaping, as a substrate for the cultivation of special crops (fruits, grapes, and asparagus), to improve the soil and in-home sites. Sawdust generated from trees can mainly be used for energy purposes (for example, in biomass power plants)
Possibilities of removal and disposal of source material	composting waste (screened film, etc.) is subject to processing in other ways (for example, thermal)
Necessity of further measures, additional processing	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 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
Need for personnel	the need largely depends on the performance of the installation. Approximately 10 people are employed at an average installation

Special characteristics and application requirements	
	(1 director, 6-8 operators and technicians, 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 clamps, their shape and mixing technology. For triangular clamps 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 clamps 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% – rotting area (of which 40% – for moving equipment)

Table 2.6 shows the approximate investment, operating and specific total costs and possible revenues of the bio-waste composting method.

Table 2.6 – Approximate performance indicators (costs and revenues) of the method of bio-waste composting

Investment costs	Operational costs	Specific general costs
Mainly: - laying engineering communications – depending on local conditions and installation sizes and process type; - construction structures – 70-100 EUR/t per year; - machines and equipment – 110-140 EUR/t per year (the purchase of an irrigation unit costs approximately 2,000 EUR)	1) insurance, current operation (fuel and lubricants, electricity, insurance, etc.); 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€/t, closed composting = 65€/t	About 30-70 EUR/t (composting municipal bio-waste is more expensive – 50-70 EUR/t than composting tree 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 2.7 shows the main advantages and disadvantages of the bio-waste composting method.

Table 2.7 – Advantages and disadvantages of bio-waste composting method

Advantages	Disadvantages
Production of a scarce product that has high demand	The possibility of processing only some organic fractions of municipal waste
The possibility of recycling a significant proportion of waste, which leads to the unloading of landfills and other waste treatment facilities, allowing to reduce the harmful environmental impact and the amount of costs	The need for separate collection of biological waste
Relative simplicity of management, high reliability of the system	A rather high need for space, a long processing process
Relatively low volume of investment funds	High requirements for the quality of the raw material (compost) can lead to problems in its sale
The technology is widespread and there are no opponents	Partially unpleasant odors near the installation

2.2.2 Mechanical biological waste treatment

Mechanical biological treatment (MBT) is a method of pre-treatment of solid waste for treatment of mixed waste with a high content of bio-waste. The purpose of this type of treatment is to stabilize waste and reduce potential risks while simultaneously significantly reducing the mass and volume of waste due to its biological decomposition (due to the reduction of the percentage of biologically active waste buried in the landfill) and the simultaneous separation of waste into different material streams, the selection of materials that are disposed of, to improve the properties of waste before it is submitted to further treatment processes. Table 2.8 shows the list of waste most suitable for the MBT.

Table 2.8 – Types of waste most suitable for the MBT

Type of waste	Features of use
Mixed municipal waste	–
Wood waste	Only in small quantities, for example, residues without hazardous impurities from sorting, material processing or use in special energy production plants is better suited
Specific production or industry waste	Without dangerous impurities and capable of biological destruction
Other types of waste	All biodegradable materials without harmful impurities

At MBT, residual mixed waste is treated by various mechanical and biological methods. As a result, their reactivity and potential for the formation of harmful substances are reduced, which allows them to be placed in safe storage. In addition, the combination of different treatment methods helps to reduce the amount of waste, obtain materials suitable for further use and, in some cases, generate energy.

There are different configurations of technological processes. However, in all cases, the central idea is to combine mechanical processes with biological treatment. Some combinations of processing methods have been brought to the level of plant technologies, which include control of the emission of harmful substances and neutralization of unpleasant odors in closed systems. Due to the high flexibility of MBT technologies, they can be easily modified to adapt to changing waste composition or to increase plant productivity. With this method of treatment, there is no need to introduce strict requirements for waste collection, that is, there is no need for preliminary separation of waste.

The main concepts of MBT differ according to the sequence of technological operations and the purpose of biological treatment.

At the same time, either mechanical preparation of waste is carried out to obtain an energy-rich fraction for thermal utilization and an energy-poor fraction for biological treatment (tunnel composting), or biological stabilization of all waste with a further mechanical treatment stage (dry stabilization).

Table 2.9 shows the input and output materials and the approximate energy balance of the MBT method.

Requirements for the quality of raw materials - waste after MBT should have a low moisture content and low respiratory activity when the waste is buried. In addition, appropriate treatment of wastewater from the process of anaerobic digestion is necessary, which will allow it to be discharged into surface waters.

Table 2.9 – Input and output materials of the MBT method

Input materials	Output materials*
100% mixed municipal waste	2-5% impurities
water (in the presence of a biological fermentation phase)	1-2% of metals (groups of iron and non-ferrous metals)
	6-7% of secondary raw materials 30-45% alternative fuel RDF/SRF
	40-50% of the fine fraction for biological treatment, including: - 10-25% loss of mass due to biological decomposition - up to 20% yield as water - 5% of biogas is produced - 30-50% are to be taken to landfill

*based on the average composition of waste in European countries

Modern installations for MBT have the following performance indicators:
- minimum productivity (simple decay): 25,000 t/year;
- minimum productivity (anaerobic fermentation): 60,000 t/year;
- maximum productivity: approximately 300,000 t/year.

When using tunnel-composting processes, only a certain part of the waste is biologically treated. The biological process involves anaerobic fermentation, composting, or components of both technologies.

If the anaerobic fermentation process is used, it is usually aimed at optimizing the production of biogas. If the stage of aerobic treatment is a biological treatment technology, then during the composting process mixed waste, which turns into a stabilized material, is sent to a landfill. In dry stabilization (the principle of mechanical-biological stabilization (MBS) or mechanical biological treatment (MBT)), all waste is subjected to biological treatment (drying with heat release), after which the stabilized material is divided into utilization fractions, alternative fuel RDF/SRF and residual waste. In addition, here the main goal is to obtain a burnable alternative fuel RDF/SRF (fuel substitute).

MBT with a fermentation stage produces about 70-170 m³ of biogas from 1 ton of waste for fermentation. Studies on the determination of the ecological load (including the formation of CO_2) have shown that landfilling of stabilized waste produces only 10% of landfill gas and 10% of leachate compared to untreated waste. The use of closed systems for the biological treatment stage helps to reduce emissions and reduce the release of greenhouse gases into the atmosphere.

The average energy requirement of MBT is about 20-70 kW·h/t, and a significant part of the energy (about 10-30 kW·h/t) is required for preliminary mechanical treatment. A comparison of the energy consumption of various variants of the MBT process is given in the table. 2.10).

Table 2.10 – Comparison of energy consumption of different variants of the MBT process

Consumption of MBT	MBT (Composting)	MBT (Fermentation)	MBS (Stabilization)
Electricity	45 kW·h/t	65 kW·h/t	100 kW·h/t
Heat	0	contained in the gas	0
Gas (with reduction due to thermal oxidation)	41(39) kW·h/t	58 (45) kW·h/t	25 (25) kW·h/t

MBT is the phase preceding waste disposal. Although waste treated in this way does not have special requirements for separate collection, and pre-treatment contributes to better compliance with the criteria for safe storage of waste, the technological process should be organized in such a way that a significant part of the valuable substances contained in the waste and energy carriers was separated from the waste for further disposal (utilization).

The central point of MBT of waste is the biological process, in which only fractions subject to biological decomposition can be used. Therefore, waste must go through mechanical treatment processes of different intensities and directions depending on the methods of further waste disposal and the required quality of fractions. These mechanical treatment processes are applied either before biological treatment to separate materials suitable for disposal and those that are not subject to decomposition from the composition of biological fractions, or after biological processing. Because of these processes, material flows intended for disposal or use as an alternative fuel to RDF/SRF are separated from the volume of waste.

<u>Mechanical treatment</u>

As a rule, mechanical treatment includes various mechanical processes that serve to change the physical and fuel properties, as well as the composition of processed waste to facilitate subsequent processes and improve the possibility of using different fractions.

To ensure effective mechanical treatment of waste, the following minimum *technical equipment is required*:

- equipment for storing and loading waste;
- devices for separating impurities and foreign materials;
- devices for preliminary grinding.

If mechanical treatment is carried out before biological, that is when using the technological principle of MBT, *processing is carried out in the following sequence*.

<u>1) Storage and loading</u>

Incoming waste is loaded into semi-bunkers or underground bunkers. Impurities can be partially removed from semi-bunkers using forklifts or special grabs. In addition, this method of storage makes it easy to control the waste being transported. During the delivery of waste of substandard composition, it can be excluded from the process of further treatment. In addition, it is easier to store different fractions separately in semi-bunkers (for example, dry production waste, bulky waste, and wet MW). These bunkers are cheaper than underground ones but require a larger area.

In underground bunkers, it is easier to mix the waste that is delivered. At the same time, it is more difficult to sort non-standard waste and impurities from them. Underground bunkers are most suitable for storing wet solid waste. It is more convenient to store dry waste in semi-bunkers. Therefore, semi-bunkers are usually preferred for MBT of waste.

<u>2) Separation of impurities and extraneous materials</u>

When storing waste in semi-bunkers, the separation of impurities and extraneous materials can be carried out with the help of special grabs (grab excavators) or truck loaders. Other non-standard waste (batteries, large pieces of synthetic film, etc.) are usually sorted on conveyors or conveyor belts. The method of manual sorting in cabins with ventilation is often used when processing dry BW and industrial waste. Due to the potential health hazard, this method is not suitable for sorting wet MSW. For this purpose, technical means (for example, grapple excavators) are used.

3) Grinding

At this stage of processing, the formation of a homogeneous mixture of waste, an increase in their reaction surface and the removal of packaging from various materials that are subject to further processing are achieved. Considering the fact that the pre-grinding operation is one of the most energy-intensive in mechanical processing, it is used only in certain cases. However, BW and industrial waste must always be pre-shredded. Cutting devices (for example, rotary knives), shredders and crushers are used for preliminary grinding (up to a particle size of 250-500 mm). Rotary knives, shredders and cascade mills are used for basic grinding operations (up to 100-250 mm). Fine grinding (< 25 mm) is carried out using hammer crushers.

In addition, mechanical treatment may include *the following operations*.

4.1) Separation of ferrous metals

Large metal components are sorted in the storage area.

Small metal pieces remaining in the waste can be extracted from the moving and fairly well-distributed waste stream using electromagnets installed above the conveyor. Since iron group metals are easily extracted and utilized, their removal operation is a standard component of the MBT installation process.

4.2) Separation of non-ferrous metals

In addition, it is possible to separate non-ferrous metals, especially from the material flow with particle size <80 mm. The possible sale of sorted non-ferrous metals makes it possible to obtain significant income.

5.1) Screening of coarse-grained fractions

If there is a significant proportion of synthetic materials and wood in the waste, they are often separated Total with paper and cardboard in a drum screen. Sifting out particles with a size of 100 to 150 mm allows obtaining a high-calorie fraction (a mixture of paper, cardboard, plastic and wood) in the product on the screen.

Biodegradable materials remain in the under-screen product. A drum screen is not suitable for sifting large waste. In the case of the formation of an RDF/SRF alternative fuel mixture in the overhead product, it is subjected to additional grinding, as well as drying and compaction.

5.2) Separation of light and heavy fraction by pneumatic method

By sorting, for example, with the help of a pneumatic separator, it is possible to separate stones and broken glass from the high-calorie fraction. However, this technology is not used as often as rattling.

6) Separation by manual sorting

If dry waste (especially industrial, bulky BW and construction waste) contains a significant proportion of recyclable materials, it is possible to organize manual sorting. As a rule, this sorting is carried out directly after coarse sieving. For the production of alternative fuel RDF/SRF and the careful separation of different fractions from mixed waste, pneumatic separation is more effective.

7) Additional grinding

In the case of using the high-calorie fraction as an alternative RDF/SRF fuel, additional grinding is often required. For this, high-speed shears are often used, which allow for shredding waste to a size of 60-80 mm. If grinding into smaller particles is required, it is necessary to make pellets from the waste, which is associated with significant technical costs.

8) Pressing into packages

To optimize storage and facilitate transportation, sorted materials (plastics and waste paper) are often pressed into packages.

When using the technological principle of MBT, biological stabilization is usually followed by operations of mechanical metal separation (*4*), and screening (to obtain the mineral fraction). Before biological treatment, it may be necessary to separate impurities and pre-grind.

Biological treatment

Various technologies can be used for biological treatment (these include intensive decomposition and composting or anaerobic digestion).

Variants of implementation of the biological phase of treatment within the framework of the technological principle of MBT

As with composting, static and dynamic methods can be used for waste decomposition. Static methods include simpler methods of decomposition. At the same time, waste is not mixed in the process of biological decomposition. Turned into a homogeneous mixture, the waste is placed in piles, triangular or trapezoidal clamps. Clamps are built on a hermetic basis to avoid contamination of groundwater.

The method of intensive decomposition in tunnels

In the simplest cases and with less strict requirements for the treatment of waste gas, the method of biological decomposition based on the principle of the exhaust pipe is usually implemented. As a result of the self-heating of the decomposing material, an airflow occurs, which ensures the supply of the decomposing material with oxygen. Decomposition systems without air circulation and without the use of technical means to improve air circulation and humidification are used in most decomposition processes with passive air circulation (in open landfills).

To ensure active decomposition, methods with active air supply and regulation of humidity and oxygen content are used.

Composters and manure containers work in loading-unloading mode. The air is supplied through the perforated bottom, the used air is sucked out and filtered. Before rotting, waste requires thorough mechanical processing. Intensive rotting lasts 8-10 days. The technology is simple and durable.

It is possible to use such dynamic and quasi-dynamic methods as humus drums, tunnel reactors and clamps with regular loosening.

Intensive decomposition technologies show excellent results at MBT plants. They are used for biological drying and sterilization of the entire waste stream and allow obtaining materials that are mostly suitable for incineration. The biological properties of waste are used during drying. For these purposes, technical systems are filled to the brim with mainly unsorted, however, homogenized waste. Filtered water and air are collected, and the latter is purified. Considering the unsorted incoming waste, the high formation of harmful substances and filtration water at the first stage of treatment, the process should proceed in a closed system.

Due to moisture reduction due to biological drying and subsequent separation of non-combustible materials, the treated waste is suitable for use as an alternative fuel to RDF/SRF. The calorific value of the fuel obtained in this way is about 12-16 MJ/kg, which allows it to be used in industrial furnaces.

In *anaerobic fermentation,* biological decomposition occurs without the presence of oxygen in a closed reactor. There is a dry and wet fermentation method.

At MBT installations, anaerobic digestion is used, as a rule, to optimize the production of biogas, in some cases it is aimed at optimizing the production of biogas and alternative fuel RDF/SRF. Given the heterogeneity of the material subject to fermentation, the most common is the one-stage *dry fermentation method*, the advantages of which are low water consumption and, given the increased content of dry mass, the possibility of wider use of sediment (compared to the wet method). The fermentation process lasts approximately 18-21 days. After that, the raw material is dehydrated by pressing. Solid residues are submitted for composting with further removal to the landfill, and the wastewater is subjected to additional treatment.

Exhaust air from MBT and MBS installations is subject to mandatory collection and purification. For this, depending on the applied technologies, air volumes and regulatory documents, biological filters or thermal methods such as regenerative oxidation technology can be used. The advantages of thermal methods include the almost complete removal of organic compounds. Their disadvantages include high energy consumption (especially in the absence of the plant's biogas) and relatively high maintenance costs. In addition, the processing of residual waste by the method of anaerobic digestion presents certain requirements for equipment, personnel qualifications and installation planning.

Table 2.11 shows the special characteristics and basic requirements for the application of the MBT method (including the form and scope of its application).

Table 2.11 – Special characteristics and basic requirements for the application of the MBT method

Special characteristics and application requirements	
Necessity of preliminary processing	no need
Possibilities of using the initial material	ferrous and non-ferrous metals go to remelting, high-calorie fractions can be used for energy production (by industrial combustion). Also, as far as legal requirements allow, residual waste can be used after appropriate additional treatment (sieving, additional stabilization) to cover waste deposited in storage, as well as in site rehabilitation works
Possibilities of neutralization and disposal of initial material	processed fine fraction is suitable for storage or further heat treatment
Need for additional processing	necessary measures to minimize the impact and further treatment of the resulting emissions (exhaust air, wastewater). In addition, the burial of waste that has passed the MBT, additional monitoring measures are required
Special safety requirements	exhaust air from MBT installations is subject to collection and purification. When wastewater is generated, it must also be collected and treated. In addition, it is necessary to take additional technical and organizational measures to prevent and minimize the spread of unpleasant odors. Special precautions must be taken due to the spontaneous combustion of the waste from the point of view of fire safety
Potential risks to human health	there is an increased danger of the presence of microorganisms and spores in the air during open processes of treatment and MBT of waste. Employees must use the provided technical and individual protective equipment (half masks)
Aids and materials	only the aids and materials indicated above
Need for personnel	need for manpower depends largely on the productivity of the plant. The average number is similar to the number of employees at a composting facility. In the presence of a manual sorting line, the need for manpower increases accordingly. Specially trained personnel are needed especially when performing plant processes
Required area, implementation features	The minimum occupied area depends on the performance of the installation. Almost no additional space is required if the installation is part of a waste storage facility (only the area for curb clamp composting and humus areas is required). Roughly, it is possible to proceed from the need for space for composting and anaerobic fermentation installations

Table 2.12 shows the approximate investment, operating and specific total costs and possible income of the MBT method.

Table 2.12 – Approximate performance indicators (costs and revenues) of the MBT method

Investment costs	**Operational costs**	**Specific general costs**
Mostly: - purchase of a site of land, laying of communications – depending on local conditions and planned productivity (costs are much lower when the installation is built on a landfill site); - buildings and equipment: *mechanical phase*: - houses with a bunker: 40 EUR/(ton per year) - stationary equipment: 20-80 EUR/(t per year) - mobile equipment: 5-10 EUR/(t per year) *biological phase:* Decomposition: - construction elements: 70-90 EUR/(t per year) - stationary equipment: 110-140 EUR/(t per year) Fermentation: - construction elements: 50-60 EUR/(ton per year) - stationary equipment: 130-180 EUR/(t per year) *approximately a fully equipped MBT installation with a capacity of 50,000 t/year costs about 12 million EUR, with a capacity of 220,000 t/year – about 40 million EUR. When organizing simplified MBT processes at existing landfills – 15-20 EUR per ton of waste	- salary (depending on prices on the local labor market) - energy consumption, insurance, etc - repair and maintenance (for each component of the installation: approximately 1% of the investment volume) - mobile equipment (for example, forklifts): 8-15% of the investment volume **installations for MBT through anaerobic digestion have increased wear compared to installations for decomposition of bio-waste, which causes higher costs for their maintenance (the total cost of an installation with annual productivity of 150 thousand tons is 90 EUR/ton)	About 40-120 EUR/t for treatment only (without landfill costs and using alternative fuels RDF/SRF)
Possible income		
From the sale of secondary raw materials		

Table 2.13 shows the main advantages and disadvantages of the MBT method.

Table 2.13 - Advantages and disadvantages of the MBT method

Advantages	**Disadvantages**
Reduction of the volume and reaction potential of waste that is placed in storage, which contributes to the reduction of the areas required for storage, as well as the reduction of the release of harmful gases, the volume of filtration water and the formation of unpleasant odors	Due to the incomplete mineralization, the waste requires additional treatment, and landfills are subject to further monitoring
Treatment of various materials and obtaining different fractions for further disposal	Incomplete use of the energy value of waste
Possibility of energy production (use of biogas from a biological process and/or by using the obtained alternative fuel RDF/SRF)	
Possibility of implementation in a simplified and cheaper form	

2.2.3 Incineration of waste (in a layer furnace)

Incineration of waste in a layer furnace is a method of thermal treatment of waste used to reduce the volume and risk potential of stored waste by mineralization, destruction and precipitation of most of the inorganic pollutants and to obtain energy from waste (flue gas cleaning is an integrated part of the process). The method is one of the most common incineration technologies, which is used for mass incineration of mixed municipal and industrial waste, and the field of application of this technology is still the world leader. It includes the ability to produce energy from waste (in particular, cogeneration). Unlike other incineration methods, waste is fed onto the grates in the combustion chamber. Table 2.14 shows the list of waste most suitable for the method of burning in a layer furnace.

Table 2.14 – Types of waste most suitable for the incineration method in a layer furnace

Type of waste	Features of use
Mixed municipal waste **Paint waste**	–
Paper/cardboard/ cardboard products	Priority is given to material means of disposal, while mechanical preparation is necessary. Combustion in a layer furnace should be used only for the treatment of combustible components that are separated during the sorting of this waste
Wood waste	It is necessary to check the possibility and give preference to the disposal of individual materials (wood recycling), especially the fractions of untreated natural wood. It is also possible to use special wood burning technologies (mono-installations)
Used oil	Only in small quantities. The possibility of treatment materials or other heat treatment (for example, industrial incineration) should be checked and, if necessary, preferred
Hazardous waste (HW)	Partially only combustible substances
Specific production or industry waste other types of waste	Combustible substances

Table 2.15 shows the input and obtained output materials of the method of combustion in a layer furnace. Table 2.16 shows the approximate energy balance of the method.

Table 2.15 – Input and obtained output materials of the combustion method in a layer furnace*

Input materials	Source materials
Municipal waste	Slag – 200-350 kg per ton of input materials
Water (steam generator, cooling), the need for fresh water is at least 1 m³/h for each t/h of consumption	Ash/dust from the boiler and from flue gas cleaning – 25-40 kg per ton of input materials
	Flue gases – 4,500-6,000 m³ per ton of input materials
	Water (from the steam generator)

*due to the content of the share of regenerative components in the waste (which reaches an average of 50% in Europe) compared to fossil fuels; it is possible to achieve a positive CO_2 balance.

Table 2.16 – Approximate energy balance of the combustion method in a layer furnace

Input materials		Output materials	
Municipal waste	100%	Flue gases and combustion losses	18%
Auxiliary energy (e.g. natural gas)	<3% of input municipal waste	Steam	82%, of which: - 1.6% for own needs - up to 29% electricity (of which 81% – transmission of electricity, 19% – for own needs) - 19% for own needs

The supply of incinerated waste to the grate by loading systems, as well as incineration is carried out in this method continuously throughout the day, while the delivery of waste to the installation is carried out periodically (in most cases during the day). Therefore, an underground bunker is always installed in front of the layer furnace. In addition to constant storage of the necessary stock, it provides mixing of waste, which ensures their homogenization before burning (establishment of approximately stable indicators of calorific value).

Currently, there are various systems of hearths with grates on the market. According to the main directions of waste and flue gas supply, there are the following system variants:

- *direct flow systems* (it is advisable to use for waste with a high calorific value (> 9 MJ/kg). Flue gases that are not completely burned are forced to pass through the zone with the maximum temperature, which ensures better combustion of flue gases and slag. Due to this, the chamber can be dispensed with afterburning);
- *counterflow systems* (more suitable for waste with a low calorific value. High temperature of flue gases contributes to the drying and burning of waste, however, a possible risk is poor mixing of flue gases, in connection with which their afterburning is necessary);
- *systems with a central flow* (used if waste with a wide range of calorific value is received for incineration).

Grating systems transport waste in a way that ensures good mixing and passage through different temperature zones.

There are three different systems:

- in the case of *a system with pushing grates,* waste is transported through the grates. An inclined surface of the grill is not necessary, although it is offered by some manufacturers. By accelerating the movement of the grating, the feed speed can be increased. This provides an opportunity to control the residence time in the furnace and to adapt to fluctuations in the loading of waste onto the grate. Pushing grates are currently the most important grate system on new installations;
- with *a system with a reciprocating grid,* waste is transported under the influence of gravity. The sloped surface is necessary because the waste and grate move in opposite directions. Reciprocating gratings are suitable, for example, for wet waste.

In both types of grates, water-cooled rods can be used.

- in *the system with roller grates,* the material is transported due to the combination of gravity as a result of the slope of the grate surface and the movement of the rollers for transporting waste. Moving motions transport the waste downwards. Faster rotation of the rolls leads to faster transport, but not better mixing.

Effective burning on grates takes place at a temperature of 850-950°C. At the end of the slowly moving grate, the combustion residues fall into a water-filled slag removal device. Flue gases formed during the combustion process enter the afterburner, where they are burnt at a temperature of 850°C. Flue gases originate mostly in the afterburner area, where they burn out at temperatures from 850°C to over 1,000°C. In a steam boiler, flue gases are cooled to 200-400°C. At the same time, superheated steam is formed in most cases (no more than 40 bar, 400°C). Steam can be used for electricity generation and as process steam for district heating.

The productivity required for profitable operation is at least 50 thousand t/year = consumption 6.5 t/h, the maximum calculated indicators are about 225 thousand t/year = consumption per line 30 t/h, and the number of lines is not limited. The productivity of today's largest installations is 800-1,000 thousand tons/year.

New systems of water-cooled grates allow the burning of high-calorie waste mixtures with a calorific value of about 16 MJ/kg. Until now, the calorific value was kept only at a level below 12 MJ/kg, as otherwise the thermal load on the lattice systems became too high and there was a danger of melting or significantly reducing the life of the lattice.

Furnaces with grates in principle can be used in combination with all pre-incineration measures and waste treatment processes, they perform the task of mineralizing all combustible substances that cannot be used or processed in another way. An advantage is also the synergistic effect when interconnected with processes/industries that have a large need for thermal energy, which they can obtain from waste incineration plants or carry out the supply of the main load of the centralized heat supply.

The method of combustion in layer furnaces must be connected with the cleaning of flue gases since the gases produced during combustion contain a significant amount of substances harmful to health.

Combined production and supply of electrical and thermal energy is also possible and desirable. However, the following rule applies an increase in the production of steam for the use of heat leads to a decrease in the potential for electricity production. Typical cases of the combination are, for example, 5% electricity plus 35% heat output or 10% electricity plus 20% heat output. Depending on the location, modern installations can significantly improve these figures.

Table 2.17 shows the main technical requirements for the method of burning in a layer furnace.

Table 2.17 – Basic technical requirements for the method of burning in a layer furnace

Parameter	Requirements
Quality of incoming material (waste)	Use of input material (waste) with the following parameters: 1) calorific value: - with air cooling of grill grates – > 6 MJ/kg and < 12 MJ/kg - with water cooling of grill grates – 6 MJ/kg to 25 MJ/kg; 2) particle size: < 300 mm (exception up to 1000 mm)
Flue gas cleaning	Necessary
Presence of excess thermal energy	Preferably, it should be possible to return excess thermal energy (steam or hot water) to third-party consumers
Cogeneration of electricity	Alternatively or additionally, it is necessary to have a connection for the transmission of electricity to the public network

Table 2.18 shows the special characteristics and basic requirements for the application of the method of burning waste in a layer furnace (including the form and scope of its application).

Table 2.19 shows the approximate investment, operating and specific total costs and possible income of the waste incineration method in a layer furnace.

Table 2.18 – Special characteristics and basic requirements for the application of the method of burning waste in a layer furnace

Special characteristics and application requirements	
Necessity of preliminary treatment	Large interfering components (e.g. large metal parts) must be removed from the waste. Waste must not contain radioactive components (input control). In some cases, preliminary grinding is required (for BW)
Possibilities of using the initial material	The slag produced by incineration can be landfilled or used after further treatment, which includes separation of metals and grinding/homogenization, after which the material can be used for construction purposes (e.g. road construction)
Possibilities of neutralization and disposal of initial material	Residues after incineration (slag, ash) are suitable for disposal at a landfill, but the substances separated during flue gas cleaning must be treated as hazardous waste (HW) and sent for disposal at special facilities suitable and approved for these substances

Special characteristics and application requirements	
	It is preferable to dispose of the material by depositing it in spent underground mines or by burying it in underground waste storage facilities (landfill for HW)
Need for additional processing	Substances captured in the process of cleaning flue gases and other thermal treatment processes belong to the category of hazardous substances and are subject to appropriate treatment when buried in special landfills
Special safety requirements	Exhaust gases from combustion sources must be treated and cleaned in such a way that there is no increased risk to health or adverse effects on the environment. During the construction of waste incineration plants, in particular, to reduce the noise level, the minimum distance to the nearest buildings should be taken into account
Potential health risks	The release of untreated flue gases poses a great risk to the health of the population in the surrounding areas, which can be effectively countered by applying modern cleaning technology and protective measures. Waste incinerators using state-of-the-art flue gas cleaning technology are considered safe for health
Aids and materials	- oil or natural gas (for starting and stopping the installation and additional firing at reduced temperatures in the afterburner chamber); - adsorbents and other reagents (lime and liquid ammonia and other parts) (for flue gas cleaning)
Need for personnel	For the 24/7 mode of operation of the installation, it is necessary: - 15 trained workers per line per day (at least 1 engineer and 2 foremen); - additional personnel for administration, assembly work and watch service. Qualified personnel are needed especially for technical personnel management. The number of lines in the installation has less influence on the need for personnel than the installed flue gas cleaning equipment
Required area, implementation features	The minimum required area is about 10,000 m² with a consumption of 50,000 t/year or 30,000 m² with a consumption of 200,000 t/year. Due to the presence of an underground bunker, the groundwater level should not be too high

Table 2.19 – Approximate indicators of operation (costs and revenues) of the method of burning waste in a layer furnace

Investment costs	Operational costs	Specific general costs
vary greatly depending on the applied process technology and can be during the construction of a new plant from 50 to/more than 200 million EUR	1) operating costs range from 34 EUR/ton to 102 EUR/ton; 2) repair and maintenance costs (from investment costs per year): - about 1% for each element; - equipment and electrical engineering about 3-4%; 3) personnel costs – depending on the local labor market	approximately 80-250 EUR/t* (including flue gas cleaning) * high plant productivity, simple flue gas cleaning and a good situation in the field of obtaining revenues from the sale of electricity and steam generally improve the cost situation
Possible income		
Due to the sale of electricity and steam/hot water		

Table 2.2 shows the main advantages and disadvantages of the method of burning waste in a layer furnace.

Table 2.20 – Advantages and disadvantages of the method of burning waste in a layer furnace

Advantages	Disadvantages
Maximum reduction of the amount of waste going to landfill (due to reliable and proven waste disposal technology)	High investment costs (in particular to meet security requirements)
Reduction of the potential of harmful substances and reactivity of waste	Community residents are actively concerned about potential health risks
The possibility of using energy from waste to generate electricity and heat/cold	The need for a large number of highly qualified workers
Recovery of ferrous and non-ferrous metals during processing of ash and slag	High dependence on compliance with technological regulations
Treatment of fractions containing hazardous substances to remove them from the disposal cycle	The need for a system of chemical cleaning of flue gases

2.2.4 Briquetting

Briquetting uses for temporary storage of solid waste that needs further treatment; it is not a waste treatment technology.

It is recommended to use special presses with a specific pressure of at least 20 kg/cm² for briquetting of MW. The components of MW either obtained during the separate collection of waste or because of sorting the general waste stream on waste sorting lines are subject to briquetting. Compaction helps to reduce the occupied volume by 5-6 times and saves space during storage and transportation for further processing.

2.2.5 Selection of technology for treatment and preparation for waste landfilling

Waste treatment operations based on the principle of anaerobic digestion or fermentation should be considered as a complementary element to composting in the field of biological waste treatment. At the same time, they have an advantage, because the energy contained in the waste is additionally used. As a rule, the installations take up less space and have fewer restrictions on the purity of the starting material. Anaerobic fermentation can therefore be used as an independent process for the treatment of biological, if possible, separately collected waste, but it can also be an integral component of the MBT of mixed residual waste, which has been established as a method of waste treatment, with the introduction of a ban on the burial of untreated waste. This type of waste treatment, along with, for example, alternative incineration, allows for significantly reducing the volume of the waste stream to be buried and, in particular, to minimize biologically reactive substances in this waste stream. This technology combines, at many stages of the process, the separation of substances for recycling, as well as energy use and/or stabilization of the biodegradable fraction before landfilling.

MBT of waste is a general concept for all concepts involving the treatment of waste by a combination of mechanical and biological processes, including technologies with the reverse sequence of processes. The main distinguishing features of different concepts are the sequence of the most important stages of the process and the purpose of the biological stage of processing. The main stages of the process in the general technological chain are oriented either on the concept of "decomposition" or on the idea of "stabilization".

In the case of the "decomposition" variant, first, there is a mechanical division of the total flow of raw materials into those suitable for different disposal, in certain cases used for energy purposes or fractions subject to further biological processing. Decomposition or fermentation methods or a combination of individual elements of both methods can be used as a stage of biological treatment.

When using the anaerobic fermentation method as a biological stage of treatment, the main attention during the configuration of the process is paid to the optimized production of biogas. When applying the decomposition method in the case of mixed residual waste, the main task is to obtain biologically stabilized or freed from harmful substances and materials suitable for energy use.

When approaching from the standpoint of "stabilization", the waste is fully biologically treated. The goal is biological drying and maximum sanitation of waste before the next mechanical separation of non-combustible components. The stream of material that remains can be used as a so-called fuel substitute for energy production in suitable combustion plants.

MBT of waste is not a method of complete waste treatment, since the residue obtained in this process must be subjected to additional operations in the form of orderly burial or incineration. However, it is necessary to choose one of the two specified operations even before the construction of installations or the use of MBT waste.

Incineration of waste or its thermal use is widely used as an important component of implementing a modern integrated waste management strategy. Among the variants for obtaining energy and removing heat from waste incineration is still the most reliable and effective, which benefits from the method of disposal of non-recyclable waste that cannot be disposed of in any other way. Conventional incineration methods, such as grate incineration and suspended bed incineration, are also constantly being improved in terms of safety and efficiency. In addition, in combination with appropriate cleaning and aftercare technology, they are also suitable for a very wide range of waste materials, including waste with a high content of harmful substances, and are well-established worldwide.

Using waste as an alternative RDF fuel or fuel substitute in the industry for energy production is a way to treat selected or relevant waste components. It is about the co-incineration of specially processed (separated from other waste materials) and prepared high-calorie waste in industrial furnaces (cement furnaces or power plants, paper industry furnaces) or their use in the form of mono-incineration at power plants specializing in this.

All heat treatment processes must be subject to strict regulations and requirements for the prevention, reduction and control of potentially toxic and other emissions that have a significant impact on the environment. These conditions or interventions greatly affect the capital requirements and production costs of waste incinerators. The type of emissions that ultimately occur and the need for their treatment or control are highly dependent on the composition of the waste and the process used to incinerate it. When applying and improving thermal processing methods, it is necessary to pay increased attention to reducing emissions. Flue gas cleaning technologies play an extremely important role.

The choice of the method of waste treatment and the type of construction of the waste management facility in a specific settlement or oblast depends entirely on local conditions and is carried out based on technical-economic and ecological-hygienic factors.

The main factors determining the choice of MSW treatment methods can be composition, properties and amount of MSW, methods of their collection; local conditions – population size, needs for secondary raw materials, the presence of local enterprises that can process individual components of MW; the possibility of using the useful properties of MW components; capital and other initial costs for the implementation and processing of MW; operating costs for the processing of MW, taking into account the returned sums of the value of the processing products, etc. The possibility of allocating land sites for such objects is also taken into account.

One of the main tasks in waste treatment is to reduce the risk to human health and environmental pollution. The priority methods are those that nullify the negative consequences or at least allow them to be minimized. In any case, risk reduction in waste management must be ensured by compliance with sanitary rules and relevant hygienic standards. Research on the morphological and fractional composition of waste, its density, humidity, and thermotechnical properties is basic.

CHAPTER III. RISKS ANALYSIS OF THE IMPLEMENTATION OF VARIOUS PROJECTS OF THE CONSTRUCTION (LOCATION) OF THE SECONDARY RAW MATERIALS TREATMENT (SORTING) FACILITY

During the implementation of design tasks and operational functions of any project or enterprise, events or phenomena occur that can affect their effectiveness and efficiency. It is important to determine these events, taking into account their potential to create new opportunities for the enterprise or, conversely, their possible negative impact on the achievement of their objectives (mission), goals, tasks, quality of service provision, etc. In addition, it is important to take into account both internal and external circumstances that led to the occurrence of these events.

3.1 Analysis of the safety basis for the implementation of projects in the field of waste management

Currently, in Ukraine and selected oblasts, the implementation of projects based on various variants for the treatment of municipal waste (MW), including mechanical-biological treatment (MBT), may face several risks that will lead to a delay in the implementation of the project or to its complete stop.

Table 3.1 shows the outlined issues in the context of the formation of a safety basis for the implementation of waste management projects at the state, economic, social and technological levels within the framework of the factorial PEST analysis.

Table 3.1 – PEST analysis of the safety basis for the implementation of projects in the field of waste management

Political (state) factors	Economic factors
Implementation of the National Waste Management Plan in Ukraine until 2030	Implementation of the extended producer responsibility mechanism
Advariant of subordinate legal acts to the Law of Ukraine “On Waste Management” in order to implement the established mechanisms	Introduction of the investment component of tariffs for services (reimbursement of economically justified costs for waste management and maintenance)
Development of the institutional structure of distribution of powers and responsibilities of various executive bodies in the field of waste management	Development of the market of secondary raw materials
Development and promotion of public-private partnership	Strengthening payment discipline among the population
Provision of credit programs for the creation of oblasts waste management infrastructure facilities	Ensuring standardization of products after waste treatment
Social factors	**Technological factors**
Awareness and active public participation in decision-making	Creation of infrastructure for collection, transportation, treatment and landfilling of waste
Observance of ecological, sanitary and hygienic standards for the well-being of the population	Expansion of technical and technological capabilities of waste collection, transportation, sorting, composting, treatment and landfilling
Increasing the level of coverage of waste collection services, including separate collection through the container system, with the help of points of acceptance of secondary raw materials, points of acceptance of goods that were in use, points of acceptance of goods for the purpose of repair, etc.	Reclamation of the municipal waste landfill according to modern standards

Provision of eco-education for the population	Creation of an information-analytical system for accounting for volumes of municipal waste
Ensuring public access to information about the state of waste management	Compliance with the rules of operation of waste management infrastructure facilities and systems of collection, transportation, treatment and landfilling
Ensuring inclusive access to waste collection and removal systems and facilities	Ensuring timely modernization, reconstruction, technical re-equipment of waste management infrastructure facilities, machines and mechanisms

The specified chapter of factors demonstrates the interconnectedness of the set of tasks based on the National Waste Management Plan in Ukraine until 2030 and shows that coordinated management is able to ensure ecologically and socially safe development, the implementation of construction projects in the field of waste management, and create risks of non-fulfillment or delays implementation.

3.2 Risks analysis of the implementation of various construction projects of the waste treatment facility

Based on the PEST analysis of the safety basis for the implementation of projects in the field of waste management, the main risks that may arise during the implementation of the construction project of the waste treatment facility (including various technological variants) were investigated. Table 3.2 shows the results of the assessment. Risks are divided into economic, social and technological. The degree of risk impact on technical and economic indicators is assessed as “high” and “medium”. A high impact can stop the implementation of the project or significantly postpone the planned activity. The medium impact can change work efficiency and affect technical and economic indicators. Risks with low impact were not taken into account.

Table 3.2 – Analysis of the risks of implementation of various construction projects of the waste treatment facility

Name of the risk	**Impact assessment**	**Possible tools impact on risk**
Economic risks		
Reduction of purchase prices for secondary raw materials	High	A municipal waste treatment enterprise must meet the requirements of ISO 9000 and ISO 14000. Following these standards, the enterprise organizes a system of monitoring and forecasting prices for secondary raw materials and a form of plans for the sale of secondary raw materials
The increase in the cost of energy carriers, electricity and thermal energy, and other communal services	High	Compensation for the cost of energy carriers is due to a timely change in the tariff for the service. The task of the enterprise and local self-government bodies is to achieve coordinated and synchronous actions on a timely and economically justified change in the tariff
Lack of guaranteed consumers of secondary raw materials or commercial products	Medium	A municipal waste treatment enterprise must meet the requirements of ISO 9000 and ISO 14000. Following these standards, the enterprise organizes work on a contractual basis, organizes the sale of secondary raw materials using electronic auctions, etc.

Name of the risk	Impact assessment	Possible tools impact on risk
The growth of the exchange rate of foreign currencies	High	The increase in the exchange rate of foreign currencies affects the technical and economic indicators of the waste treatment enterprise, if the project was implemented at the expense of the credit funds of the MFI. When developing the project and signing the loan agreement, the forecast growth of the foreign currency exchange rate is laid down. The difference in the projected exchange rates is usually compensated by the local budget
Absence of an economically justified tariff for municipal waste management service	High	It is important to maintain high standards of waste management services. A municipal waste treatment company must meet the requirements of ISO 9000 and ISO 14000. The conclusion of a credit agreement usually guarantees the advariant of an economically justified tariff by local self-government bodies.
Reduction of timely payment for waste management services by the population	High	Conducting educational campaigns, notifying the public through mass media, holding one-off promotions and a transparent waste management system for the public usually contribute to the timely payment of services. At the same time, the tasks of local self-government bodies include the development of the community's well-being, which will contribute to the timely payment of services
Social risks		
Growing social dissatisfaction of the community population due to possible environmental consequences	Moderate	Conducting of educational campaigns, notifying the public through mass media, holding one-off promotions and a transparent waste management system for the public usually contribute to the loyal opinion of the public. Experts recommend creating an ecological educational center based on the waste treatment facility, which will make a significant cultural and educational contribution. Creation of environmental significance of the waste treatment facility increases the reputation of the management system as a whole. The enterprise must systematically communicate with the population by all available means and actively involve young people and children in environmental education
Technological risks		
Reduction of efficiency of technological processes	Moderate	Development and compliance with the requirements of technological regulations of the enterprise
Delay in delivery to the municipal waste processing facility due to unforeseen circumstances	Moderate	Creating a daily amount of municipal waste accumulation (creating a hopper-accumulator, using heavy-duty containers) or creating a pre-accumulated volume of separately collected secondary raw materials

Name of the risk	Impact assessment	Possible tools impact on risk
Stoppage of individual technological links	Moderate	Development and compliance with the requirements of technological regulations of the enterprise
Organizational risks		
Lack of qualified workforce	Moderate	Salary increase. Creation of conditions for the interest of students of local higher education institutions (excursions, internships, studies, work)
Lack of unskilled labor	Moderate	Salary increase

Thus, the risks of occurrence of events that can affect the technical and economic indicators of the waste treatment facility or implementation of the project are possible. To establish effective enterprise management, it is recommended to implement ISO 31000 "Enterprise risk management system".

Effective risk management at the enterprise should include a set of measures and strategies aimed at the identification, analysis, reduction, control and minimization of possible negative consequences of events that may affect the achievement of the organization's goals. Below the components of effective risk management are summarized:

A) *Risk identification*: identification of all possible risks at the enterprise that may affect the activity. These can be financial, technical, operational, legal, reputational, etc.

B) *Risk analysis*: expert assessment of the likelihood and possible impact of each identified risk.

C) *Risk response planning*: development of strategy and action plans to reduce the impact of risks on the organization. This may include taking measures to prevent risks, transfer risks through insurance or contracts, mitigate through response planning, etc.

D) *Implementation of risk management measures*: implementation of necessary changes and measures in the organization that will help reduce risks. This may include the introduction of new procedures, changes in technological regulations, staff training, etc.

D) *Monitoring and control*: risk tracking and assessment. Based on the results of risk monitoring, adjustments are made to the enterprise's strategies, plans and technological regulations.

In general, effective risk management is an integral part of the successful management of any enterprise and helps to ensure the sustainability and stability of its operation.

CHAPTER IV. ANALYSIS OF MAIN TECHNOLOGICAL, CONSTRUCTION AND ARCHITECTURAL AND PLANNING SOLUTIONS

4.1 Existing municipal waste collection system in Uzhhorod

Reducing the volume of municipal waste (MW), which is taken to the MW landfill for disposal, is tasked in Uzhhorod. One of the most important processes in the proposed concept of waste management in the work "Analysis of the Current Waste Management System" (hereinafter – Analysis)[10] is the process of sorting through the introduction of a system of separate collection of waste throughout the city, including valuable recyclable components (paper, cardboard, glass, polymer materials, metals). This will allow not only a significant reduction for MW to be removed (buried) at the MW landfill, but also to reduce their impact on the environment and the general ecological situation and to receive funds from the sale of sorted secondary raw materials. The organization of a separate collection of waste is one of the most promising ways to solve the problem of waste.

Separate collection of residual municipal waste (mixed, without secondary raw materials) is carried out at the local level and includes

- container park (renovation) for residual MW (mixed) type KMP classes 1-4 according to DSTU 8476:2015 (with a capacity of up to 1.3 m³).

Separate collection of resource-valuable components of municipal waste (secondary raw materials) is carried out at the local level and includes:

- container park (update) for resource-valuable components of the KSP type of classes 1-4 according to DSTU 8476:2015 (with a capacity of up to 1.3 m³);
- creation of specialized municipal waste collection points that accept the following types of waste:
  - hazardous waste (HW) as part of municipal;
  - bulky waste (BW) (furniture, large municipal items, etc.);
  - secondary raw materials;
  - waste electrical and electronic equipment (WEEE), spent batteries, batteries, and accumulators;
  - garden and park waste of biological origin (grass, leaves, branches, etc.) (bio-waste);
  - construction and demolition waste (CDW).

Based on the fact that specialized communal waste collection points are implemented in settlements with a population of more than 50 thousand people, for Uzhhorod 2 items were accepted.

Separate collection of biodegradable waste (food waste, mainly of vegetable origin) is carried out at the local level and includes

1) stimulation and encouragement by local self-government bodies of city residents to separate collection and composting of the organic component of waste (bio-waste), primarily in private municipals of individual manor buildings that do not require infrastructure development.

Separate collection of municipal hazardous waste. The collection of HW as part of the MW is carried out in the following ways:

- specialized communal waste reception points;
- mobile (movable) points of reception of HW.

[10] 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 Management of Biodegradable Waste in Uzhhorod" within the Framework of the Implementation 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

Separate collection of spent batteries, batteries, accumulators and WEEE until the introduction of the principle of extended producer responsibility in Ukraine and the implementation of the collection system at the national level, it can be carried out within the framework of pilot projects in the following directions:

- creation of specialized communal waste reception points;
- creation of mobile (movable) collection points for HW and WEEE.

Separate collection of other waste*:* bulky waste, construction and demolition waste from the population, construction and demolition waste. The method of organization of collection is determined independently by the relevant local self-government bodies and includes the following:

- creation of specialized communal waste reception points;
- implementation of a collection system (can be collected at container sites near homes in portal roller containers of the KZR or "Big Bag" type) and removal of BW and CDW from the population according to the application scheme;
- removal of construction and demolition waste from the city territory separately from other types of waste according to the specified schedule.

The main planned objects of the infrastructure of the municipal waste collection system

Based on the available initial data and local conditions, it is planned to create and develop the main infrastructure facilities of the MSW collection system in Uzhhorod (Table 4.1), which include specialized municipal MW collection points; a container system for the separate collection of waste (resource-valuable components) and a container system for the collection of mixed waste (including underground containers). In addition, by the National Waste Management Strategy in Ukraine by 2030, the creation of:

- networks **of collection points for the reuse of furniture, municipal appliances, clothes and other goods that were in use,** which can be created as a component of the volume-spatial plan of specialized communal waste collection points with a separate room, or separately (until 2030, in oblast centers);

- **waste collection centers for their repair for reuse** (primarily WEEE) (100 centers in Ukraine as a whole by 2023 and 250 centers by 2030, respectively).

Table 4.1 – Infrastructure objects of the municipal waste collection system in Uzhhorod

Name of the location area	**Number of population**	**Specialized communal points for waste collection**	**Collection points for the reuse of goods that were in use**	**Waste collection centers for their repair for re-use**	**Underground containers**
	persons	**units**	**units**	**units**	**units**
Uzhhorod	115,542	2	1	1	12

The selection of secondary raw materials from MW collected in containers or loaded into garbage trucks is allowed only at specialized MW treatment enterprises (with sorting) and by the requirements of waste management and sanitary legislation. Further MW sorting and treatment should be carried out with sufficient volumes of waste, which allow achieving economic efficiency of using the treatment (sorting) facility.

See Annex A for variants for MW management.

4.2 Analysis of possibilities/variants for installing closed-type sites and underground containers, taking into account the location of underground networks

4.2.1 Analysis of types of container sites

Container sites (CS) are specially equipped sites for placing containers for storage of municipal waste intended for timely collection of municipal waste, creation of safe conditions for their storage, removal from residential areas and courtyards, public roads and other objects of improvement of settlements and carrying out mass events.

Two types of CS are used to collect MW: surface and underground (semi-underground).

Ground container sites are *of the open* (free access to installed containers for MW) and *closed* (restricted access to installed containers for MW – have either a code or a padlock) type. With the installation of closed-type sites, the process of collecting solid waste becomes much more comfortable and convenient, which to a certain extent allows ensuring the proper sanitary condition of the CS, including by preventing access to them by outsiders. The cost of making a ground-type CS ranges from UAH 16,000 to UAH 23,000, and depends on the number of installed containers.

Underground (semi-underground) container sites are underground (semi-underground) container systems that are:

- *with its lifting mechanism* – in the form of a lifting platform, which is installed in a prepared concrete bunker, euro-containers with a volume of 1.1 m³ are placed on the platform, which rises to the surface with the available hydraulic lifting mechanism, and are rolled out from under the platform and classically served by garbage trucks. Container maintenance does not require expensive special utility equipment, but there is a possibility of failure of the existing equipment for lifting the platform, the cost of manufacturing the system is 200,000 UAH based on 1 container;

- *with an external lifting device* – in the form of an underground concrete bowl, in which special containers with a volume of up to 5 m³ are installed, which are lifted and taken away by garbage trucks with special manipulator cranes. Container maintenance requires expensive special utility equipment, but there is no built-in equipment for lifting containers, which can fail, and it is possible to significantly save space for installing such platforms on the territory of the settlement, the cost of manufacturing the system is from 200,000 UAH based on 1 container.

The main requirement for the installation of both types of underground CS is the absence of underground communications, and for systems with an external lifting device, the absence of overhead communications.

Underground container sites are a modern and innovative way of collecting and temporarily storing MSW. The main advantages of underground CS are the proper sanitary condition of the territory of the sites and their appearance, the restriction of access to accumulated waste, the absence of an unpleasant smell, the possibility of reducing the number of containers needed for the accumulation of waste in the serviced territory, thanks to the reduction of the amount of waste, which occurs due to the impossibility of throwing out oversized waste into containers, etc.

4.2.2 Normative conditions for placement of container sites

It is recommended to use underground and semi-underground containers for the collection of solid waste, which does not contain organic substances, and the separation of certain components of solid waste generated in multi-apartment residential buildings, enterprises, institutions and organizations, as well as at public works facilities, in densely built-up conditions.

It is recommended to install underground and semi-underground containers in places free from engineering communications on the territory of improvement facilities and at a distance from multi-apartment residential buildings. For the underground chamber, where the containers are placed, it is recommended to choose such an overlap that will not impede the movement of pedestrians and vehicles. In addition, it is important to create conditions for wet cleaning of the underground chamber and drainage. To prevent storm water from entering the underground chamber with containers, it is recommended to cover it with a concrete contour of a profile shape.

Following the requirements of DBN B.2.2-5:2011 “THE PROVIDING OF PUBLIC SERVICES AND AMENITIES OF THE TERRITORIES”[11], underground containers are placed on hard surface areas within multi-apartment buildings for the collection of mixed municipal waste (MW) or separate fractions of MW (secondary raw materials). The minimum distance from the site with the underground container to the windows of residential buildings is established by the State SanPin “Rules for Maintaining the Territories of Populated Areas”[12] (approved by Order of the Ministry of Health of Ukraine dated 17.03.11 No. 145, registered with the Ministry of Justice of Ukraine on 05.04.11 No. 457/19195). The service radius of one underground container is no more than 300 m. The distance from the underground part of the underground container structure to the gas pipeline must be at least 5 m.

According to clause 9.2.11 DBN B.2.2-5 the site for placing an underground container must be adjacent to driveways, sidewalks or pedestrian roads, and not obstruct the movement of vehicles or pedestrians. In the case of separate placement of the underground container, it is necessary to provide for the possibility of convenient passage of specially equipped vehicles and the availability of turning areas with an area of at least 12x12 m.

The surface of the site for placing the underground container should be placed at the same level as the driveways, sidewalks or footpaths.

4.2.3 Analysis of possibilities/variants for setting up container yards in Uzhhorod

The priority area of activity of local self-government bodies is the solution of issues, including those related to the improvement of the city, in particular in the field of waste management this is the solution of the problems of waste collection and garbage removal, which critically harm the environment and create an unsatisfactory appearance of the territories.

Working in this direction, in Uzhhorod it is advisable to start work on the installation of various types of modern container sites, including closed type and underground containers.

Closed container sites

According to the results of the analysis of the possibilities/variants for the installation of closed container sites, it was established that these CS can be of various configurations and designs, to ensure ease of use for both residents and waste management service enterprises, and do not have special requirements for placement and arrangement, compared to the usual CS that are available on the territory of the city, but will make it more aesthetically attractive and neat, and the population will be conscious. The disadvantage of these CS is their higher cost than conventional open CS.

When setting up a container system for the separate collection of solid waste and the collection of mixed solid waste in Uzhhorod, it is proposed to gradually introduce the use of closed-type CS in the majority of the city to organize the collection of solid waste and proper sanitary maintenance of residential areas.

Container sites with underground containers

According to the results of the analysis of the possibilities/variants for the installation of container sites with underground containers, taking into account the location of underground networks, it was established that in the conditions of Uzhhorod, it is possible to install them in the places indicated in the fig. (Annex C) and Fig. C.1-C.12 (Annex C).

Therefore, when setting up a container system for a separate collection of solid waste, it is proposed to additionally arrange 12 units systems with an underground container in the densely built-up area of Uzhhorod. Fig. 4.1 shows the appearance and technical characteristics of which.

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[11] https://e-construction.gov.ua/laws_detail/3199614993616077840?doc_type=2
[12] https://zakon.rada.gov.ua/laws/show/z0457-11#Text

Appearance

Technical Characteristics

- container volume
  for municipal waste – 5 m³
- material – hot-dip galvanized steel
- dimensions of the underground part container, m: L=1.85×W=1.85×D=2.63
- dimensions of the garbage disposal
- columns, m:
  L=0.79×W=0.724×H=0.975
- load capacity – up to 2.0 tons

Figure 4.1 – Proposed system with an underground container
(according to the commercial offer of “KF-SYSTEMS”, Kyiv (Annex D))

The advantages of the proposed system are following:

– the volume of the container is 5 m³ with a required area of 3.4 m²;
– availability of a system for monitoring occupancy;
– the presence of a safety system (during unloading of the container, the bowl remains closed, which makes it impossible for a person to fall inside);
– the presence of a fire extinguishing system (when the temperature inside the container rises, the fire extinguisher is activated);
– presence of a pedal for opening the drum (clean hands);
– there is no need to supply electricity (all systems of the container are powered by a solar battery);
– there is no need to supply/install drainage and drains;
– lack of access to re-sorting of garbage by third parties;
– complete absence or slight smell;
– concern for ecology (closed system, cast s/b pit, no contact with the soil).

This will not only partially solve the problem of the lack of free space in the city, including the one necessary to install more containers for waste due to their large volumes, but will also satisfy the increase in existing sanitary and hygienic requirements.

4.3 Calculations of the loading of sites with underground containers

4.3.1 Methodology for calculating loading volumes of container sites

To determine the volume of solid waste generation in the areas where it is proposed to arrange a CS with underground containers, the provisions of the “Rules for Determining the Standards for the Provision of Services for the Removal of Municipal Waste” (approved by the Order of the Ministry of Housing and Communal Affairs of Ukraine dated July 30, 2010 No. 259[13]) and “Methodical Recommendations for the Organization of Collection, Transportation, Processing and Disposal of Municipal Waste”[14] (approved by the Order of the Ministry of Housing and Communal Affairs of Ukraine dated 07.06.2010 No. 176).

[13] https://zakon.rada.gov.ua/laws/show/z0871-10#Text
[14] https://zakon.rada.gov.ua/rada/show/v0176662-10#Text

4.3.2 Calculation of loading volumes of container sites

For a certain number of underground containers for collecting solid waste in Uzhhorod, the necessary parameters are set for calculations, namely:

- the maximum daily volume of waste generation, based on the population density in the service radius of 300 m, following the requirements of DBN B.2.2-5, is taken as equal to 450 people/ha (according to the requirements of DBN B.2.2-12:2019 “Planning and bulding of territories”[15]);

- the daily coefficient of unevenness is taken at the level of 1.2;

- the passport capacity of containers (5 m³) and the filling factor of containers are taken at the level of 1.0 (100% filling of the volume).

At the same time, the main calculation parameter will be the periodicity of removal and the amount of waste generation per week.

Table 4.2 shows the calculation results.

Table 4.2 – Calculation of volumes of municipal waste generation at container sites with underground containers

Location of container site	Graphic image of container site on the fragment detailed plan	Average normative density buildings (DBN B. 2.2-12), persons/hectare	Calculated amount formation of municipal waste, t/month	Calculated periodicity transportation of municipal waste
Railway Str. (district of the bus station)	Figure C.1 (A1)	300	12.30	4 times for a week
Along the Railway Str.	Figure C.2 (A2)	200	8.20	2 times for a week
14, Ferenc Rakotsi Str.	Figure C.3 (A3)	250	10.30	2 times for a week
crossing Lomonosov Str. and Hoyda Str.	Figure C.4 (A4)	200	8.20	2 times for a week
Crossing V. Commander Str. and Svobody Ave.	Figure C.5 (A5)	300	12.30	4 times for a week
Crossing Orthodox Embank, prov. Baconia, and Ryska Str.	Figure C.6 (A6)	200	8.20	2 times for a week
Sandor Petefi square (square)	Figure C.7 (A7)	200	8.20	2 times for a week
Along the 4, Nebesna Sotnia Str. (near the stairs)	Figure C.8 (A8)	250	10.30	2 times for a week
Along the Dovzhenka Str. (near the park Alpinarii)	Figure C.9 (A9)	150	6.15	2 times for a week
11, Minayska Str. (A. Makarenko Str.)	Figure C.10 (A10)	200	8.20	2 times for a week
crossing Robocha Str. and Mukachivska Str.	Figure C.11 (A11)	250	10.30	2 times for a week
4, Lomonosova Str.	Figure C.12 (A12)	300	12.30	4 times for a week

Notes: fig. C.1-C.12 in ANNEX C shows the container site on a fragment of the detailed plan; the average density of municipal waste is taken at the level of 150 kg/m³

According to the results of the calculations of the loading of container sites with underground containers, it was established that their arrangement in the densely built-up area of Uzhhorod will allow for the removal of 114.95 t/month or 1,379.4 t/year of municipal waste.

[15] https://e-construction.gov.ua/laws_detail/3074154596122232048?doc_type=2

4.4 Study of the feasibility of the construction of the waste treatment (sorting) facility of secondary raw materials for Uzhhorod

When studying the possibility of implementing a project for the construction of a municipal waste treatment facility, including sorting of secondary raw materials, for Uzhhorod needs to conduct an analysis and evaluation of various technologies for waste treatment.

4.4.1 Multifactor analysis of various technological variants

Multifactor analysis is a statistical research method used to analyze the influence of several independent variables (factors) on a dependent variable. This analysis allows revealing the interaction between various factors and their influence on the result. Thus, having established the criteria for the analysis of technological variants for waste treatment, it is possible to select the most desirable and effective variant.

4.4.2 Formation of criteria for technology assessment

The formation of criteria, y_i', for technology assessment includes the following:

1) *Taking into account urban planning conditions and restrictions* y_1' based on the requirements of c. 12 DBN B 2.2-12[16] (terrain slope, soils, flood ability, mining, seismicity). Special location conditions: the site for construction is approximately 118 m above sea level and has a slope of 3-5%; according to ZSR-2004-A(B) – 7 points of seismicity.

2) *Taking into account the requirements for atmospheric conditions for self-cleaning* according to Annex No. 2 SanPiN-173[17] y_2' for enterprises of I and II hazard class (fogging, low-temperature inversions and other unsatisfactory conditions for self-cleaning of the natural environment, which correspond to the category of atmospheric pollution potential “high” and “very high”). For Uzhhorod, according to DSTU-N B.V.1.1-27[18], the repeatability of calm is 25.1% which corresponds to the category of “increased” pollution potential.

3) *The possibility of locating a sanitary protection zone* (SPZ) on a designated site for construction (by the requirements of SanPiN-173) y_3': waste incineration and waste sorting enterprises – 500 m; composting – 300 m; garbage overflow – 100 m.

4) *Achieving the indicators of the National Waste Management Strategy in Ukraine*[19], namely: increasing the amount of waste destined for recycling – 50 percent by 2030, y_4'.

5) *Achieving the minimum design capacity of* 50,000 t/year, y_5'.

6) *The maximum distance of transportation of*, y_6', waste and commercial products is no more than 40 CS.

4.4.3 Characteristics of the main technological alternatives

Alternative No. 1. Facility for heat treatment of municipal waste (incineration)

General characteristics. The object of heat treatment of waste allows changing the physical, chemical or biological properties of waste with the help of an industrial treatment process at high temperatures. The purpose of thermal treatment is to reduce the volume of waste, as well as to obtain

[16] DBN B.2.2-12:2019 "Planning and development of territories" // http://surl.li/kgygf
[17] SanPiN-173 " State sanitary rules for planning and development of settlements" // http://surl.li/hivnz
[18] DSTU-N B V.1.1-27:2010 "Building Climatology"
[19] "National Waste Management Strategy in Ukraine until 2030"// http://surl.li/kgyjj

thermal and/or electrical energy. After incineration of MW, approximately 30-35% of slag and ash remain, which can be used in construction works.

Compliance with the criteria. Heat treatment facilities are most efficient at a capacity of 150,000 tons/year[20]. Such facilities require an effective flue gas cleaning system and placement of an underground storage bunker. The location of the enterprise should be in the territory with a high self-cleaning potential[21]. After incineration, approximately 330 kg of slag remains from 1 ton of municipal waste. There are currently no guaranteed consumers of slag within a radius of 40 KS. The treatment level reaches 67%. SPZ is – 500 m.

Alternative No. 2. Mechanical-biological treatment plant

General characteristics. MW MBT plant makes it possible to extract secondary raw materials from mixed and separately collected waste as efficiently as possible. The main technological process is the mechanical and manual sorting of waste. Sorting separates the biological component of waste, secondary raw materials, combustible components and unsorted residue, which is sent to landfill. The biological component at the MBT plants is directed to 1) anaerobic fermentation, which allows for obtaining biogas; 2) stabilization of bio-waste, which allows for significant reduction of the volume of bio-waste and reduce the level of its organic component; 3) composting, to obtain commercial compost.

Compliance with the criteria. Such plants are easy to build. Almost do not affect the environment, so they can be placed in areas with any self-cleaning potential. The percentage of treatment reaches the level of more than 60%. The minimum design capacity of the MBT plant is 50,000 t/year. There are consumers of secondary raw materials within a radius of up to 40 CS. The radius of the transportation of waste to the treatment plant is also up to 40 CS. SPZ is 500 m.

Alternative No. 3. Municipal solid waste sorting line

General characteristics. The municipal solid waste sorting line is used for sorting light packaging materials (containers), which are collected in a separate container as secondary raw materials. Mechanical and manual separation of waste by individual components takes place on the sorting line, which is a simplified technological scheme of the MBT plant. The main goal is the selection of high-quality secondary raw materials. The waste sorting line is usually not used for mixed MSW due to its low efficiency.

Compliance with the criteria. The municipal waste sorting line is easy to install and can be located in any urban development conditions. Almost does not affect the environment, so it can be placed in areas with any self-cleaning potential. The percentage of processing reaches approximately 5-7% of the total volume of waste in the city. There are consumers of secondary raw materials within a radius of up to 40 CS. The radius of the transportation of waste to the processing facility is also up to 40 KS. SPZ is 500 m.

Alternative No. 4. Briquetting

General characteristics. Briquetting is used for temporary storage of solid waste that requires further processing. At the same time, the MW is compacted and baled with the help of a film and tied with a wire[22]. Bales are stored in a specially designated area, the surface of which is covered with geotextile. Not a waste treatment technology.

Compliance with the criteria. The introduction of briquetting technology requires an additional site for the temporary storage of waste in bales. It is not a processing technology, as the waste does not change its physical state and individual components are not returned to circulation. The radius of the transportation of waste to the treatment facility is also up to 40 KS. SPZ is 500 m.

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[20] VDI 3460 Blatt 1 – Emissionsminderung // http://surl.li/kgyqs
[21] Energy from waste // www.eew-energyfromwaste.com - EEW
[22] Packaging system EUREC RBS-2 EuRec RBS-2 | EuRec

Alternative No. 5. Composting

General characteristics. Composting is an aerobic fermentation of bio-waste, resulting in a humus-like substrate with fertilizer properties. Composting technology is used only for separated or separately collected bio-waste, as a component of MW. The resulting commercial compost is sold for the needs of green farming, reclamation of disturbed lands, as fertilizer for ornamental plants, etc. Usually, in agriculture, compost after MBT is not used.

Compliance with the criteria. Composting technology is used for a separate component of MW bio-waste. As an independent technology can be used for composting waste from green areas. The level of MW treatment is 30-40%. There are potential consumers of compost within a radius of up to 40 CS. SPZ is 300 m.

Alternative No. 6. Degassing

General characteristics. Degassing is used for the extraction of biogas, which is formed during the disposal of solid waste at municipal waste landfills[23]. Active and passive degassing systems at landfill sites make it possible to significantly reduce the risk of spontaneous combustion, reduce emissions of greenhouse gases (biogas), and use biogas for energy purposes. Degassing is not an independent waste treatment technology. Degassing is mandatory at the stage of landfill reclamation.

Compliance with the criteria. The degassing technology is used at the stage of waste disposal at landfills and is not a waste treatment technology. SPZ of the landfill site is 500 m.

4.4.4 Determination of the most acceptable variant of the technological alternative

Compliance with the set criteria, y'_i, is coded as 1 if the requirement is met and coded as 0 if the requirement is not met.

Generalized response for all indicators calculates:

$$Y_1 = \prod_{i=1}^{n} y_i , \qquad (4.1)$$

The most acceptable alternative variant will be the one that meets all the established criteria and receives a generalized feedback of 1.

Table 4.3 shows the determination of compliance of the above-mentioned technological alternatives with the established evaluation criteria and their generalized feedback for Uzhhorod.

Table 4.3 – Multifactor analysis of various technological alternatives

Number of alternative	**Compliance with established criteria, y'_i**						**Generalized response, Y_i**
	y'_1	y'_2	y'_3	y'_4	y'_5	y'_6	Y_1
No. 1	1	0	1	1	0	0	0
No. 2	**1**	**1**	**1**	**1**	**1**	**1**	**1**
No. 3	1	1	1	0	0	1	0
No. 4	1	1	1	0	1	1	0
No. 5	1	1	1	0	0	1	0
No. 6	1	1	1	0	0	1	0

[23] DBN V.2.4-2-2005 "Municipal Solid Waste {Landfills. Basic Provisions of Design" // http://surl.li/kgyrt

Thus, according to the results of the multifactor analysis of various technological variants for waste treatment for Uzhhorod, it was established that the most acceptable technological variant according to the established criteria is the implementation of mechanical-biological waste treatment. This technology allows treating more than 60% of municipal waste with minimal impact on the environment, with the extraction of secondary raw materials, obtaining biogas or compost and alternative fuel RDF/SRF. The MBT technology with RDF production is reflected in the European Commission's Best Available Waste Management Guidelines[24].

4.5 Material and resource potential of municipal waste in Uzhhorod

An important characteristic when choosing both waste treatment technologies and variants for operation and the selection of equipment for their treatment facilities is the morphological composition of waste materials, as it characterizes the content and potential volumes of selection and use of raw materials and valuable components of the formed waste materials, which also affects economic indicators functioning of the waste treatment facility.

According to the data obtained as a result of on-site studies on the determination of the morphological composition of solid waste generated in Uzhhorod, the content of resource-valuable components that can be used as secondary raw materials in the composition of solid waste of the city is 36.85% (by mass) of which the largest share is glass – 27.4%, plastics (plastic packaging and PET bottles) – 5.65%, waste paper (cardboard and paper) – 3.2%, metals – 0.6%. About 36.5% is bio-waste. Table 4.4 shows the calculated data obtained regarding the material and resource potential of the city's MW for the period 2023-2035.

Table 4.4 – Material and resource potential of municipal waste in Uzhhorod

Name	%	2023	2025	2027	2029	2031	2033	2035
Volume of waste generation, t	100.00	50,396.00	50,901.22	51,411.50	51,926.90	52,447.47	52,973.26	53,504.32
The content of resource-valuable components, t:	36.85	18,570.93	18,757.10	18,945.14	19,135.06	19,326.89	19,520.65	19,716.34
- cardboard and paper, t	3.20	1,612.67	1,628.84	1,645.17	1,661.66	1,678.32	1,695.14	1,712.14
- commercial broken glass, t	27.40	13,808.50	13,946.93	14,086.75	14,227.97	14,370.61	14,514.67	14,660.18
- metals, t	0.60	302.38	305.41	308.47	311.56	314.68	317.84	321.03
- PET bottle, t	1.10	554.36	559.91	565.53	571.20	576.92	582.71	588.55
- plastic packaging, t	4.55	2,293.02	2,316.01	2,339.22	2,62.67	2,386.36	2,410.28	2,434.45
Bio-waste, t	36.50	18,394.54	18,578.95	18,765.20	18,953.32	19,143.33	19335.24	19529.07
Other, t	26.65	13,430.53	13,565.18	13,701.17	13,838.52	13,977.25	14,117.37	14,258.90

Notes: for the period 2023-2025 the number of IDPs is taken into account, but after 2026 it is accepted to return to indicators of municipal waste generation without IDPs. The following assumptions were made during the calculations: 1) the population during the forecasting period remains unchanged (without IDPs); 2) indicators of waste generation per inhabitant will increase every year by 0.5% (according to the recommendations of the World Bank); 3) adopted coefficients of selection of secondary raw materials in the categories "cardboard and paper" – 0.5; "commodity glass" – 0.8; "metals" – 0.7; "PET bottle" – 0.8; "plastic packaging" (LDPE, HDPE grade 2, low-pressure film) – 0.6

[24] The BAT (Best Available Techniques) Reference Document (abbreviated as "BREF"), entitled "Waste Treatments Industries"

The data of the averaged morphological composition of the soil testifies to the sufficient secondary resource potential in Uzhhorod. However, the specified volumes of secondary raw materials are potential, which can be obtained in practice under the condition of implementation of various modern technologies of sorting and selection of secondary raw materials. To achieve in-depth processing of waste materials (up to 60...80%) and significantly reduce the load on waste disposal sites and landfills, it is necessary, simultaneously with the expansion of the volume of separate collection and procurement of secondary raw materials, to create sorting and processing plants with various technologies for processing not only separately collected secondary raw materials, as well as the undivided remainder of mixed MW, such as MBT plants.

4.6 Forecasting income from the sale of secondary raw materials in Uzhhorod

Table 4.5 shows the forecast of revenues from the sale of secondary raw materials obtained at the MBT plant in Uzhhorod. See Annex E for the cost of secondary raw materials as of August 2023.

Table 4.5 – Estimated forecast of income from the sale of secondary raw materials (MBT plant in Uzhhorod)

Secondary raw materials	**Years**						
	2023	**2025**	**2027**	**2029**	**2031**	**2033**	**2035**
	million UAH						
Cardboard and paper	3.05	3.40	3.00	3.34	3.72	4.14	4.61
Commercial glass	25.06	27.91	24.66	27.46	30.57	34.05	37.91
Metals	4.94	5.50	4.86	5.41	6.02	6.70	7.47
PET bottle	9,11	10,14	8.96	9.98	11,11	12.37	13.77
Plastic packaging	31,22	34.76	30,71	34.20	38.08	42.40	47.22
Total	**73.37**	**81.70**	**72.18**	**80.37**	**89.50**	**99.66**	**110.98**

Notes: the following assumptions were made during the calculations: 1) indicators of waste generation per inhabitant will increase by 0.5% every year (according to the recommendations of the World Bank); 2) coefficients of selection of secondary raw materials in the categories “cardboard and paper” – 0.5; “commodity glass” – 0.8; “metals” – 0.7; “PET bottle” – 0.8; “plastic packaging” (LDPE, HDPE grade 2, low-pressure film) – 0.6. 3) In 2023-2025, the increased number of the formation of PW is shown, taking into account the change in the number of IDPs. From 2026, it is assumed that the indicators of MW formation will return to the indicators of 2022.

4.7 Assessment of the level of affordability of the tariff for municipal waste management services

The cost of collecting waste and transporting it to the central treatment facility and the costs associated with the removal (burying) of the residual part of waste are decisive for the tariff for waste management services.

Per the provisions of the “Methodical Recommendations for the Development of Oblast Waste Management Plans”[25] (approved by the Order of the Ministry of Environmental Protection and Natural Resources dated 10.09.2021 No. 586), it is recommended to consider an economically affordable tariff for waste management to be paid by the population at the level of 1-1,5% of the average monthly income per residents.

Table 4.6 shows the estimated level of availability of the tariff for waste management services and its forecast growth in Uzhhorod.

The decision of the executive committee of the Uzhhorod City Council No. 27 dated January 25, 2023 established the tariff for services for solid waste management (Table 4.7). In comparison, the current tariff for the service of waste management in Uzhhorod is 958.2 UAH/t, and the recommended level of tariff availability is 1,893.00 UAH/t in 2023 and 3,399.56 UAH/t in 2035.

[25] https://zakon.rada.gov.ua/rada/show/v0586926-21#Text

Table 4.6 – Assessment of the level of affordability of the tariff for municipal waste management services in Uzhhorod

Indicator	Year						
	2023	2024	2027	2029	2031	2033	2035
Average disposable income per person	–	–	–	–	–	–	–
thousand UAH/ year	189.3	208.7	230.1	253.7	279.7	308.4	339.9
thousand UAH/month	15.77	17.39	19,17	21,14	23,31	25.69	28,33
The level of availability of the tariff for services in the field of waste management	–	–	–	–	–	–	–
1% of the average disposable income, UAH/person/year	1,893.00	2,087.03	2,300.95	2,536.80	2,796.82	3,083.50	3,399.56
1.5% of the average disposable income, UAH/person/year	2,839.50	3,130.55	3,451.43	3,805.20	4,195.23	4,625.25	5,099.33
1% of the average disposable income, UAH/person/month	157.75	173.92	191.75	211.40	233.07	256.96	283.30
1.5% of the average disposable income, UAH/person/month	236.63	260.88	287.62	317.10	349.60	385.44	424.94

Notes: the calculations assume that wages in Uzhhorod will increase by 5% every year

Table 4.7 – Tariffs for waste management services in Uzhhorod as of 2023

Tariff for municipal waste management service		Tariff for municipal waste management service (with VAT)		Scope of municipal waste management service	
transportation AVE-Uzhhorod, LLC	disposal KP "KATP-072801"				
UAH/m³ (with VAT)	UAH/m³ (with VAT)	UAH/m³	UAH/ton	thousand m³	thousand tons
158.99	33.61	192.60	958.2*	252.66	50.4

Notes: * the tariff for the municipal waste management service in mass units is obtained by recalculation through the average density, which is taken as 0.201 t/m³

4.8 Technological schemes of various variants for the operation of the object of processing (sorting) of secondary raw materials

Based on the results of the analysis and evaluation of various waste treatment technologies and the averaged morphological composition of solid waste, it was established that in the conditions of Uzhhorod, the most acceptable variant of the solid waste treatment facility is the MBT plant, the implementation of the construction of which will, among other things, allow to increase the amount of extracted resource-valuable components of the MW and to obtain secondary raw materials of better quality.

The choice of technological scheme for the operation of the MBT plant depends on many factors, the main ones should be productivity, location and geological structure of the site and the need for briquetting of sorted waste.

The construction of the MBT plant has three main possible technological schemes for their assembly:

A) sorting of municipal waste with the extraction of secondary raw materials; obtaining alternative fuel RDF/SRF (up to 30% of the total mass of waste), composting of bio-waste (up to 40% of the total mass) and landfilling of unsorted residue and inert waste (variant No. 1);

B) sorting of municipal waste with the extraction of secondary raw materials; anaerobic fermentation of bio-waste to obtain biogas (up to 40% of the total mass); landfilling of unsorted residue and inert waste (variant No. 2);

C) sorting of municipal waste with the extraction of secondary raw materials; stabilization of bio-waste (up to 40% of the total mass) and landfilling of unsorted residue and inert waste (variant No. 3).

4.8.1 Technological scheme of operation of the waste treatment facility according to variant No. 1

Brief description of the technological process of operation of the MBT plant according to variant No. 1

The MBT plant according to technological variant No. 1 (Fig. 4.2) provides mechanical sorting of solid waste with the extraction of secondary raw materials (6% of the total mass); obtaining alternative fuel RDF/SRF (up to 30% of the total mass of waste), composting bio-waste (up to 40% of the total mass) and landfilling unsorted residue and inert waste (24%).

The main components of the revenue part: are the sale of secondary raw materials, and the tariff for the waste treatment service. Implementation of compost and RDF/SRF is assumed zero.

The main components of the expendable part: wages, electricity, fuel and lubricants, etc.

Evaluation of the material and resource parameters of the MBT plant according to variant No. 1

There are no guaranteed consumers of alternative fuel RDF/SRF in Uzhhorod and Transcarpathian oblast. At the same time, transportation over long distances outside the oblast is also considered economically impractical. Therefore, a zero rate for the implementation of RDF/SRF is adopted in the calculations. The use of bio-waste for anaerobic fermentation will significantly reduce the volume of waste that is buried at the solid waste landfill.

Thus, the technological variant of the MBT plant according to variant No. 1 includes the following workshops:

- shop for mechanical sorting and treatment (sorting and grinding);
- biological treatment workshop: bio-waste composting.

Table 4.8 shows the calculated parameters of the material balance of the MBT plant according to variant No. 1 for Uzhhorod.

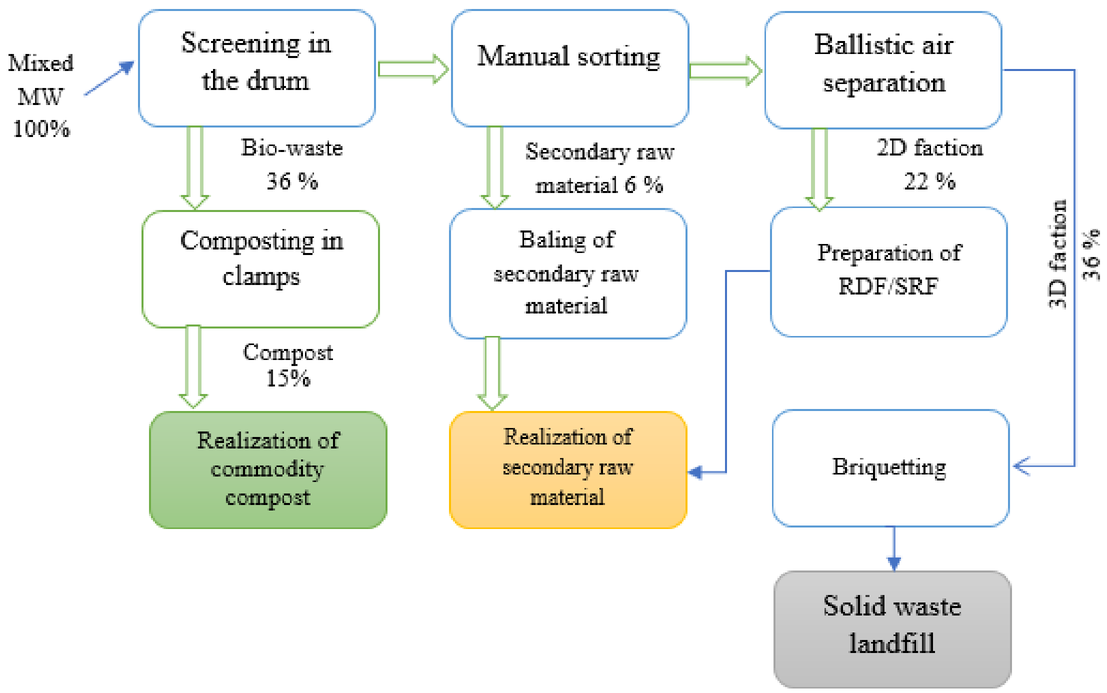

Figure 4.2 – Technological scheme of operation of the waste treatment facility (sorting) of secondary raw materials according to variant No. 1

Table 4.8 – Calculation parameters of the material balance of the MBT plant according to variant No. 1

Parameter	Units	Value
Total population served	persons	115,449
Number of IDPs	persons	28,000
Volume of waste generation (excluding IDPs)	t/year	50,396
Design capacity of the MBT plant (1 shift per day)	t/year	50,000
	%	100
Extraction of resource-valuable components	t/year	13,900
	%	≈28
Volume of bio-waste for composting (input)	t/year	18,000
	%	36
Residue destined for landfill (excluding residues after fermentation)	t/year	18,100
	%	36

Notes: The calculations assume: electricity consumption of 65 kWh per design ton of MW per day; production capacity – 25 t/h; number of working days per year – 250; shift of 8 hours (sorting shop); the density of methane under standard conditions is taken to be 0.67 kg/m³ (DSTU ISO 13443:2015 Natural gas. Standard conditions)

The staff list of employees of the MBT plant according to variant No. 1 for the accepted design capacity of the enterprise is accepted following the requirements of GBN B.2.2-35077234-001[26] (listed in Table 4.9).

Table 4.9 – Approximate staff list of employees of the MBT plant according to variant No. 1

No.	Position	Number of people
Administrative and managerial employees		
1	Director	1
2	Deputy Director	1
3	Chief Engineer	1
4	Chief Accountant	1
5	Deputy Chief Accountant	1
6	Economist	1
7	Head of the Chemical Laboratory	1
8	Dispatcher	1
	Total	**8**
Reception department and waste sorting station		
1	Chief	1
2	Deputy Chief	1
3	Chief Mechanic	1
4	Mechanic	1
5	Energy Engineer	1
6	Electrician	1
7	Master	1
8	Locksmith	1
9	Sorters	27
	Total	**35**
Department of composting		
1	Chief	1
2	Deputy Chief	1

[26] GBN V.2.2-35077234-001:2011 "Enterprises for Sorting and Processing of Solid Municipal Waste. Requirements for Technological Design" // http://surl.li/cbyrg

No.	Position	Number of people
3	Master Technologist	1
4	Crane Operator	1
5	Mechanic	1
6	Operator	2
8	Laboratory Chemist	1
	Total	**8**

Note: the average salary for Uzhhorod as of August 1, 2023 is accepted at the level of UAH 17,500.

The installation capacity of the MBT plant according to variant No. 1 is 65 kW per 1 ton of municipal waste. The annual need for the use of electrical energy is 3,250 MW. Table 4.10 shows the calculated balance of electrical energy of the MBT plant according to variant No. 1.

Table 4.10 – Balance of electrical energy of the MBT plant according to variant No. 1

No	Name	Number, MW/year	Cost of electrical energy	
			Tariff, UAH	Sum, million UAH
1	Total need for the use of electricity per year	3,250	1,803.49	5,861

Notes: The calculation was made based on the tariff from 31/07/2023 for the 2nd class of enterprises, namely UAH 1,803.49. According to the calculation, the total use of electricity for the enterprise will be 3,250 MW per year at a calculated load of 50,000 t/year

Technical and economic indicators characterize the material and production base of the enterprise and the plant use of resources. They are used for planning and analysis of the organization of production and work, levels of technology, product quality, use of fixed and working capital, labor resources.

Table 4.11 shows the technical indicators of the MBT plant according to variant No. 1, taking into account the selected site for the construction of the plant.

Table 4.11 – Technical indicators of the MBT plant according to variant No. 1

No.	Indicator	Value
1	Production productivity of the MBT plant for the waste treatment, t/h	25
2	Number of working shifts/hours	1/8
3	Number of working days	250
4	Number of working hours per year	2,000
5	The amount of waste that can be processed, t/year	50,000
6	Plot of minimum dimensions L×W, m/ha	100×200/2
7	Number of working personnel, persons	51
8	Installation capacity of equipment/real electricity consumption, MW/year	3,250/ 3,250
9	Terms of construction of the plant, months	12

Notes: in periods when the volume of waste exceeds the nominal productivity of the plant of 50,000 tons/year, an increase in the volume of treatment is achieved by introducing additional changes

4.8.2 Technological scheme of operation of the waste treatment facility according to variant 2

Brief description of the technological process of operating the MBT plant according to variant No.2

The MBT plant according to technological variant No. 2 (Fig. 4.3) provides mechanical sorting of municipal waste with the extraction of secondary raw materials (6%); anaerobic fermentation of bio-waste to obtain biogas (up to 40% of the total mass) with subsequent recovery into electrical energy to meet one's own needs; obtaining alternative fuel RDF/SRF (up to 30% of the total mass of waste); and landfilling of unsorted residue and inert waste (24%).

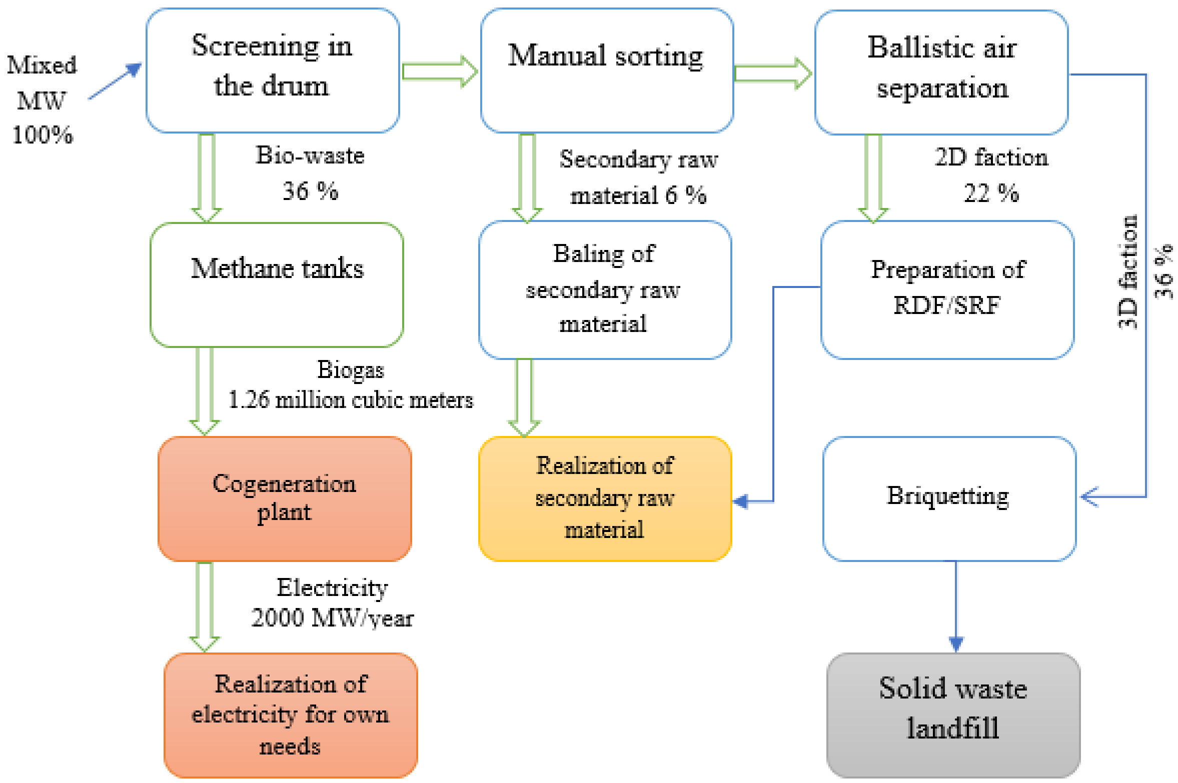

Figure 4.3 – Technological scheme of operation of the waste treatment facility (sorting) of secondary raw materials according to variant No. 2

The main components of the income part: the sale of secondary raw materials, the tariff for the waste treatment service, the sale of electricity or biogas (partially covers own needs). RDF/SRF implementations are zero-rated.

The main components of the expense part: wages, expenses for electricity consumption (consumption is reduced due to the operation of the cogeneration plant), expenses for the purchase of fuel and lubricants, etc.

Evaluation of the material and resource parameters of the MBT plant according to variant No. 2

There are no guaranteed RDF/SRF consumers in Uzhhorod and Transcarpathian oblast. At the same time, transportation over long distances outside the oblast is also considered economically impractical. Therefore, in the calculations, we assume a zero rate for the implementation of RDF/SRF. The use of bio-waste for anaerobic fermentation will significantly reduce the amount of waste and obtain biogas, which can be used in cogeneration plants to obtain electrical energy. Electric energy will partially cover the needs of the plant.

Thus, the technological variant of the MBT plant according to variant No. 2 includes the following functional workshops:

- workshop for mechanical sorting and treatment (sorting, grinding and preparation of bales of secondary raw materials);
- biological treatment plant: anaerobic decomposition with biogas production and further utilization of biogas in a cogeneration plant.

Table 4.12 shows the calculated parameters of the material balance of the MBT plant according to variant No. 2 for Uzhhorod.

Table 4.12 – Calculation parameters of the material balance of the MBT plant according to variant No. 2

Parameter	**Units**	**Value**
Total population served	persons	115,449
Number of IDPs	persons	28,000
Volume of waste generation (excluding IDPs)	t/year	50,396
Design capacity of the MBT plant (1 shift per day)	t/year	50,000
	%	100
Extraction of resource-valuable components	t/year	13,900
	%	≈28
Biogas formation	m³/year	1,260,000
Volume of bio-waste for fermentation (input)	t/year	18,000
	%	36
Residue destined for landfill (excluding residues after fermentation)	t/year	18,100
	%	36

Notes: The calculations assume the following: electricity consumption 65 kWh per 1 design ton of MW per day; production capacity – 25 t/h; number of working days per year – 250; shift of 8 hours (sorting shop); density of methane under standard conditions 0.67 kg/m³ (DSTU ISO 13443:2015 Natural gas. Standard conditions)

The staff list of employees of the MBT plant according to variant No. 2 for the accepted design capacity of the enterprise is accepted in accordance with the requirements of GBN B.2.2-35077234-001[27] (listed in Table 4.13).

Table 4.13 – Approximate staff list of employees of the MBT plant according to variant No. 2

No.	**Position**	**Number of people**
Administrative and managerial employees		
1	Director	1
2	Deputy Director	1
3	Chief Engineer	1
4	Chief Accountant	1
5	Deputy Chief Accountant	1
6	Economist	1
7	Head of the chemical laboratory	1
8	Dispatcher	1
	Total	**8**
Reception department and waste sorting shop		
1	Head	1
2	Deputy chief	1
3	Chief mechanic	1
4	Mechanic	1

[27] GBN V.2.2-35077234-001:2011 "Enterprises for Sorting and Processing Solid Household Waste. Requirements for Technological Design" // http://surl.li/cbyrg

No.	Position	Number of people
5	Energy engineer	1
6	Electrician	1
7	Master	1
8	Locksmith	1
9	Sorters	27
	Total	**35**
	Separation of anaerobic fermentation of organic matter extracted from MW	
1	Head	1
2	Technologist	1
3	Master	2
4	Operator	4
5	Electrician	2
6	Locksmith-Mechanic	2
7	Head of the Laboratory	1
8	Laboratory Chemist	2
	Total	**15**
	Cogeneration plant for biogas utilization	
1	Head	1
2	Chief Energy Engineer	1
3	Energy Engineer	1
4	Mechanic	1
5	Senior Master	1
6	Mechanic	1
7	Master	2
8	Machinist of a cogeneration plant (3 shifts)	3
9	Locksmith	2
	Total	**13**

Note: the average salary for the city of Uzhhorod as of August 1, 2023 is accepted at the level of UAH 17,500

The installation capacity of the MBT plant according to variant No. 2 is 65 kW per 1 ton of municipal waste. The annual need for the use of electrical energy is 3,250 MW. Due to the implementation of a cogeneration plant with a capacity of 1 MW/h. it is possible to compensate up to 2,000 MW/year of electric energy. Table 4.14 shows the calculated balance of electrical energy of the MBT plant according to variant No. 2.

Table 4.14 – Balance of electrical energy of the MBT plant according to variant No. 2

No.	Name	Number of MW/year	The cost of electricity	
			Tariff, UAH	Amount, million UAH
1	Total need for the use of electricity per year	3,250	1,803.49	5,861
2	Amount of electricity obtained from the anaerobic fermentation of bio-waste with the production of biogas	2,000	–	–
3	Volumes of electricity to cover the needs of the plant (operating costs)	1,250	1,803.49	2,254

Notes: The calculation was made based on the tariff from 31/07/2023 for the 2nd class of enterprises, namely UAH 1,803.49. According to the calculation, the total use of electricity for the enterprise will be 3,250 MW per year. The enterprise will receive 2,000 MW per year from the anaerobic fermentation of bio-waste to produce biogas. The amount of electricity for additional purchase will be 1,250 MW per year at a load calculation of 50,000 t/year

Technical and economic indicators characterize the material and production base of the enterprise and the plant use of resources. They are used for planning and analysis of the organization of production and work, levels of technology, product quality, use of fixed and working capital, labor resources.

Table 4.15 shows the technical indicators of the MBT plant according to variant No. 2, taking into account the selected site for the construction of the plant.

Table 4.15 – Technical indicators of the MBT plant according to variant No. 2

No	Indicator	Value
1	Production productivity of the MBT plant for the waste treatment, t/h	25
2	Number of working shifts/hours	1/8
3	Number of working days	250
4	Number of working hours per year	2,000
5	Amount of waste that can be processed, t/year	50,000
6	Plot of minimum dimensions L×W, m/ha	100×200/2
7	The number of working personnel, persons	71
8	Installation capacity of the equipment/real consumption of electricity, MW/year	3,250/1,250
9	Terms of construction of the plant, months	24

Notes: in periods when the volume of waste exceeds the nominal productivity of the plant of 50,000 tons/year, an increase in the volume of processing is achieved by introducing additional changes

4.8.3 Technological scheme of operation of the waste treatment facility according to variant No. 3

Brief description of the technological process of operation of the MBT plant according to variant No. 3

The MBT plant according to technological variant No. 3 (Fig. 4.4) provides mechanical sorting of municipal waste with the extraction of secondary raw materials (6% of the total mass); obtaining alternative fuel RDF/SRF (up to 30% of the total mass of waste), stabilization composting of bio-waste (up to 40% of the total mass) and disposal of unsorted residue and inert waste (24%) at the landfill.

The main components of the revenue part: are the sale of secondary raw materials, and the tariff for the waste treatment service. Implementation of compost and RDF/SRF is assumed zero.

The main components of the expendable part: wages, electricity, fuel and lubricants, etc.

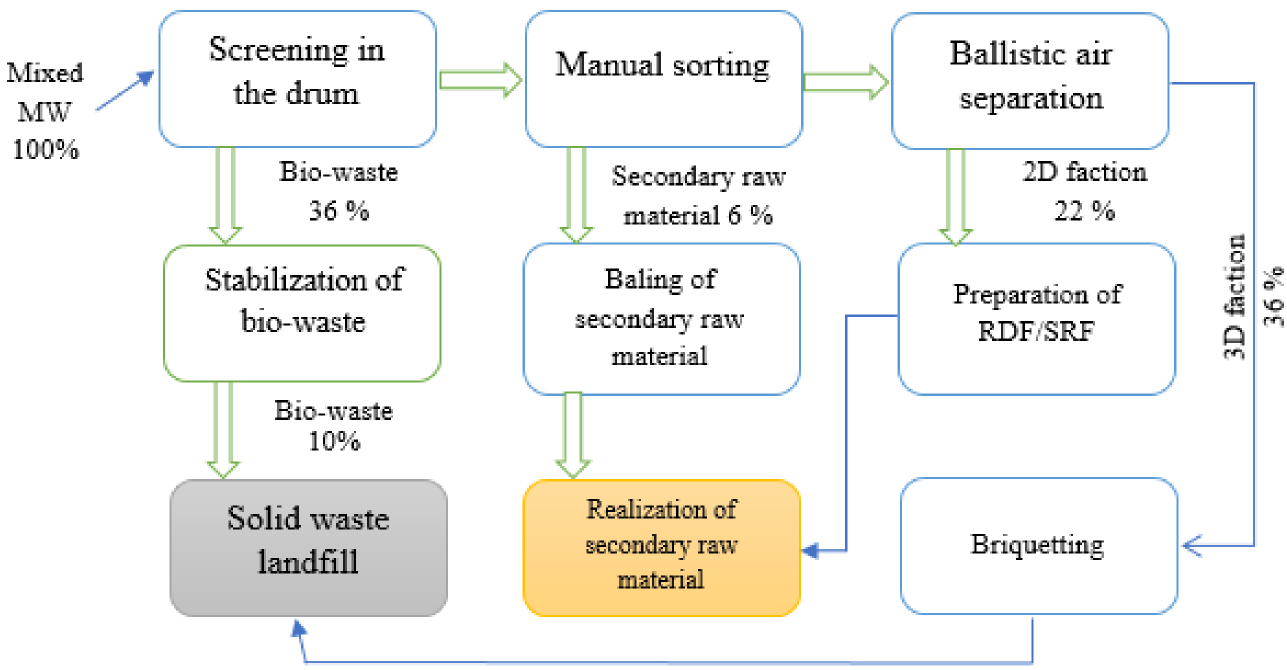

Figure 4.4 – Technological diagram of operation of the waste treatment facility (sorting) of secondary raw materials according to variant No. 3

Evaluation of the material and resource parameters of the MBT plant according to variant No. 3

There are no guaranteed consumers of alternative fuel RDF/SRF in Uzhhorod and Transcarpathian oblast. At the same time, transportation over long distances outside the oblast is also considered economically impractical. Therefore, in the calculations, we assume a zero rate for the implementation of RDF/SRF. However, an RDF/SRF implementation is necessary. The use of stabilization composting of bio-waste will significantly reduce the amount of waste to be disposed of at the landfill.

Thus, the technological variant of the MBT plant according to variant No.3 includes the following workshops:

- shop for mechanical sorting and treatment (sorting and grinding);
- biological treatment workshop: stabilization composting of bio-waste.

Table 4.16 shows the calculated parameters of the material balance of the MBT plant according to variant No. 3 for Uzhhorod.

Table 4.16 – Calculation parameters of the material balance of the MBT plant, variant No. 3

Parameter	Unit	Value
Total population served	persons	115,449
Number of IDPs	persons	28,000
Volume of waste generation (excluding IDPs)	t/year	50,396
Design capacity of the MBT plant (1 shift per day)	t/year	50,000
	%	100
Extraction of resource-valuable components	t/year	13,900
	%	≈28
Volume of bio-waste for stabilization composting (input)	t/year	18,000
	%	36
Residual destined for landfilling	t/year	18,100
	%	36

Notes: The following is accepted in the calculations: electricity consumption 65 kWh per design ton of MW per day; production capacity – 25 t/hour; number of working days per year – 250; shift of 8 hours (sorting shop); density of methane under standard conditions 0.67 kg/m³ (DSTU ISO 13443:2015 Natural gas. Standard conditions)

The staff list of employees of the MBT plant according to variant No. 3 for the adopted design capacity of the enterprise is accepted following the requirements of GBN B.2.2-35077234-001[28] (listed in Table 4.17).

Table 4.17 – Approximate staff list of employees of the MBT plant according to variant No. 3

No.	Position	Number of people
Administrative and managerial employees		
1	Director	1
2	Deputy Director	1
3	Chief Engineer	1
4	Chief Accountant	1
5	Deputy Chief Accountant	1
6	Economist	1
7	Head of the Chemical Laboratory	1
8	Dispatcher	1
	Total	**8**

[28] GBN V.2.2-35077234-001:2011 "Enterprises for Sorting and Processing Solid Household Waste. Requirements for Technological Design" // http://surl.li/cbyrg

No.	Position	Number of people
Reception department and waste sorting station		
1	Chief	1
2	Deputy Chief	1
3	Chief mechanic	1
4	Mechanic	1
5	Energy Engineer	1
6	Electrician	1
7	Master	1
8	Locksmith	1
9	Sorters	27
	Total	**35**
Bio-waste stabilization station		
1	Chief	1
2	Deputy Chief	1
3	Master Technologist	1
4	Crane Operator	1
5	Mechanic	1
6	Operator	2
8	Laboratory chemist	1
	Total	**8**

Note: the average salary for Uzhhorod as of August 1, 2023 is accepted at the level of UAH 17,500

The installation capacity of the MBT plant according to variant No. 3 is 65 kW per 1 ton of municipal waste. The annual need for the use of electrical energy is 3250 MW. Table 4.18 shows the calculated balance of electrical energy of the MBT plant according to variant No. 3.

Table 4.18 – Balance of electrical energy of the MBT plant according to variant No. 3

No.	Name	Number of MW/year	The cost of electricity	
			Tariff, UAH	Sum, million UAH
1	Total need for the use of electricity per year	3,250	1,803.49	5,861

Notes: The calculation was made based on the tariff from 31/07/2023 for the 2nd class of enterprises, namely UAH 1,803.49. According to the calculation, the total use of electricity for the enterprise will be 3,250 MW per year at a load calculation of 50,000 t/year

Technical and economic indicators characterize the material and production base of the enterprise and the plant use of resources. They are used for planning and analysis of the organization of production and work, levels of technology, product quality, use of fixed and working capital, labor resources.

Table 4.19 shows the technical indicators of the MBT plant according to variant No. 3, taking into account the selected site for the construction of the plant.

Table 4.19 – Technical indicators of the MBT plant according to variant No. 3

No.	Indicator	Value
1	Production productivity of the MBT plant for the treatment of waste, t/h	25
2	Number of working shifts/hours	1/8
3	Number of working days	250
4	Number of working hours per year	2,000
5	The amount of waste that can be processed, t/year	50,000
6	Plot of minimum dimensions L×W, m/ha	100×200/2.0
7	Number of working personnel, persons	51

No.	Indicator	Value
8	Installation capacity of the equipment/real consumption of electricity, MW/year	3,250/3,250
9	Terms of construction of the plant, months	12

Notes: in periods when the volume of waste exceeds the nominal productivity of the plant of 50,000 tons/year, an increase in the volume of processing is achieved by introducing additional changes

4.9 Layout of the planned objects and structures of the waste treatment facility (sorting) of secondary raw materials

The MBT plant is designed for the processing of MSW obtained as a result of their separate collection into separate containers (or bags) in Uzhhorod, the main raw materials for the MBT plant are mixed MSW and separately collected secondary raw materials, which are delivered by special vehicles for treatment or sorting. When using the planned MBT plant, there is no need to change the existing logistics and transportation of waste from the places of accumulation to the object of processing by the business entity in the field of waste management.

4.9.1 Plot for the construction of a municipal waste processing facility

The implementation of the project for the construction of a municipal waste treatment facility (including the sorting of secondary raw materials) (MBT plant) for Uzhhorod is proposed on a site located outside Uzhhorod, near the landfill, at coordinates 48.578717, 22.351197 (Fig. 4.5).

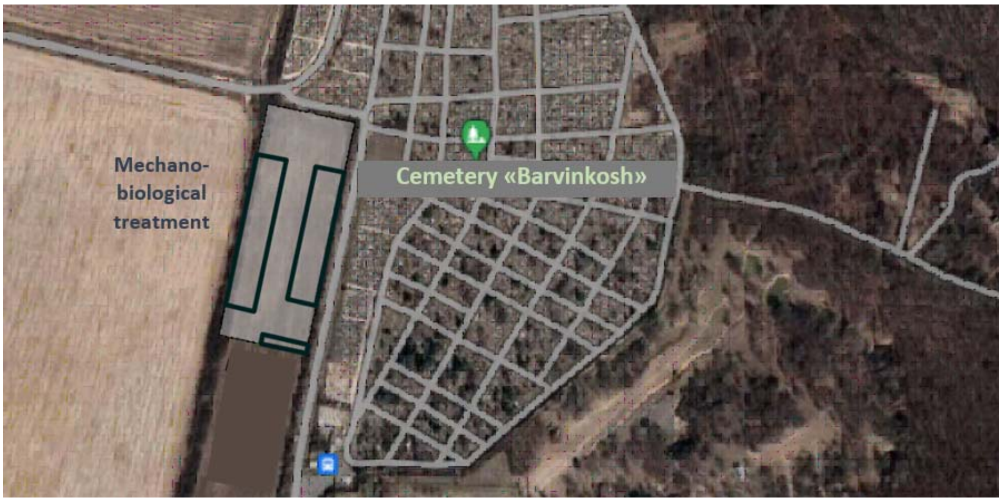

Figure 4.5 – Site plan for the location of the municipal waste treatment facility (MBT plant) for Uzhhorod

The total area of the site for the location of the planned objects and structures of the WW processing facility by the design capacity is 2.0 ha. The boundaries are determined by the dimensions of the MBT plant, which will be fenced around the perimeter. There are no multi- and low-rise manor house buildings in the area.

4.9.2 Planned objects and structures of the waste treatment facility (sorting) of secondary raw materials

Functional zoning of the MBT plant

The technology used by the MBT plant includes the processes of manual and mechanical sorting, pressing, and treatment of bio-waste. In the process of operation of the MBT plant, extraction using combined sorting of waste and subsequent obtaining of recycled raw materials or finished products is envisaged.

Functional zones of the MBT plant (including landscaping, road surface, and adjacent territories outside the plant fence):

- *pre-factory zone* – located at the entrance (main entrance) to the enterprise from the clamp of the settlement and includes parking lots for motor vehicles and landscaping elements;
- *industrial (technological zone)* – occupies most of the territory of the enterprise and includes the main workshops, constructions and open technological installations: it consists of a waste sorting shop (mechanical treatment stage) with a production line for RDF alternative fuel and a bio-waste treatment shop with compost production (biological treatment stage);
- *auxiliary zone* – includes the territory of the enterprise, occupied by objects of auxiliary (municipal and municipal premises, repair, storage rooms, etc.), energy (power supply networks), sanitary and technical (water treatment facilities), communication (ventilation and air conditioning networks, heating, sewage) and other purposes;
- *warehouse zone* – includes territories necessary for storage of raw materials, materials, finished products, and is the most loaded and saturated with transport routes.

Architectural and planning solution of the MBT plant

See Annex F for the drawing for main planning decisions and the location scheme of the planned objects and structures of the waste treatment facility (sorting) of secondary raw materials are determined by the presence of a site free from development for construction on the territory of the community and technological solutions for the location of the MBT plant.

Placing (layout) of the main facilities of the waste treatment facility (sorting) of secondary raw materials, including elements of the MBT plant inside all buildings (structures), is carried out taking into account the more rational use of their area, planning, communication systems, external entrances, etc.

The proposed MBT plant consists of (see drawings in Annex F):

1. Areas where the sorting shop is located with the appropriate equipment, including the RDF alternative fuel production line.

2. Areas where the composting shop is located with the appropriate equipment.

3. Block of premises for the auxiliary technical purpose of sorting and composting shops and the general functioning of the MBT plant.

4. External spatial metal structures for fastening technological equipment of sorting and composting shops and necessary for the general functioning of the MBT plant.

The pre-factory area outside the fence of the MBT plant is located at the entrance from the northern part of the construction site. The open area of passenger car transport is calculated from the number of employees and according to DBN B.2.3-5[29] and DBN B.2.5-15[30].

A precast concrete fence with a height of less than 1.6 m surrounds the territory of the MBT plant. The passage is located on the north clamp of the territory of the construction site of the MBT plant. The main facade of the building is in the north.

All technological equipment of the MBT plant is located under the roof of quickly assembled prefabricated structures. As an example, these can be structures in the form of bent bearing arches made of high-quality aluminum, between which pre-stressed membrane panels are placed. The maximum width of the structure reaches 30 m. The product is certified by UkrSEPRO and has permits for use in Ukraine. Structures can be disassembled, moved and assembled in a new location with 100% preservation of the quality of the new structure. The modular configuration allows you to add new chapters to increase the length of the workshop area. The advantage of the structures, in the case of acceptable soil conditions, is the absence of the need to build foundations for spans up to 40 m wide. The structures have a 30-year warranty.

[29] DBN V.2.3-5:2018 Streets and Roads of Settlements. With Amendment No. 1

[30] DBN V.2.2-15:2019 Buildings and Structures. Residential Buildings. Substantive Provisions. With Amendment No. 1

Improvement and landscaping of the territory

Asphalt concrete paving with a width of 1.0 m is planned along the perimeter of the buildings of the MBT plant.

For technological and fire-fighting maintenance of the MBT plant, designed passageways are used. Roads are covered with asphalt concrete. Driveways, sidewalks and playgrounds are limited by curbs.

A sidewalk with a minimum width of 1.0 m has been designed for the passage of workers from the shops and premises of the plant to the driveways.

The project offers a site for staff recreation, as well as a site for smoking.

The territory of the plant is landscaped.

To ensure normal sanitary and hygienic conditions on the territory of the construction site, the greening of areas free from construction is planned by:

- planting decorative trees;
- sowing lawns with perennial grasses.

When planting new trees, up to 50% of plant soil is added. When arranging lawns, a layer of vegetable soil with a thickness of 0.15 m is added, and when arranging flowerbeds is 0.20 m.

Table 4.20 shows the main indicators of the general plan of the construction site of the MBT plant.

Table 4.20 – Main indicators of the general plan of the construction site (MBT plant)

No.	Indicator	Unit	Value
1	The total area of the construction site (MBT plant with landscaping)	ha	2.0
2	Built-up area of the waste sorting shop*	m²	3,600
3	Building area of bio-waste composting shop	m²	4,050
4	Landscaping area of the construction site	m²	6,000
5	Area of asphalt concrete pavement	m²	6,350

*productivity of the waste sorting line of the MBT plant is assumed 25 t/h

Organization of surface runoff, drainage and water supply

Organization of surface runoff of the MBT plant must be carried out taking into account the topography of the area, markings of existing roads, the minimum volume of earthworks and reliable drainage of rainwater from the planned structures.

Preparation of the territory – backfilling from local soil to project marks with the planning of the surface of the site.

Drainage of surface rainwater from the territory of the MBT plant is carried out along the planned surface of the road surface with a minimal slope to the existing road, and then to the local treatment facilities (LTF) of the MBT plant.

As an LTF, it is proposed to use closed-type reinforced concrete blocks, which include:

1. Underground hermetic reinforced concrete tank with internal waterproofing, divided into technological compartments. Technological equipment and pipelines are installed inside the tank. Polypropylene hatches 1,000/1,000 mm with heat and sound insulation are provided for access to the tank and equipment service. Which allows to service or repair of equipment without stopping the LTF.
2. A mechanical pre-treatment unit consisting of a mechanical grid, a sand trap and a storage basket. It is installed next to a reinforced concrete tank in a reinforced concrete well.
3. An above-ground modular house with technological equipment, equipped with a heating and ventilation system, in which the following equipment is located:

- air blowing station
- sand-gravel filter after cleaning
- wastewater disinfection unit
- the central control panel of treatment facilities
- sludge dewatering unit with flocculants preparation tank (variantal)
- air filter unit.

The plant's water supply is provided with the help of decentralized water supply, the source of which is 2 wells with a depth of up to 150 m (necessary clarification when carrying out geological investigations). The flow rate of the well is up to 9 m^3/hour.

Systems of collection and treatment of leachate from MW

The formation of leachate from MW is assumed in the following places of the technological cycle:

- unloading sites of special vehicles (places for storage of waste before sorting) and from the drum screen;
- on the storage site of stacks for ripening compost.

To collect the leachate from the MW, a drainage arrangement is provided along the sole of the MW storage site, before its subsequent loading to the drum screen. Drainage of the leachate is proposed in the form of a drain laid along the sole of the upper slope of the storage site with subsequent supply of the leachate to the MW of the MBT plant. The formed filtrate from the drum screen is fed to the LTF through the chutes.

The filtrate from MW entering the LTF, after cleaning (purified water) is used to moisten the compost mixture. Excess purified water is discharged to the city sewer.

4.9.3 Brief description of the main operations and characteristics of the planned facilities and structures of the waste treatment facility (sorting) of secondary raw materials

Block of reception and sorting of MW (main operations)

1. Acceptance of waste. Mixed waste is delivered to the receiving department by garbage trucks. Garbage trucks are weighed and radioactivity is monitored. Unloading garbage trucks to the reception area.
2. Selection of large-sized waste that accidentally entered the mixed waste collection system - selection of tires, construction waste, large-sized waste. Direction of the selected waste to the boxes of the MBT plant.
3. Loading MW on the conveyor. MW on the conveyor goes to the breaker of packages and boxes. When the bags are torn, air with dust is sucked out and cleaned in filters.
4. MW enter the drum screen for separation. Organic and ballast components are separated (under-screen fraction - the first “tail”), which enter the composting shop. The other fraction (on-screen fraction) enters the manual sorting chamber.
5. Secondary raw materials are separated in the manual sorting chamber. Selected secondary raw materials are stored in boxes.
6. From the boxes on the conveyor, the recycled material enters the press for briquetting.

An RDF block

1. The rest of the unsorted fraction of MW (the second “tail”) after manual sorting: shoes, rags, parts of furniture, plastic and rubber products, leather, tetra pack, diapers, etc. The rest of the unsorted MW passes through an automatic magnetic separator, is crushed, pressed and packed in bays.

Composting unit

1. The remainder of the sorted fraction of MW (the first “tail”): biodegradable fraction of MW (bio-waste), inert and ballast parts, metal parts. The remainder is formed into rows of edges covered with metal sheets. They are periodically mixed and moistened until ripening. Aeration is controlled and artificial. If necessary, filler or other substances are added. The finished product is sifted and packed. Screening after composting (inert and ballast parts, metal parts) falls into special boxes.

CHAPTER V. CONSOLIDATED ESTIMATED CALCULATIONS OF THE COST OF IMPLEMENTATION OF VARIOUS PROJECTS OF THE CONSTRUCTION (LOCATION) OF THE WASTE TREATMENT FACILITY (SORTING) OF SECONDARY RAW MATERIALS

Calculations regarding the determination of the main estimated financial and economic indicators of the central waste treatment facility in Uzhhorod and forecast parameters of its functioning were performed, including, using the results of field studies of the morphological composition of municipal waste (MW) in Uzhhorod (Table 4.4) and the forecast of revenues from the sale of secondary raw materials obtained at the MBT plant in Uzhhorod (Table 4.5).

The consolidated estimate of the cost of construction includes the totals for all object estimates, and estimates for individual types of costs. The following summaries are included in the calculations:
Chapter 1. Preparation of the construction area.
Chapter 2. Main objects of construction.
Chapter 3. Objects of auxiliary and service purpose.
Chapter 4. Objects of energy economy.
Chapter 5. Objects of transport and communication.
Chapter 6. External networks and structures of water supply, sewage, heat and gas supply.
Chapter 7. Improvement and greening of the territory.
Chapter 8. Temporary buildings and structures.
Chapter 9. Other works and expenses.
Chapter 10. Customer service maintenance and copyright supervision.
Chapter 12. Project and search works.

Consolidated estimates of the cost of implementation of the project of construction (location) of the facility for processing (sorting) of secondary raw materials for Uzhhorod are given for the following (considered in Chapter 4) variants for completing the plant of mechanical and biological treatment (MBT):

1) composting (making compost);
2) anaerobic fermentation of bio-waste (production of biogas and its utilization in a cogeneration plant);
3) stabilization of bio-waste (obtaining inert waste).

5.1 Assessment of the estimated cost of construction and the main financial and economic indicators of the MBT plant (according to variant No. 1)

Estimates of the cost of construction of the MBT plant according to variant No. 1 (composting of bio-waste) include the construction of a sorting shop, a shop for biological processing of bio-waste, construction work, design work and the author's supervision of the construction.

Table 5.1 shows the capital costs for the construction of the MBT plant in Uzhhorod according to variant No. 1. Table 5.2 shows the operating costs of the MBT plant according to variant No. 1 in Uzhhorod.

Table 5.1 – Investment (capital) costs for the construction of the MBT plant in Uzhhorod according to variant No. 1 (with composting)

Name of expenses	Estimated cost	
	million UAH	million EUR
Mechanical sorting workshop	181.17	4.50
Biological treatment (composting) shop	126.82	3.15
Construction and installation work	140.91	3.50
Design and author supervision	24,15	0.60
Total	**473.05**	**11.75**

Notes: as of July 31, 2023, the euro to hryvnia exchange rate was accepted at 40.26 UAH for 1 euro

Table 5.2 – Operating costs of the MBT plant according to variant No. 1 (with composting)

Expenses	Forecast	Year 1	Year 3	Year 5	Year 7	Year 9	Year 11	Year 13
Expenditures for the purchase of electricity, million UAH	0.05	5.86	6.46	7,12	7.85	8.66	9.55	10.52
Expenses for wages, million UAH	0.10	10.71	12.96	15.68	18.97	22.96	27.78	33.61
Equipment maintenance costs, million UAH	0.10	18.91	22.89	27.69	33.51	40.54	49.06	59.36
Transportation costs, million UAH	0.03	1.22	1.29	1.37	1.46	1.55	1.64	1.74
Total	–	**36.70**	**43.60**	**51.87**	**61.79**	**73.71**	**88.02**	**105.24**

Notes: the electricity tariff of PJSC "Zakarpattiaoblenergo" for voltage class 2 as of 31/07/2023 is UAH 1,803.49 per 1 MWh, excluding VAT; the installed capacity of the plant is assumed to be 65 kW/t; transportation takes into account additional transportation related to the operation of the plant; the wage fund is accepted according to the average wage in Transcarpathian oblast, taking into account the accepted number of employees

Table 5.3 shows the consolidated estimate for the new construction of a waste treatment facility (MBT plant according to variant No. 1). Table 5.1 shows the results of Chapters 1-10 and 12 of the consolidated estimate calculation.

Table 5.3 – Consolidated estimate for the new construction of a waste treatment facility (MBT plant according to variant No. 1)

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Estimated value, thousand UAH
1	Workshop for mechanized sorting of municipal waste	120.0×30.0×6.5	3,600	Metal columns, trusses (60 kg/m²), foundations	49,640
2	Automated sorting line	108.0×30	3,240	The equipment is assembled on embedded fasteners	99,693
3	Bio-waste treatment plant	126×30×6.53	–	Metal columns, trusses (60 kg/m²), foundations	49940
4	Checkpoint	8.0×4.0	32	A typical building made of brick (heating)	303.42
5	Weight	8.0×3.0	24	A typical building made of brick (unheated)	250.49
6	Weighing equipment, automation	–	–	–	248.61
7	Pit for disinfection and washing of wheels	8.0×3.5×0.3	28	Concrete base, canopy-metal structures, gates	547.95
8	Parking area for vehicles	100.0×50.0	5,000	Asphalt concrete	720.16
9	Fence, m	606	–	FC fence panels with a height of 1.6 m	4,368.37

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Estimated value, thousand UAH
10	Equipment for composting (as part of item 1.2)	126×30×6.53	3,780	Vertical layout, concrete floor, composting equipment, electricity, no heating	17,520
11	Wood waste processing module	10.0×2.5	25	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,250.3
12	Glass waste processing module	5.0×2.0	10	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	925.45
13	Polymer waste processing module	2.5×3.0	7.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,302.12
14	Rubber waste processing module	2.5×3.0	7.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	550.67
15	Textile waste processing module	2.0×1.5	3	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	450.8
16	Hazardous waste processing module	1.0×1.5	1.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	650.78
17	Oversized waste processing module	10.0×12.0	120	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,200
19	Module of return water supply and local treatment facilities	10.0×30.0	300	Metal structures (40 kg/m²), foundations	19,100
20	Storage facilities (for secondary raw materials)	50.0×30.0	1,500	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,680.5

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Estimated value, thousand UAH
21	Repair and technical module	50.0×12.0	600	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,065.46
22	Module for sanitary treatment of transport and containers	36.0×12.0	432	Vertical layout, asphalt concrete	360.71
23	Administrative and municipal module	35.0×6.0	210	Modular prefabricated houses	5,761.29
24	Recreation area	6.0×6.0	36	Non-capital construction (without foundation)	106.55
25	Transformer substation (external power supply)	6.0×9.0	54	A typical building	1,115.18
26	including equipment for TS	–	–	Equipment	3,061.41
27	External water supply networks	–	–	–	2,358.36
28	External electrical networks	–	–	–	1,653.02
29	Roads	–	–	Asphalt concrete	1,322
30	Landscaping, greening	–	–	–	943.13
31	Construction and installation work	–	–	–	1,40910
32	Design and author supervision	–	–	–	24150
	Total	–	–	–	**432,789.02**

The creation of a central waste treatment facility in Uzhhorod is beyond the capacity of the local budget, therefore funds from service providers or investment funds (credit) from international financial institutions may be involved. Other costs related to the purchase of equipment, machines and tools for the implementation of the service of management solid waste in Uzhhorod are covered by the local budget or a special fund of the oblast budget.

In the calculations for the implementation of the MBT plant in Uzhhorod, the terms of granting a loan are adopted, similar to those in the credit agreement in Khmelnytskyi. The loan term is 13 years. Percentage is 5.75% per annum, one-time commission is 1.2%. Table 5.4 shows an indicative estimate of loan repayment costs by year for the implementation of the MBT plant in Uzhhorod.

The difference between the recommended and existing tariff for waste management in Uzhhorod during the implementation of the MBT plant will be presented as a separate indicator “contribution to the tariff”. A forecast assessment of the change in the tariff for waste management was made (Table 5.5).

Table 5.4 – Indicative assessment of loan repayment costs by year (implementation of the MBT plant according to variant No. 1)

Period	Year 1	Year 3	Year 6	Year 8	Year 11	Year 13
Reimbursement for the loan, million UAH	51.75	57.05	66.05	72,82	84.3	92.94

Notes: the calculation is made taking into account the annual loan rate of 5.75% and the projected growth of the euro exchange rate by 5% annually

Table 5.5 – Calculation of the impact on the tariff of municipal waste management services (MBT plant according to variant No. 1)

Characteristic	Period					
	Year 1	Year 3	Year 6	Year 8	Year 11	Year 13
Operating expenses, UAH million/year	36.70	43.60	56,60	67,48	88.02	105.24
Sale of secondary raw materials, million UAH year	58.20	64.80	76.20	84.80	99.66	110.98
Loan obligations, UAH million/year	51.75	57.05	66.05	72,82	84.30	92.94
Contribution to the tariff for municipal waste processing service, million UAH/year	30,25	35.85	46,45	55.50	72.66	87.20
Tariff for municipal waste processing service, UAH/ton	605.00	717.00	929.00	1110.00	1453.20	1744.00
Tariff for municipal waste management service, UAH/ton	1,563.21	1,694.47	1,936.09	2,137.33	2,511.66	2,823.74

According to the results of the calculations, it can be seen that the tariff for the service for the management of solid waste at the beginning of the implementation of the project (MBT plant under variant No. 1) is 1,886.21 UAH/t with an economically recommended tariff of 2,087 UAH/t, which is equal to the internal rate of return (IRR) at 10% and a payback period of 6-7 years. Based on the current rate of service provision, the tariff for the population will be 379.12 UAH/m³ per year.

5.2 Assessment of the estimated cost of construction and the main financial and economic indicators of the MBT plant (according to variant No. 2)

Estimates of the cost of construction of the MBT plant according to variant No. 2 (with anaerobic fermentation and utilization of biogas in a cogeneration plant) include the construction of a sorting plant, a plant for biological treatment of bio-waste, installation work of a cogeneration plant, construction work, design work and author's supervision of construction.

Table 5.6 shows the capital costs for the construction of the MBT plant in Uzhhorod according to variant No. 2. Table 5.7 shows the operating costs of the MBT plant according to variant No. 2 in Uzhhorod.

Table 5.8 shows the summary estimate for the new construction of a plant for the solid waste treatment (MBT plant according to variant No. 2). Table 5.6 shows the results of Chapters 1-10 and 12 of the consolidated estimate calculation.

Table 5.6 – Investment (capital) costs for the construction of the MBT plant according to variant No. 2 (with anaerobic fermentation and biogas utilization)

Expenses	Estimated cost	
	million UAH	million EUR
Mechanical sorting shop	181.17	4.5
Biological treatment workshop (generation of biogas in methane tanks with subsequent electricity generation)	161.04	4.0
Equipment for the production of electrical energy (1 MW)	36.23	0.9
Construction and installation work	152.99	3.8
Design and author supervision	24,15	0.6
Total:	**555.58**	**13.8**

Notes: as of July 31, 2023, the euro to hryvnia exchange rate was accepted at 40.26 UAH for 1 euro

Table 5.7 – Operating costs of the MBT plant according to variant No. 2 (with anaerobic fermentation and biogas utilization)

Expenses	Forecast	Year 1	Year 3	Year 6	Year 8	Year 11	Year 13
Expenditures for the purchase of electricity, million UAH	0.05	2.26	2.49	2.88	3.18	3.68	4.06
Expenses for wages, million UAH	0.1	14.91	18.04	24.01	29.06	38.67	46.79
Equipment maintenance costs, million UAH	0.1	19.91	24.09	32.07	38.80	51.64	62.49
Transportation costs, million UAH	0.03	1.22	1.29	1.41	1.50	1.64	1.74
Total		**38,30**	**45.92**	**60.38**	**72.53**	**95.63**	**115.08**

Notes: the electricity tariff of PJSC "Zakarpattiaoblenergo" for voltage class 2 as of 31/07/2023 is 1,803.49 UAH per 1 MWh, excluding VAT; the installed capacity of the plant is assumed to be 65 kW/t; transportation takes into account additional transportation related to the operation of the plant; the wage fund is accepted according to the average wage in Transcarpathian oblast, taking into account the accepted number of employees

Table 5.8 – Consolidated estimate for the new construction of a plant for the solid waste treatment (MBT plant according to variant No. 2)

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Estimated value, thousand UAH
1	Workshop for mechanized sorting of municipal waste	120.0 × 30.0 × 6.5	3,600	Metal columns, trusses (60 kg/m²), foundations	49,640.00
2	Automated sorting line	108.0 × 30	3,240	The equipment is assembled on embedded fasteners	99,693.00
3	Bio-waste processing plant	126 × 30 × 6.53	–	Metal columns, trusses (60 kg/m²), foundations	49,940.00
4	Checkpoint	8.0 × 4.0	32	A typical building made of brick (heating)	303.42
5	Weight	8.0 × 3.0	24	A typical building made of brick (unheated)	250.49
6	Weighing equipment, automation	–	–	–	248.61

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Estimated value, thousand UAH
7	Pit for disinfection and washing of wheels	8.0 × 3.5 × 0.3	28	Concrete base, canopy – metal structures, gates	547.95
8	Parking area for vehicles	100.0 × 50.0	5,000	Asphalt concrete	720.16
9	Fence, m	606	–	FC fence panels with a height of 1.6 m	4,368.37
10	Methane tanks and equipment for biogas generation, drying and conditioning (as part of item 1.2)	126 × 30 × 6.53	3,780	Vertical layout, concrete floor, methane tanks, dehumidification equipment, biogas conditioning, electricity, no heating	92,000.00
11	Wood waste processing module	10.0 × 2.5	25	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	50.3
12	Glass waste processing module	5.0 × 2.0	10	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	925.45
13	Polymer waste processing module	2.5 × 3.0	7.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,302.12
14	Rubber waste processing module	2.5 × 3.0	7.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	550.67
15	Textile waste processing module	2.0 × 1.5	3	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	450.80
16	Hazardous waste processing module	1.0 × 1.5	1.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	650.78
17	Oversized waste processing module	10.0 × 12.0	120	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,200.00

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Estimated value, thousand UAH
18	Energy module with placement of a cogeneration plant	48.0 × 24.0	1,152	Brick capital building	36,230.00
19	Module of return water supply and local treatment facilities	10.0 × 30.0	300	Metal structures (40 kg/m²), foundations	19,100.00
20	Storage facilities (for secondary raw materials)	50.0 × 30.0	1500	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,680.50
21	Repair and technical module	50.0 × 12.0	600	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,065.46
22	Module for sanitary treatment of transport and containers	36.0 × 12.0	432	Vertical layout, asphalt concrete	360.71
23	Administrative and municipal module	35.0 × 6.0	210	Modular prefabricated houses	5,761.29
24	Recreation area	6.0 × 6.0	36	Non-capital construction (without foundation)	106.55
25	Transformer substation (external power supply)	6.0 × 9.0	54	A typical building	1 115.18
26	including equipment for TS	–	–	Equipment	3,061.41
27	External water supply networks	–	–	–	2,358.36
28	External electrical networks	–	–	–	1,653.02
29	Roads	–	–	Asphalt concrete coating	1,322.00
30	Landscaping, greening	–	–	–	943.13
31	Construction and installation work	–	–	–	152,990.00
32	Design and author supervision	–	–	–	24,150.00
	Total	–	–	–	**555,580.00**

The creation of a central waste treatment facility in Uzhhorod is beyond the capacity of the local budget, therefore funds from service providers or investment funds (credit) from international financial institutions may be involved. Other costs related to the purchase of equipment, machines and tools for the implementation of the service of management solid waste in Uzhhorod are covered by the local budget or a special fund of the oblast budget.

In the calculations for the implementation of the MBT plant in Uzhhorod, the terms of granting a loan are adopted, similar to those in the credit agreement in Khmelnytskyi. The loan term is 13 years. Percentage is 5.75% per annum, one-time commission is 1.2%. Table 5.9 shows an indicative estimate of loan repayment costs by year for the implementation of the MBT plant in Uzhhorod.

The difference between the recommended and existing tariff for waste management in Uzhhorod during the implementation of the MBT plant presents as a separate indicator "contribution to the tariff". A forecast assessment of the change in the tariff for waste management was made (Table 5.10).

Table 5.9 – Indicative assessment of loan repayment costs by year (implementation of the MBT plant according to variant No. 2)

Years	Year 1	Year 3	Year 6	Year 8	Year 11	Year 13
Reimbursement on credit, UAH million	65.9	72.6	84.1	92.7	107.3	118.3

Notes: the calculation is made taking into account the annual loan rate of 5.75% and the projected growth of the euro exchange rate by 5% annually

Table 5.10 – Forecast of changes in the tariff for the municipal waste management service (MBT plant according to variant No. 2)

Characteristic	Period					
	Year 1	Year 3	Year 6	Year 8	Year 11	Year 13
Operating expenses, million UAH/year	38.70	45.92	60.38	72.53	95.63	115.08
Sale of secondary raw materials, million UAH year	58.20	64.80	76.20	84.80	99.66	110.98
Loan obligations, million UAH/year	65.9	72.6	84.1	92.7	107.3	118.3
Contribution to the tariff for municipal waste processing service, million UAH/year	46.40	53.72	68,28	80.43	103.27	122.40
Tariff for municipal waste processing service, UAH/ton	928.00	1,074.36	1,365.53	1,608.70	2,065.50	2,447.96
Tariff for municipal waste management service, UAH/ton	1,886,21	2,051.83	2,372.62	2,636.03	3,123.96	3,527.70

According to the results of the calculations, it can be seen that the tariff for the municipal waste management service at the beginning of the implementation of the project (MBT plant according to variant No. 2) is 1,886.21 UAH/t with an economically recommended tariff of 2,087 UAH/t, which is equal to the internal rate of return (IRR) at 10% and a payback period of 6-7 years. Based on the current rate of service provision, the tariff for the population will be 379.12 UAH/m³ per year.

5.3 Assessment of the estimated cost of construction and the main financial and economic indicators of the MBT plant (according to variant No. 3)

Estimates of the cost of construction of the MBT plant according to variant No. 3 (with stabilization composting of bio-waste) include the construction of a sorting shop, a shop for biological processing of bio-waste, construction works, design works and the author's supervision of the construction.

Table 5.11 shows the capital costs for the construction of the MBT plant in Uzhhorod according to variant No. 3. Table 5.12 shows the operating costs of the MBT plant under variant No.3 in Uzhhorod.

Table 5.11 – Investment (capital) costs for the construction of the MBT plant according to variant No. 3 (with stabilization composting of bio-waste)

Expenses	Estimated cost	
	million UAH	**million EUR**
Mechanical sorting workshop	181.17	4.5
Bio-waste stabilization station	163.05	4.05
Construction and installation work	148.96	3.7
Design and author supervision	24,16	0.6
Total:	**517.34**	**12.85**

Notes: as of July 31, 2023, the euro to hryvnia exchange rate was accepted at 40.26 UAH for 1 euro

Table 5.12 – Operating costs of the MBT plant according to variant No. 3 (with stabilization composting of bio-waste)

Expenses	Forecast	Year 1	Year 3	Year 5	Year 7	Year 9	Year 11	Year 13
Expenditures for the purchase of electricity, million UAH	0.05	5.86	6.46	7,12	7.85	8.66	9.55	10.52
Salary expenses, million UAH	0.10	10.71	12.96	15.68	18.97	22.96	27.78	33.61
Equipment maintenance costs, million UAH	0.10	18.91	22.89	27.69	33.51	40.54	49.06	59.36
Transportation costs, million UAH	0.03	1.22	1.29	1.37	1.46	1.55	1.64	1.74
Total	–	**36.70**	**43.60**	**51.87**	**61.79**	**73.71**	**88.02**	**105.24**

Notes: the electricity tariff of PJSC "Zakarpattiaoblenergo" for voltage class 2 as of 31/07/2023 is 1,803.49 UAH per 1 MWh , excluding VAT; the installed capacity of the plant is assumed to be 65 kW/t; transportation takes into account additional transportation related to the operation of the plant; the wage fund is accepted according to the average wage in Transcarpathian oblast, taking into account the accepted number of employees

Table 5.13 shows the consolidated estimate for the new construction of a plant for the solid waste treatment (MBT plant according to variant No. 3). Table 5.11 shows the results of Chapters 1-10 and 12 of the consolidated estimate calculation.

Table 5.13 – Summary estimate for the new construction of a plant for the solid waste treatment (MBT plant according to variant No. 3)

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Expensive cost, thousand UAH
1	Workshop for mechanized sorting of municipal waste	120.0×30.0×6.5	3,600	Metal columns, trusses (60 kg/m²), foundations	49,640
2	Automated sorting line	108.0×30	3,240	The equipment is assembled on embedded fasteners	99,693

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Expensive cost, thousand UAH
3	Bio-waste processing plant	126×30×6.53	–	Metal columns, trusses (60 kg\m²), foundations	49,940
4	Checkpoint	8.0×4.0	32	A typical building made of brick (heating)	303.42
5	Weight	8.0×3.0	24	A typical building made of brick (non-heating)	250.49
6	Weighing equipment, automation	–	–	–	248.61
7	Pit for disinfection and washing of wheels	8.0×3.5×0.3	28	Concrete base, canopy – metal structures, gates	547.95
8	Parking area for vehicles	100.0×50.0	5,000	Asphalt concrete	720.16
9	Fence, m	606	–	FC fence panels with a height of 1.6 m	4,368.37
10	Arrangement of bio-chambers for the stabilization of bio-waste, installation of air-blowing and drainage equipment, installation of a dust removal system	126×30×6.53	3,780	Vertical layout, concrete floor, bio chambers with automatic mixture supply, air blowing equipment, drainage system, electricity, without heating	94,010
11	Wood waste processing module	10.0×2.5	25	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,250.3
12	Glass waste processing module	5.0×2.0	10	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	925.45
13	Polymer waste processing module	2.5×3.0	7.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,302.12
14	Rubber waste processing module	2.5×3.0	7.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	550.67
15	Textile waste processing module	2.0×1.5	3	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	450.8

No.	Name of the building	Size (L×W×H), m	Area, m²	Structural diagram	Expensive cost, thousand UAH
16	Hazardous waste processing module	1.0×1.5	1.5	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	650.78
17	Oversized waste processing module	10.0×12.0	120	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1200
19	Energy module with placement of a cogeneration plant	48.0×24.0	1,152	Brick capital building	0
20	Module of return water supply and local treatment facilities	10.0×30.0	300	Metal structures (40 kg/m²), foundations	19,100
21	Storage facilities (for secondary raw materials)	50.0×30.0	1,500	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,680.5
22	Repair and technical module	50.0×12.0	600	Vertical layout, concrete floor, light metal wall structures (30 kg/m²), electricity, no heating	1,065.46
23	Module for sanitary treatment of transport and containers	36.0×12.0	432	Vertical layout, asphalt concrete	360.71
24	Administrative and municipal module	35.0×6.0	210	Modular prefabricated houses	5,761.29
25	Recreation area	6.0×6.0	36	Non-capital construction (without foundation)	106.55
26	Transformer substation (external power supply)	6.0×9.0	54	A typical building	1,115.18
27	Including equipment for TS	–	–	Equipment	3,061.41
28	External water supply networks	–	–	–	2,358.36
29	External electrical networks	–	–	–	1,653.02
30	The roads	–	–	Asphalt concrete	1,322
31	Landscaping, greening	–	–	–	943.13
32	Construction and installation work	–	–	–	148,960
33	Design and author supervision	–	–	–	24,160
	Total	–	–	–	**517,339.02**

The creation of a central waste treatment facility in Uzhhorod is beyond the capacity of the local budget, so funds from service providers or investment funds (credit) from international financial institutions may be involved. Other costs related to the purchase of equipment, machines and tools for the implementation of the service of management solid waste in Uzhhorod are covered by the local budget or a special fund of the oblast budget.

In the calculations for the implementation of the MBT plant in Uzhhorod, the terms of granting a loan are adopted, similar to those in the credit agreement of Khmelnytskyi. The loan term is 13 years. The percentage is 5.75% per annum, one-time commission is 1.2%. Table 5.14 shows the indicative estimate of loan repayment costs by year for the implementation of the MBT plant in Uzhhorod.

Table 5.14 – Indicative assessment of loan repayment costs by year (implementation of the MBT plant according to variant No. 3)

Period	Year 1	Year 3	Year 6	Year 8	Year 11	Year 13
Reimbursement on credit, UAH million	47.16	60.00	60,19	66,36	76,82	84.70

Notes: the calculation is made taking into account the annual loan rate of 5.75% and the projected growth of the euro exchange rate by 5% annually

The difference between the recommended and existing tariff for waste management in Uzhhorod during the implementation of the MBT plant will be presented as a separate indicator "contribution to the tariff". An iterative assessment of the contribution to the increase in the tariff for waste management at the end of the first year of project implementation was made (Table 5.15).

Table 5.15 – Calculation of the impact on the tariff of municipal waste management services (MBT plant according to variant No. 3)

Characteristic	Period					
	Year 1	Year 3	Year 6	Year 8	Year 11	Year 13
Operating expenses, million UAH/year	38.70	45.92	60.38	72.53	95.63	115.08
Sale of secondary raw materials, million UAH year	58.20	64.80	76.20	84.80	99.66	110.98
Loan obligations, million UAH/year	47.16	52.00	60,19	66,36	76,82	84.70
Contribution to the tariff for municipal waste processing service, million UAH /year	27.66	33.12	44.37	54.09	72.79	88.80
Tariff for municipal waste processing service, UAH/ton	553.20	662.36	887.33	1,081.90	1,455.90	1,775.96
Tariff for municipal waste management service, UAH/ton	1,511.41	1,639.83	1,894,42	2,109.23	2,514.36	2,855.70

According to the results of the calculations, it can be seen that the tariff for the municipal waste management service at the beginning of the implementation of the project (MBT plant according to variant No. 3) is 1,511.41 UAH/t with an economically recommended tariff of 2,087 UAH/t, which is equal to the internal rate of return (IRR) at 10% and a payback period of 6-7 years. Based on the current rate of service provision, the tariff for the population will be 303.79 UAH/m^3 per year.

CHAPTER VI. ASSESSMENT OF THE IMPACT ON THE ENVIRONMENT OF VARIOUS CONSTRUCTION PROJECTS (LOCATION) OF THE WASTE TREATMENT FACILITY (SORTING) OF SECONDARY RAW MATERIALS FOR UZHGOROD

6.1 Description of the planned activity

To expand the possibilities of the system of separate collection of secondary raw materials in Uzhhorod, based on the obtained results of research and calculations, including the work “Analysis of the Current Waste Management System”[31] (hereinafter - Analysis), the waste treatment facility – the central object of MW treatment - a plant of mechanical and biological treatment (MBT) of waste with anaerobic fermentation (MBT plant), as it contains more sources of negative impact on the environment.

6.1.1 Description of the place of planned activity

For the implementation of the construction project (placement) as the central waste treatment facility of the MBT plant for the conditions of Uzhhorod, it has been determined that the approximate area of its territory should be 2.0 hectares.

Fig. 6.1 shows the recommended location of the waste treatment facility.

The site for the placement of the MBT plant is located in the sanitary zone of the waste disposal landfill in Uzhhorod (in the village Barvinok) next to the forest plantations of the branch “Uzhhorod Forestry” of the State Enterprise “Forests of Ukraine”, to the north is the waste disposal landfill, to the east a cemetery, to the west and the south private land sites.

Fig. 6.1 – Recommended location of the planned waste treatment facility

6.1.2 Goals of the planned activity

Following the “National Strategy of Waste Management in Ukraine until 2030”[32], it is necessary to achieve the target indicator of 30% landfilling of solid waste, i.e. to ensure a reduction in the amount of landfill using a set of measures for the separate collection of solid waste with the extraction of resource-valuable components and their further direction for processing, composting of the waste component biodegradable, in private municipals and mixed waste treatment activities. Achieving such an indicator is possible only if a central municipal waste processing facility is built.

[31] "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 Management of Biodegradable Waste in Uzhhorod" within the framework 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), 2022

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

As a rule, plants for mechanical and biological processing are built with an optimal capacity of at least 50,000 tons per year. In Uzhhorod, more than 50,000 tons of municipal waste is generated in the catchment area per year, with a projected increase of 0.5% every year.

The construction of the MBT plant will allow to increase in the volume of extracted resource-valuable components and obtain secondary raw materials of better quality. These factors affect the economic performance of this facility.

6.1.3 Description of the characteristics of the activity during the implementation of the planned activity

The technological variant of the MBT plant, which is being considered for the conditions of Uzhhorod, includes the following units:

- mechanical sorting and treatment unit (sorting and grinding);
- biological treatment unit: anaerobic decomposition with biogas production and further utilization of biogas in a cogeneration unit.

Table 6.1 shows the calculated parameters of the material balance of the MBT plant for Uzhhorod.

Table 6.1 – Calculation parameters of the material balance of the MBT plant

Parameter	Units	Value
Total population served	persons	115,449
Number of IDPs	persons	28,000
Volume of waste generation (excluding IDPs)	t/year	50,396
Design capacity of the MBT plant (1 shift per day)	t/year	50,000
	%	100
Extraction of resource-valuable components	t/year	13,900
	%	≈28
Biogas formation	m^3/year	1,260,000
Volume of bio-waste for fermentation (input)	t/year	18,000
	%	36
Residue destined for landfill (excluding residues after fermentation)	t/year	18,100
	%	36

Notes: The calculations assume: electricity consumption 65 kW·h. per design ton of MW; production capacity – 25 t/h; number of working days per year – 250; shift of 8 hours (sorting shop); density of methane under standard conditions 0.67 kg/m³ (DSTU ISO 13443:2015 Natural gas. Standard conditions)

The staff list of employees of the MBT plant for the adopted design capacity of the enterprise is adopted by the requirements of GBN B.2.2-35077234-001[33] (listed in Table 6.2).

Table 6.2 – Approximate staff list of employees of the MBT plant

No.	Profession and position	Calculated number of positions
1	Administrative and managerial employees	8
2	Reception department and waste sorting	35
3	Workshop for anaerobic fermentation of bio-waste, which was removed from the MW	15
4	Cogeneration plant for biogas utilization	13
	Total	**71**

[33] GBN V.2.2-35077234-001:2011 "Enterprises for sorting and processing solid household waste. Requirements for technological design" // http://surl.li/cbyrg

6.2 Description of the current state of the environment (baseline scenario) and description of its likely change without the implementation of the planned activity within the extent to which natural changes from the baseline scenario can be assessed on the basis of available environmental information and scientific knowledge

6.2.1 Climate and microclimate

The climate of the area of the planned activity is moderate-continental with hot summers and mild winters, with an average annual air temperature of +9.7°C. The warmest month of the year is July (20.3°C), the coldest is January (minus 0.2°C) (according to DSTU-N B V.1.1-27[34]).

A stable transition of the average daily air temperature by +8°C occurs in the spring period on average 1/IV, in autumn 29/X. The average duration of the growing season is 230-240 days. The average duration of the frost-free period is 175 days.

Predominant wind direction: in winter – southeast; in summer - northwest, east. In Uzhhorod, strong winds (over 15 m/s) are more frequent in winter and spring, have a north-easterly direction, and are associated with the invasion of cold air masses through the mountains. In summer, strong winds are associated with short-term daytime squalls and are accompanied by showers, thunderstorms, and hail[35].

The average annual relative humidity is 72%. Humidification zone II according to DBN B.2.4-2-2005[36]. Average annual precipitation is 745 mm/year. Precipitation falls unevenly throughout the year, the largest amount falls in June, the least in March.

Table 6.3 shows the main climatic characteristics of the area of the planned activity.

Table 6.3 – Main climatic characteristics [34,37]

No	Characteristic	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1	Air temperature (AMSC Uzhhorod), °C	-2.8	-0.2	-4.7	10.7	15.6	18.5	19.9	19.4	15.5	10.3	4.6	-0.4	9.7
2	Precipitation, mm (AMSC Uzhhorod)	57	47	49	46	71	88	86	71	54	50	59	70	748
3	Relative humidity %	82	77	69	63	65	67	67	69	72	75	81	84	73
4	Average wind speed, m/s	2,2	2.5	2.9	3.1	2.7	2.4	2,3	2.1	2,3	2,3	2.4	2,2	–
5	Temperature maximum, °C	13	17	27	32	33	37	39	40	34	31	29	17	40
6	Temperature minimum, °C	-29	-32	-24	-12	-2	3	6	4	-2	-18	-22	-25	-32

6.2.2 Geological environment

In terms of geomorphology, Uzhhorod is located on the border of the transition from the volcanic Vyhorlat-Hutyn range to the Transcarpathian lowland, which is visible in the relief. The old part of the city lies on the hills, and the younger part is on the left bank of the Uzh River, where the Transcarpathian lowland begins, which is part of the Middle Danube lowland.

The spurs of the Vyhorlat-Hutinsky range are represented by low elevations in the north and east, as well as separate remnants (Zamkova Hill) in the central part of the city. The lowlands are characterized by relatively small surface slope angles, mostly up to 10-12%, and slight dismemberment of the territory. The existing beams have a cut depth of up to 50 m (a beam in the area of the brandy plant) and are characterized by gentle slopes. Areas of slopes with surface slopes of 12% have a limited distribution within the lowlands and are limited, as a rule, to outcrops of crystalline rocks on the day surface.

[34] DSTU-N B V.1.1-27:2010. Protection from dangerous geological processes, harmful operational influences, from fire. Building climatology. Effective from 2011-11-01. Kind. officer Kyiv: SE "Ukrakhbudinform", 2011. – 123 p.

[35] Regional information center "Karpaty" CLIMATE CONDITIONS OF THE REGION (part 1). Regional information center "Karpaty". URL: http://carpaty.net/?p=31101 And (access date: 11.07.2023).

[36] https://zakon.isu.net.ua/sites/default/files/normdocs/dbn_v.2.4-2-2005_poligoni_tverdikh_pobutovikh_vidkhodiv_-_zi_.pdf

[37] Ozymko R.R. Heavy and extraordinary precipitation in the Transcarpathian region: diss. ... doctor of philosophy in the field of geology: 103. Odessa, 2020. 207 p. URL: http://eprints.library.odeku.edu.ua/8781/1/Дисертация_Озимко%20Р.Р.pdf .

The Chop-Mukachiv depression and the Uzh River valley occupy the lowland part of the city. The relief of this territory is flat with small surface slopes and the presence of closed depressions in which meltwater and rainwater accumulate. Within the boundaries of the Uzh River, the floodplain and the 1st supraflood terrace, which are periodically inundated in floods, are distinguished. The floodplain of the Uzha can be traced in the floodplain part and within the boundaries of the Chop-Mukachiv plain.

The absolute levels of the alluvial plain vary from 113 m in the southwestern border of the city to 125 m in the northeastern part of the Chop-Mukachevo plain. The general slope of the surface has a south-western direction[38].

Uzhhorod is characterized by heavy soils with a predominance of turf type. The highest content of humus (3%) was in the soils of the southern outskirts of the city, and the lowest (0.52%) – in the soils of the eastern part. The northern part of the city is represented by sod-brown earth-podzolic unglazed and gleyed unwashed and slightly washed light loamy soils and their variations. In the southern part, soddy, deep neoglean and silty loamy soils and their variations prevail. The soil cover is characterized by relative diversity, which is due to the size of the city's territory and its geomorphological features. The city is rich in deposits of brick and tile raw materials, coal, and natural stone.

The site for the construction (location) of the waste treatment facility is geomorphologically located on a slope. The absolute surface marks are 134.5 m (top) and 124.5 m (bottom). The capacity of the aeration zone is 2.0 m, and the composition and structure are natural loam. The depth of underground water is 5.0 m, conditionally protected. Groundwater is spontaneous and seasonal, located at a depth of 4.0-5.0 m. The presence of filtration phenomena - runoff during precipitation.

The topography of the site is calm. According to the sanitary classification, the facility is assigned to the II class of buildings with the size of the sanitary protection zone of 500 m[39].

6.2.3 Atmospheric air

According to the “Oblast Report on the State of the Natural Environment in Transcarpathian Oblast in 2021”, during 2020 there was a slight decrease in emissions of pollutants into the atmospheric air from stationary sources of pollution. The volumes of pollutants that entered the air basin in 2020 from stationary sources of pollution, according to the General Directorate of Statistics, decreased by 10.8% compared to 2019 and amounted to 3.3 thousand tons against 3.7 thousand tons in 2019. Of the total number of emissions of pollutants, 28.9% are substances belonging to greenhouse gases, in particular, methane. In addition, 0.2 million tons are the volume of carbon dioxide emissions.

Out of the total volume of emissions of polluting substances into the atmospheric air, Uzhhorod district accounts for 45.1% of pollution, Uzhhorod city – 2.61%.

Emissions of pollutants into the atmosphere from stationary sources of pollution in 2020 for Uzhhorod amounted to 86.4 tons, which is 34.2 tons less than in 2019; for the Uzhhorod district, this indicator was 1,493.9 tons in 2020, which is 8.8 tons less than in 2019.

The volumes of emissions of pollutants from stationary sources of pollution per capita decreased compared to 2019 (from 3.0 kg to 2.6 kg).

Motor vehicles continue to be the main air polluter in the city, the number of motor vehicles has grown significantly in recent years, and gas stations have grown, which is a significant source of air pollution.

Emissions of the most common polluting substances by stationary sources into the atmospheric air in 2019 remained almost unchanged compared to 2018. Emissions of dust solids compared to the previous year decreased from 0.34 to 0.30 thousand tons. Emissions of nitrogen oxides into atmospheric air remained almost unchanged at the level of 0.02 thousand tons. Emissions of sulfur dioxide into atmospheric air increased from 0.17 to 0.2 thousand tons. Carbon monoxide emissions

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[38] Uzhgorod, Transcarpathian oblast. Making changes to the city's master plan. Explanatory note, Kyiv, 2015
[39] https://zakon.rada.gov.ua/laws/show/z0379-96#Text

increased from 0.94 to 1.3 thousand tons.

In 2020, emissions from stationary sources into atmospheric air, including the most common substances (dust, sulfur dioxide, nitrogen dioxide, carbon monoxide) for Uzhhorod amounted to: dust – 0.005 thousand tons, sulfur dioxide – 0.005 thousand tons, dioxide nitrogen 0.009 thousand tons, carbon monoxide – 0.063 thousand tons; Total – 0.086 thousand tons, which is ultimately less than in 2019. For the Uzhhorod district in 2020, the total amount of emissions from stationary sources into atmospheric air, including the most common substances, amounted to 1,495 thousand tons, which is less than in 2019.

Air pollution monitoring stations (PMS) in Uzhhorod are located: PMS No. 1 – in the administrative and residential area of the city, 2 Svobody Ave.; PMS No. 2 – in the industrial district, str. Paris Commune, 2.

The analysis of observation materials on the content of pollutants in the atmospheric air during the year shows that formaldehyde, nitrogen dioxide, dust, nitrogen oxide (II) and carbon oxide (II) remain the priority air pollutants of Uzhhorod in 2021. The air pollution index with 5 priority pollutants was 4.82 (5.20 in 2020), including: formaldehyde pollution index – 2.36, nitrogen dioxide – 1.23, dust – 0.47, nitrogen oxide – 0.40 and carbon monoxide – 0.36.

High and extremely high levels of atmospheric air pollution were not observed in Uzhhorod in 2021. Formaldehyde remained the main pollutant of the city's atmospheric air. The average annual concentration of formaldehyde in the air was 2.0 MPCa.d. In January, May, November – December, the concentration of formaldehyde was at the level of 2 MPCa.d., in February, June, July, September – 2.17...2.67 MPCa.d., in March – April, August and October – 1,33...1.67 MPCa.d.. The average monthly level of atmospheric air pollution with nitrogen dioxide was higher than MPCa.d. in January, March, May, July-August and October; in September, November-December, the average concentration was equal to the average daily MPC, in other months of the year it was lower than MPCa.d. The average annual concentration was 1.23 MPCa.d. Atmospheric air pollution with nitrogen oxide during 2021 was lower than MPCa.d. The average annual concentration was 0.40 MPCa.d. The average annual dust concentration was 0.47 MPCa.d. The average annual concentration of carbon monoxide was 0.32 MPCa.d. The highest average monthly concentration of carbon monoxide was observed in February and November (0.4 MPCa.d.), the lowest – in June-July (0.27 MPCa.d.). The average annual concentration of sulfur dioxide in the atmospheric air of the city in 2021 was 0.26 MPCa.d. Atmospheric air pollution with soluble sulfates during the year remained below the value of MPCa.d. The average level of pollution was 0.04 MPCa.d. Atmospheric air pollution by heavy metals, according to the results of observations in 2021, remained lower than the MPCa.d. The content of cadmium in the atmospheric air of the city was not detected, except January, when the average concentration was 0.01 μg/m³. The average level of iron contamination is 0.69 μg/m³. The maximum level of atmospheric air pollution with iron was observed in February (0.96 μg/m³), and the minimum pollution was in January (0.48 μg/m³). The average level of manganese pollution was 0.02 μg/m³. The maximum pollution was observed in November (0.04 μg/m³), the minimum pollution of 0.01 μg/m³ was observed in August-October. The average level of copper contamination is 0.01 μg/m³. The maximum level of pollution was observed in May, November-December (0.02 μg/m³), the minimum – in March (0.00 μg/m³). The average level of nickel contamination is 0.01 μg/m³. Maximum pollution was observed in August, November – December (0.02 μg/m³); during other months of the year, pollution remained at the level of 0.01 μg/m³. The average level of lead contamination was 0.04 μg/m³. The maximum pollution was observed in January and May (0.05 μg/m³), the minimum level of pollution was observed in June (0.02 μg/m³). The average level of zinc contamination is 0.05 μg/m³. Maximum pollution was observed in October (0.13 μg/m³), minimum – in January, June-July and September (0.03 μg/m³). The average level of chromium contamination is 0.01 μg/m³. The maximum pollution was observed in October (0.03 μg/m³), the minimum – in January (0.0 μg/m³).

The study of atmospheric air to determine the state of its pollution in 2021 was carried out by the structural units of the "Transcarpathian OTSKPH of the Ministry of Health"[40]. Sampling took

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[40] State institution "Transcarpathian Regional Center for Disease Control and Prevention of the Ministry of Health of Ukraine"

place at route monitoring posts, and the results of laboratory tests were determined for 7 ingredients and were evaluated as maximum single concentrations. It is impossible to assess the possible negative impact of atmospheric air on the health of the population even in individual oblasts of the oblast based on the data of the specified laboratories, which is connected with the small amount for meaningful analysis of the data of laboratory studies of atmospheric air.

In the fall of 2022, as part of the Analysis, an analysis of the impact of the landfill in the village Barvinok was carried out on atmospheric air quality. The selection and research of air samples was carried out by the Integrated Laboratory of Natural Environmental Pollution Observations of the Transcarpathian Oblast Center for Hydrometeorology.

According to the results of the analyses, at the time of researching atmospheric air samples for the content of sulfur dioxide, nitrogen dioxide, formaldehyde and carbon monoxide, the concentration of the studied substances met the requirements of the hygienic standards for the permissible content of chemical substances in it. However, there was practically no wind at the time of the research. For a more in-depth analysis of the impact of the MBT plant on the state of the atmospheric air, it is necessary to conduct additional studies of the quality of the atmospheric air in windy weather and under other hydrometeorological conditions during the development of an assessment of the environmental impact of the planned activity of the specified object.

6.2.4 Water resources

Surface waters

Taking into account hydrographic and water management zoning, the territory of Uzhhorod belongs to the basin of the Tisza River, which is completely located within the boundaries of one oblast – Transcarpathian[41]. The Uzh River flows through the city from east to west and is a tributary of the Tisza River.

The soil-forming rocks of the Tisza River basin are Quaternary sediments and weathering products of Tertiary and volcanic rocks. Within the Uzhhorod district, the speed of the Uzh River is not high, because which part of the sediment settles, so the river flows in its sediments.

The territory of Uzhhorod is located within the boundaries of the Transcarpathian artesian basin, where underground waters are mainly layered and lie in Neogene and anthropogenic sediments.

The main source of water supply in the Transcarpathian oblast is water from surface sources are the rivers Uzh, Svalivka, Zhdymer, Borzhava, Vycha, Tysa, Shopurka, and artesian wells.

According to the “Oblast Report on the State of the Environment in Transcarpathian Oblast in 2021” out of the total number of water pipes on which the “Transcarpathian OTSKPH of the Ministry of Health” and its separate structural subdivisions conducted drinking water research, in 2021, 5.5% of the samples did not meet the standards for sanitary and chemical indicators, with distribution to the relevant water pipes: communal – 4.6 %; departmental – 14.4%; rural – 4.6%; local – 0. Out of the total number of sources of non-centralized water supply, on which laboratory studies of drinking water were carried out, according to sanitary and chemical indicators, 14.4% of samples did not meet the norms with distribution by types of sources: mine wells – 12%; catchments – 7.9%; artesian wells – 11.2%. Cases of non-infectious diseases related to chemical contamination of drinking water of both centralized and non-centralized water supply in the oblast were not registered. The content of nitrates in groundwater in 2021 met the requirements of DSanPiN, cases of water-nitrate methemoglobinemia among children were not registered.

To study the possible negative impact of wastewater and surface water discharge on the water quality of surface reservoirs, in 2021, the separate structural units of the Transcarpathian OTSKPH of the Ministry of Health conducted systematic observations of the water condition in 8 permanent reservoirs of category I and in 38 permanent reservoirs of category II with water sampling for laboratory research. According to the results of the reports, in 2021, 4.2% of the water samples taken for the determination of sanitary and chemical parameters (reservoirs of categories I and II) did not

[41] https://buvrtysa.gov.ua/newsite/?page_id=18150

meet the standards. Chemical substances, the content of which exceeded the maximum permissible concentration, are represented by pesticides, phenol, and synthetic surface-active substances.

Microbiological assessment of water quality because of the epidemic situation

Out of the total number of microbiological parameters of tap water samples examined by the "Transcarpathian OTCKPH of the Ministry of Health" and its separate structural subdivisions, 8% did not meet the norms with the distribution by types of water pipes: communal – 5.8%; departmental – 15.1%; rural – 19.8%; local - 0. Water from non-centralized water supply sources did not meet the norms according to microbiological indicators in 25.3% of cases, including mine wells – 27.4%; catchments – 1.8%; artesian wells – 24.1%. According to the results of the reports, in 2021, 231 samples were taken for the determination of microbiological indicators from water bodies of category II, of which 34 did not meet the standards (14.7%).

Radiation status of surface waters

To determine the radiological indicators of the "Transcarpathian OTCKPH of the Ministry of Health" and its separate structural subdivisions, 5 samples from water bodies of category I were examined, and no deviations were found.

Underground waters

All explored or operating underground water intakes in the oblast are infiltration, so the quality of the groundwater extracted from them depends entirely on the characteristics of the surface runoff and requires special protection[42].

Within the territory, aquifers are developed in the deposits of the Ilnytsia, Gutyna, Chopa world and the aquifer of Quaternary alluvial deposits. The latter is of practical importance for the organization of centralized water supply.

On the territory of Uzhhorod, there are more than 20 mineral waters, artificial (wells) and natural (springs), valuable in a therapeutic sense. Yes, in the park named after There is mineral water of the "Yesentuki 17" type in Gorky, and "Narzan" type water in Bozdosh park, but the use of which is characterized as limited and irrational[43].

Currently, out of 20 deposits of thermal water in the territory of Uzhhorod, the Uzhhorod deposit (Str. 5-T, city pump house) is practically used.

In the fall of 2022, as part of the Analysis, an analysis of the impact of the landfill in the Barvinok village was carried out on the quality of water bodies. In connection with the lack of water in the observation wells, to assess the state of contamination of water resources, it was decided to take water from the nearest landfill site in the village Barvinok of an open source located in the direction of the city of Uzhhorod – floodplain Lake Nilachka. Sampling and analysis were carried out by the Plant Laboratory of Natural Environmental Pollution Observations of the Transcarpathian Oblast Center for Hydrometeorology.

The following indicators were within the normative values (according to the order of the Ministry of Health dated 02.05.2022 No. 721): ammonium nitrogen – 0.7 mg/dm^3 (MPC 2.0 mg/dm^3), nitrate ions – 0.58 mg/dm^3 (MPC 45.0 mg/dm^3), nitrite ions – 0.008 mg/dm^3 (MPC 3.3 mg/dm^3), phosphate ions – 0.28 mg/dm^3 (MPC 3.5 mg/dm^3), chloride ions – 30.13 mg/dm^3 (MPC 350.0 mg/dm^3), sulfate ions – 32.06 mg/dm^3 (MPC 500.0 mg/dm^3).

Indicators of organic pollution exceeded the normatively permissible content; in particular, the COD was exceeded by almost 2 times the normative value. An excess of the content of organic compounds indicates the contamination of the reservoir with organic compounds due to its possible contamination by domestic, industrial and agricultural effluents. Pollution of Nilachka was not caused by the impact of the landfill site in the village Barvinok.

For a more detailed assessment of the impact of the planned activity of the new sewage

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[42] https://buvrtysa.gov.ua/newsite/?page_id=17003

[43] Uzhhorod, Transcarpathian region. Making changes to the city's master plan. Explanatory note, Kyiv, 2015

treatment facility on the pollution of water resources, it is necessary to conduct a study of groundwater in the area where the planned activity is conducted.

6.2.5 Soil condition and land degradation

According to the results of an agrochemical survey of 202.42 thousand hectares of agricultural land in Transcarpathian oblast (2016-2020), 133.48 thousand hectares (65.9%) of the total surveyed area are acidic soils. A significant part of the area (49.47 thousand hectares or 24.4%) is occupied by lands with a very strong and strongly acidic reaction of the soil solution. The remaining areas have a moderately acidic (43.33 thousand ha or 21.4%) and slightly acidic (40.68 thousand ha or 20.1%) reaction of the soil solution. At the same time, the category of lands with close to neutral and neutral reaction of the soil solution is 62.84 thousand hectares or 31% of agricultural land. The weighted average indicator of pHKCl is 5.24, which corresponds to the slightly acidic reaction of the soil solution. Thus, in Transcarpathian Oblast, more than half of surveyed agricultural land areas have high acidity, which is one of the main reasons for their low fertility.

The problem of humus is extremely important for the soils of Transcarpathian, as a large amount of precipitation (more than 1,000 mm per year) contributes to its leaching, especially on sloping lands.

According to the distribution of surveyed soils of the Transcarpathian oblast by classes of quality, only 13.35 thousand ha or 6.6% of high-quality soils are accounted for, of which only 0.68 thousand ha (0.3 %) and up to IV class (61-70 points) – 12.67 thousand hectares (6.3%). Soils of average quality occupy 109.18 thousand hectares or 54%, of which 46.63 thousand hectares (23%) belong to the V class (51-60 points) and 62.55 to the VI class (41-50 points) thousand hectares (31%). However, most of the area is occupied by soils of low quality – 83.47 thousand hectares or 41.2%, of which 63.6 thousand hectares (31.4%) are classified as VII class of credit rating (31-40 points) and 31.4% are classified as VIII class (21-30 points) – 19.87 thousand hectares (9.8%). Soils of very low quality occupy 0.24 thousand hectares (0.1%) and belong to the IX credit rating class (11-20 points).

In Transcarpathian Oblast, 39,600 hectares of eroded land have been recorded. 34.8 tons of fertile soil is destroyed annually from each hectare.

Removal of eroded lands from agricultural lands is the most ecologically justified and economically expedient method of their use. In general, in all soil and climatic zones of the oblast, about 37.3 thousand hectares of arable land should be removed from intensive cultivation, of which 23.0 thousand hectares should be plowed and transferred to hayfields and pastures, and 14.3 thousand hectares should be afforested.

In the fall of 2022, as part of the Analysis, an analysis of the impact of the landfill was carried out in the village Barvinok on the condition of the soil. Sampling of soil at three points: from the body of the landfill site, at a distance of 50 m from the body of the landfill site and a distance of 100 m from the landfill site.

Of total nitrogen was found in all the selected soil samples, and the content of nitrates was exceeded. The increased content of nitrogen compounds is associated with agricultural activities, which does not indicate a direct impact on the landfill site in the village. Periwinkle on the ground.

Heavy metals, namely zinc, nickel, cobalt, cadmium and copper, were not detected in all samples. Thus, the activity of the landfill site in the village of Periwinkle does not violate the normative condition of soils.

For a more detailed assessment of the impact of the planned activities of the new waste treatment facility on soil pollution, it is necessary to conduct sampling at the site of the planned activities.

6.2.6 Generation and management of waste

According to the Central Department of Statistics, 145,000 tons of hazard class I-IV waste was generated in Transcarpathian Oblast in 2020, including 1,300 tons of hazard class I-III waste.

Of the total amount of generated waste, 3.2 thousand tons were burned, 0.26 thousand tons were disposed of, and 161.0 thousand tons were removed to specially designated places. According to the main groups of waste in 2020, the largest specific weight of the total volume of generated waste was municipal and similar waste – 133.8 thousand tons or 92.3%; wood waste – 5.6 thousand tons or 3.8%; glass waste – 0.1 thousand tons or 0.007%; paper and cardboard waste – 2.0 thousand tons or 1.4%; plastic waste – 0.9 thousand tons or 0.6%; textile waste – 0.6 thousand tons or 0.4%.

The generation of waste of all hazard classes was 0.01 tons per person and 1.1 tons per 1 KS². Among the enterprises, the largest amount of waste in 2020 was generated during the activities of the factories for the production of electrical appliances "Flextronics TzOV" (1,752.2 tons of I-IV hazard classes, of which: 1,226 tons of waste paper and plastic packaging waste) and Jabil Syorkit Ukraine LLC Limited" (1,341.8 tons of hazard classes I-IV, of which: 1,050 tons of waste paper and plastic waste), LLC "EVK", engaged in sawmilling and planning production (843 tons of waste of hazard classes II, IV, of which 838 tons are for the generation of wood waste), LLC "Perspektiva", engaged in the production of veneer, plywood, plates and panels (770 tons of waste of the IV hazard class, of which 745 tons are sawdust).

As part of the implementation of the European Union project "Waste Management – EPDP Eastern Oblast" in 2010, the decision of the eleventh session of the VI convocation of the Transcarpathian Oblast Council dated November 16, 2012 No. 537 "Strategy of waste management in the Transcarpathian oblast for 15 years" was developed and approved. According to the approved Strategy for solving the problem of waste management, the organization of centralized garbage collection in all settlements of the oblast, the gradual reduction of the number of landfills and their modernization is envisaged. Centralized collection and disposal of solid waste on the territory of the city is carried out by specialized enterprises. Collection of municipal waste from the population and subjects of economic activity is also carried out independently by enterprises and organizations, separate private structures and specialized communal services under local self-government bodies. There are no municipal waste disposal facilities.

In Uzhhorod, a separate collection of solid waste (glass, plastic, waste paper and scrap metal) has been implemented. Resource-valuable components of MW are transferred to specialized enterprises (a total of 51 economic entities in the oblast). The collected waste is mainly sent for disposal outside the oblast. Production facilities for processing PET containers and other polymer waste (installations, presses, crushers) operate at the enterprises: KP "Vody Khustshchyny", PP "Brenner" (Khust), KP "Vtorma", LLC "Karpaty LTD" (Mukachevo, PP "Plastor" (Svoboda village, Beregivu district), TDV "Vinohradiv plant of plastic plumbing products" (Vynohradiv city), recycling station "Proektna, 3" (Uzhhorod). Used tires are disposed of by FOP Breza O O. (Uzhgorod district). Technological equipment for the disposal of hazardous waste is available at "New Ecosvit" LLC (Uzhhorod, location: Uzhhorod district, Kinchesh village, Bazy microdistrict).

One of the problems with the construction of new landfills for the collection of MSW and MSW treatment facilities in Transcarpathian is the scarcity of land. In mountainous areas, it is almost impossible to find land sites that would meet construction and sanitary standards for such construction.

According to the data of the Main Department of Statistics, 1 waste disposal plant, 24 waste incineration plants for energy production, 5 waste incineration plants for thermal processing, and 35 other waste removal (except incineration) plants operate in the oblast. In 2020, 5.6 thousand tons of wood waste were generated by business entities engaged in woodworking and sawmilling, of which 3.2 thousand tons were burned: 2.2 thousand tons - to obtain energy, 1,0 thousand tons for thermal processing.

According to the data of the register of waste disposal sites (WDS), as of January 1, 2022, 62 certified WDS were registered in the territory of the Transcarpathian oblast, of which 59 are waste disposal sites, 2 are wood waste (sawdust), and 1 is artificial fur waste. Most of the existing landfills have exhausted their capacities, filled to 80-85%, and the operational life of many landfills has ended. Due to the mountainous nature, high population density, the neighbourhood with 4 countries of the European Union, the only water basin of the Tisza River, the protected area, several settlements (Rakhiv, Tyachiv, Vynohradiv, Berehovo, Perechyn and Velikiy Berezny) are deprived of the possibility of choosing land sites and issuing permit documents under the WDS.

There is no storage of unsuitable or prohibited pesticides and poisonous chemicals on the territory of Transcarpathian Oblast.

As of 2023, municipal waste generated on the territory of Uzhhorod is taken for disposal at the landfill – landfill site of Uzhhorod (in the village of Barvinok) (passport of the landfill dated February 19, 2008, registration number 5-a). The environmental safety category of WDS is "A" (low risk). The established sanitary and protective zone of the MVV – 500 m is maintained. The owner of the WDS is KP "KATP-072801" (Uzhhorod, 3 Pogorelova Str.).

The location of the waste disposal site in Uzhhorod (in the village of Barvinok) is Transcarpathian Oblast, Uzhhorod district, village Barvinok, the distance from the settlement is 3.2 km from Uzhhorod, the distance from watercourses and reservoirs is 2.0 km, from water intake structures – 2.3 km. The design area of the landfill site is 9.0 hectares (3 hectares of which are occupied by the landfill). In addition to the main structure – the landfill site – the elements of the landfill site are access roads with a hard surface, the economic zone, and the main structures and networks of the landfill site.

The Uzhhorod waste disposal site (in the village of Barvinok) is operational and has been operating since November 1998 under the project of the Ukrkomundorproekt (Uzhhorod). The estimated term of its operation is 25 years. At the WDS, there is documentation regarding the accounting of receipt and disposal of waste following agreements and the accounting of transport flights. As of January 1, 2023, the total volume of removed waste amounted to 6.057 million m^3.

6.2.7 Description of the state of vegetation and animal life

The flora of Transcarpathian, which occupies 2% of the territory of Ukraine, includes about 1,900 species of higher spore and seed plants, which is half of the species floral diversity of Ukraine. Along with introduced species, more than 2,600 species grow in the oblast. According to the general botanical and geographical features of the vegetation cover, the territory of the oblast belongs to the Carpathian subprovince of the Central European province of the European broad-leaved oblast. The Transcarpathian lowland belongs to the Central European floristic province.

The forest fund of the state forestry enterprises of the oblast is represented by the most productive stands in the Carpathian oblast. The average reserve per hectare is 350 m^3, and the average annual periodic increase in the reserve is 5 m^3. The forest massifs of Transcarpathian Oblast rank first in Ukraine in terms of forest cover and wood reserves, and in terms of the area of the forest fund, they are among the top five oblasts. Forest massifs on the territory of the oblast are located mainly in the mountainous part, which accounts for 80% of the territory. Forest coverage of the oblast is 52% (in 1946, this figure was 42%). According to the register, the nature reserve fund of the Transcarpathian oblast amounts to more than 202.5 thousand ha, or 15.5% of the territory of the oblast, and in Ukraine as a whole – 4%. The largest territories of PZF of national significance are the Carpathian Biosphere Reserve, Synevyr National Natural Park, Uzhan National Natural Park and Enchanted Territory.

The modern flora of the oblast includes more than 2,000 species, which corresponds to 50% of the total number of species in Ukraine. Of these, 237 species of flora are listed in the appendices of the Convention on the Conservation of Wild Flora and Fauna and Natural Habitats in Europe, 22 species of flora are listed in the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). A total of 263 species of plants are listed in the Red Book of Ukraine, including 214 species of vascular plants, 19 species of fungi, 7 species of algae, 23 species of lichens, and 27 plant groups listed in the Green Book of Ukraine. The greatest diversity of "red book" plant species is concentrated in the basin of the Tisza River, where, according to scientific research, 145 types of vascular plants.

The modern fauna of the oblast includes more than 30,000 species. Both invertebrates and vertebrates are common in the oblast. Among invertebrates, there are representatives of more than 20 types of organisms, most of which are protozoa. About 400 species of vertebrates, 80 species of mammals, 287 species of birds, of which 197 are nesting, 10 species of reptiles, 16 amphibians, 60 fish, 100 mollusks.

The hunting farms of Transcarpathian are home to animals listed in the Red Book of Ukraine: badgers, otters, forest cats, capercaillies, the number of which has been gradually increasing in recent years.

The total number of species of fauna in the oblast is 30,428, which is 68% of the total number of species in Ukraine, of which 127 are listed in the Red Book of Ukraine, 12 species are listed in the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, 237 species are listed in the appendices of the Convention on the Conservation of Wild Flora and Fauna and Natural Habitats in Europe (Bern Convention), 21 species are listed in the appendices of the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention, CMS) and 21 species are protected in accordance with the agreement on conservation of bats in Europe (EUROBATS).

According to information[44], the constituent elements of the eco-network of Uzhhorod are wetlands with an area of 0.1 thousand hectares, forests and other wooded areas – 0.3 thousand hectares, there are no objects of the nature reserve fund. On the territory of Uzhhorod, as well as on the territory of the planned activity, there are no wetlands of international importance protected by the Ramsar Convention[45], objects of the Emerald Network[46].

There are no material objects, including architectural, archaeological and cultural heritage, on the territory of the site of the planned activity.

On the territory of the planned activity, there are no monuments of architecture, history and culture (as building objects), recreation areas, or cultural landscapes in the area of influence of the object.

Without the implementation of the planned activity, indicators of the quality of the environment will most likely remain at the current (basic) level, and the implementation of the planned activity will solve one of the environmental problems of the oblast – reducing the load on the Uzhhorod municipal landfill, due to the extraction of resource-valuable components from the amount of municipal waste.

6.3 Description of environmental factors likely to be affected by the planned activity

The planned activity is the operation of the MBT plant in Uzhhorod.

Fig 6.1 shows the recommended location of the MBT plant.

6.3.1 Description of the state of health of the population

According to the data of the Main Department of Statistics in Transcarpathian Oblast, as of January 1, 2022, the permanent population of Uzhhorod was 115,449 people[47].

According to the "Annual Report on the Health of the Population, the Sanitary-Epidemiological Situation and the Results of the Health Care System of Ukraine. 2017"[48] in Transcarpathian Oblast, during 2013-2017, the prevalence of diseases among the adult population increased.

The impact on public health from the implementation of the planned activity is not expected given the proposed location of the MBT plant near the active landfill site, as well as compliance with the technology of mechanical and biological treatment, the implementation of construction and technological requirements of the project and regulatory recommendations.

6.3.2 Description of the state of fauna, flora, biodiversity

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[44] https://ecozakarpat.gov.ua/wp-content/nd/Zakarp_reh_dop_2021.pdf
[45] https://www.ramsar.org/country-profile/ukraine
[46] https://emerald.eea.europa.eu/
[47] http://www.uz.ukrstat.gov.ua/
[48] Annual report on the state of health of the population, the sanitary-epidemic situation and the results of the health care system of Ukraine. 2017 / Ministry of Health of Ukraine, State University "UISD Ministry of Health of Ukraine". – Kyiv: "Medinform" International Center, 2018. – 458 p.

The site is free from construction, located in the sanitary zone of the waste disposal landfill in Uzhhorod (in the village Barvinok) next to the forest plantations of the Uzhhorod Forestry branch of the State Enterprise “Forests of Ukraine”, to the north is the waste disposal landfill, to the east – a cemetery, to the west and the south – private land sites.

The planned activity does not bring significant changes to the flora and fauna.

The impact of the planned activity (during construction and operation) on plant and animal impact – partially affected.

6.3.3 Description of the state of the land (including the extraction of land sites), the state of the soil and the geological environment

The proposed site is free from construction, and there are green spaces.

During the construction of the MBT plant and its operation, there will be an insignificant impact on the geological environment, which will be expressed in the alienation of land for the location of the object, a change in the topography, and an increase in the load on the soil due to the weight of buildings and cars.

In the process of mechanical and biological processing of waste, material is obtained at the output, which must be placed in the environment. Such material practically does not contain an organic component and can be considered conditionally inert. Therefore, the impact on land resources is reduced compared to the simple landfilling of hazardous waste.

The impact of the planned activity (during construction and operation) on the soil – affects.

6.3.4 Description of the state of the geological environment

To characterize the site of the planned activity, the characteristics of the location of the landfill site are also taken into account.

In terms of geomorphology, the MSW landfill is located on a slope, and three buried MSW storage sites (pits) have been built on the allocated land. The absolute surface marks are 134.5 m (top) and 124.5 m (bottom). The capacity of the aeration zone is 2.0 m, and the composition and structure are natural loam. The depth of underground water is 5.0 m, conditionally protected. Groundwater is spontaneous and seasonal, located at a depth of 4.0-5.0 m. The presence of filtration phenomena – runoff during precipitation.

The impact of the planned activity (during construction and operation) on the soil – affects.

6.3.5 Description of the state of the water environment

The site for placing the MBT plant is far from surface water bodies and is not located in the sanitary protection zones of water supply sources.

That is, the impact on surface water bodies during construction and operation is not expected. In addition, such an impact will be minimized by implementing the following measures: conducting environmental protection briefings for employees before the start of construction; maintaining cleanliness at the construction site; organization of waste removal; compliance with the technology of work performance and further operation of the object; accounting for drinking and technical water; arrangement of a proper drainage system.

It is advisable to assess the impact on groundwater during the development of project documentation.

Most MBT plants have closed water supply cycles within the enterprise, which involves the use of wastewater from one stage for other processes, the return of water to the beginning of the process, etc.

The stage of mechanical treatment of waste is a source of wastewater from the processes of washing and collecting premises, as well as leachate from waste storage areas.

Such wastewater is contaminated with suspended particles of waste and dust, dissolved organic compounds, petroleum products and oils (leakage from used mechanisms) and has high mineralization and a high level of biological pollution.

Typically, wastewater is collected using a storm sewer system, partially cleaned of suspended particles and large debris, and directed to the biological stage of the MBT process.

Aerobic waste processing processes require a constant supply of water to ensure the humidity of the waste at the level of 40-60%. If the water distribution system is imperfect, the formation of leachate containing a significant amount of easily degradable organic matter, humic acids, nitrates and suspended matter is possible.

This filtrate, after partial cleaning of suspended particles, is sent back to the irrigation system of composted waste.

That is, the negative impact of wastewater, which will be generated during the operation of the MBT plant, will be minimized by following the technological process, as well as by arranging a proper drainage system.

The impact of the planned activity (during construction and operation) on the aquatic environment – affects.

6.3.6 Description of air condition

During the anaerobic process, polluting impurities are included in the composition of biogas and enter the atmosphere during combustion. Such impurities include carbon monoxide, nitrogen oxides, sulfur oxides, hydrogen sulfide. In emergencies and when discharging through safety valves, methane and other volatile organic compounds may enter.

At the stage of mechanical processing, dust, bioaerosol and odorants enter the atmospheric air.

Emergencies and harmful emissions into the air are not expected.

If the composting technology is not followed, ammonia and carbon monoxide may be released into the atmosphere. Minimization of such an impact is expected due to compliance with the technology of processing waste.

The main source of atmospheric pollution from biogas production processes is its burning. The composition of gas emissions is similar to emissions from any thermal process. The difference lies in the almost complete absence of heavy metals and organochlorine compounds.

To minimize the negative impact on atmospheric air, it is necessary to install a system of biofilters.

For a more detailed assessment of the impact on atmospheric air during the environmental impact assessment procedure, it is necessary to measure the air quality near the site of the planned activity.

The impact of the planned activity (during construction and operation) on the air environment - affects.

6.3.7 Description of climatic factors (including climate change and greenhouse gas emissions)

Mechanical-biological treatment of waste reduces the amount of waste to be disposed of in landfills, which directly prevents methane emissions that could occur in the case of disposal in landfills and landfills. In addition, burning biogas for energy production generates less CO_2 emissions than conventional burning of fossil fuels.

Improving air quality and safety (reducing SOx, NOx and dust emissions) by burning fewer fossil fuels for electricity generation and reducing biogas emissions reduces the risk of dangerous methane concentrations at landfill sites and reduces the impact of odors in residental areas[49].

The impact of the planned activity (during construction and operation) on the climate and microclimate is not affected.

6.3.8 Description of material objects, including architectural, archaeological and cultural heritage, landscape

[49] https://saf.org.ua/wp-content/uploads/2019/08/tna-ukraine-tfs-06w.pdf

According to information[50], the constituent elements of the eco-network of Uzhhorod are wetlands with an area of 0.1 thousand hectares, forests and other wooded areas – 0.3 thousand hectares, there are no objects of the nature reserve fund.

On the territory of Uzhhorod, as well as on the territory of the planned activity, there are no wetlands of international importance protected by the Ramsar Convention[51], objects of the Emerald Network[52].

There are no material objects, including architectural, archaeological and cultural heritage on the territory of the sites of the planned activity.

The impact of planned activities (during construction and operation) on protected objects is not affected.

6.3.9 Description of socio-economic conditions

Given the location of the MBT plant, the prevailing wind direction, compliance with composting technology, the implementation of construction and technological requirements of the project and regulatory recommendations, the negative impact of the planned activity on the social and man-made environment is not expected.

On the other hand, a positive impact is expected due to the minimization of environmental pollution due to the reduction of the amount of hazardous waste that accumulates at landfills, the reduction of the man-made load on the hazardous waste landfill, the improvement of the covered settlements, the development of local waste management infrastructure, and the reduction of social tensions due to the limitation of land sites for the creation of new landfill sites in Transcarpathian. The planned activity will contribute to the improvement of the general socio-economic situation due to the payment of taxes to local budgets and the creation of new jobs.

6.4 Description and assessment of the possible impact on the environment of the planned activity, in particular, the magnitude and scale of such impact, nature, intensity and planting, probability, expected onset, duration, frequency and inevitability of the impact

6.4.1 Execution of preparatory and construction works and implementation of planned activities

<u>At the construction stage:</u>

- to atmospheric air – during the operation of the engines of construction mechanisms and transport, when the soil is poured, emissions of pollutants are expected, which do not exceed the maximum permissible concentrations (MPC) of pollutants in the atmospheric air of populated areas.
- no impact on the aquatic environment is expected.
- impact on the flora and fauna, protected objects - not expected, on the flora – a more detailed assessment should be carried out regarding the presence of forest plantations on the territory of the site for the planned activity.
- changes in climate and microclimate are not expected.
- noise and vibration during the operation of construction machinery.

Man-made environment – does not cause a violation of the surrounding man-made environment under the conditions of comprehensive compliance with the rules for the operation of buildings, structures and technological equipment.

There are no monuments of architecture, history and culture (as building objects), recreation areas, or cultural landscapes in the zone of influence of the object.

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[50] https://ecozakarpat.gov.ua/wp-content/nd/Zakarp_reh_dop_2021.pdf
[51] https://www.ramsar.org/country-profile/ukraine
[52] https://emerald.eea.europa.eu/

Soil and land resources – during the design of the object, the development of the soil will be provided following the requirements of the current legislation and the improvement of the territory after the completion of construction works.

At the operational stage:

- to atmospheric air – pollutant emissions from transport engines and special equipment are expected;
- on the aquatic environment – the formation of wastewater is expected; abstraction of water from surface and underground water sources and discharge of wastewater into surface water bodies is not foreseen;
- generation of industrial and municipal waste is expected;
- noise and vibration during the operation of technological equipment, transport;
- flora and fauna, protected objects – not expected;
- climate and microclimate – not expected;
- man-made environment – does not cause a violation of the surrounding man-made environment under the conditions of comprehensive compliance with the rules for the operation of buildings, structures and technological equipment.

There are no monuments of architecture, history and culture (as building objects), recreation areas, or cultural landscapes in the zone of influence of the object.

- soil and land resources – does not cause a negative impact under the conditions of comprehensive compliance with the rules of operation of the facility.

6.4.2 Emissions and discharges of polluting substances, noise, vibration, light, heat and radiation pollution, radiation and other impact factors, as well as the implementation of operations in the field of waste management

At the construction stage:

Impact on atmospheric air - during the operation of engines of construction mechanisms and transport, when soil is poured, emissions of pollutants are expected, which do not exceed the values of maximum permissible concentrations (MPC) of pollutants in the atmospheric air of settlements.

Impact on the aquatic environment is not expected.

Impact on flora and fauna, protected objects is not expected.

Changes to the climate and microclimate are not expected.

Man-made environment - does not cause a violation of the surrounding man-made environment under the conditions of comprehensive compliance with the rules for the operation of buildings, structures and technological equipment.

There are no monuments of architecture, history and culture (as building objects), recreation areas, or cultural landscapes in the zone of influence of the object.

Soil and land resources – the project documentation will provide for the development of the soil following the requirements of current legislation and the improvement of the territory after the completion of construction works.

Noise and vibration during operation of construction equipment.

At the operational stage:

- to atmospheric air – pollutant emissions from transport engines and special equipment are expected;
- on the water environment – the formation of wastewater is expected, water withdrawal from the surface and underground water sources and discharge of wastewater into surface water bodies is not expected;
- generation of industrial and municipal waste is expected;
- noise and vibration during the operation of technological equipment, transport;
- flora and fauna, protected objects – not expected;
- climate and microclimate – not expected;
- man-made environment – does not cause a violation of the surrounding man-made

environment under the conditions of comprehensive compliance with the rules for the operation of buildings, structures and technological equipment.

6.4.3 Risks to human health, cultural heritage objects and the environment, including due to the possibility of emergencies

Given the location of the MBT plant, the prevailing wind direction, compliance with composting technology, the implementation of construction and technological requirements of the project and regulatory recommendations, the negative impact of the planned activity on the social and man-made environment is not expected.

Instead, a positive impact is expected due to the minimization of environmental pollution due to the reduction of the amount of hazardous waste that accumulates at the hazardous waste landfill, the reduction of the man-made load on the hazardous waste landfill, the improvement of settlements, the development of local waste management infrastructure, and the reduction of social tensions due to the limitation of land sites for the creation of new landfill sites in Transcarpathia. The planned activity will contribute to the improvement of the general socio-economic situation due to the payment of taxes to local budgets and the creation of new jobs.

6.4.4 Cumulative impact of other existing facilities, planned activities and facilities for which a decision on implementation of the planned activity has been received, taking into account all existing environmental problems associated with territories of special nature protection importance, which may spread influence or on which the use of natural resources may be carried out

The probability that the implementation of the project will lead to such possible impacts on the environment or human health, which in themselves will be insignificant, but taken together will have a significant total (cumulative) impact on the environment, is insignificant.

6.4.5 Impact of the planned activity on the climate, including the nature and scale of greenhouse gas emissions, and the sensitivity of the activity to climate change

The impact of the planned activity (during construction and operation) on the climate and microclimate – not affected.

6.5 General description and assessment of the possible impact on the environment of the planned activity of the MBT plant

During the operation of the MBT plant, various risks of impact on the surrounding natural environment are possible. Table 6.4 shows the general assessment by types and amount of expected waste, emissions (discharges), pollution of water, air, soil and subsoil, noise, vibration, light, heat and radiation pollution, as a result of the implementation of the planned activity, developed based on "Methodology for the development of environmental impact assessment natural environment for solid municipal waste management facilities"[53] (approved by order of the Ministry of Construction, Architecture and Housing and Communal Services of Ukraine dated January 10, 2006 No. 8).

[53] https://zakon.rada.gov.ua/rada/show/v0008667-06#Text

Table 6.4 – Assessment by types and quantity of exposure risks (waste, emissions (discharges), water, air, soil and subsoil pollution, noise, vibration, light, heat and radiation pollution as a result of activities)

Direction of influence	Impact characteristics
Waste	Only municipal waste should enter the MBT plant (all technological variants). The ingress of hazardous, medical and industrial waste can affect the quality of the product, and the efficiency of the technological cycle of the plant and pose a danger to personnel. According to the morphological composition of the city's solid waste, no more than 2% by weight of hazardous, medical or industrial waste can enter the MBT plant. In the case of detection and identification of hazardous waste during work, it is necessary to take measures for their removal and disposal following the requirements of the current legislation of Ukraine
Surface and underground water	The operation of the MBT plant may contain uncontrolled leaks of pollutants during technological operations. The filtrate produced from "new" municipal waste is characterized by a high COD rate – more than 10,000 mgO_2 /l and a high concentration of heavy metals. The salinity of the "young" filtrate reaches 5-15 g/l. Leachates pose a serious threat to surface and underground water resources, in many cases with invisible long-term effects. Although the volumes of leachate, in comparison with municipal wastewater, are much smaller, their toxicity and concentration pose a serious threat to human health and the environment as a result of potential contamination of drinking water sources. The structural and technological scheme of the plant minimizes these risks. Technical decisions have been made regarding the collection of leachate leaks for sending them to local treatment facilities. It is possible to control leaks by following technological requirements
Soil and subsoil	The operation of the MBT plant, carried out following the requirements of the current DBN, does not pose a threat to the subsoil
Atmospheric air	The following pollutants may be formed during work and movement of equipment: dinitrogen oxide, carbon monoxide, substances in the form of suspended solid particles (microparticles and fibers), methane, carbon dioxide, nitrogen dioxide. Currently, according to the results of laboratory-instrumental studies, these substances are produced in small quantities without exceeding the MPC norms. It is possible to influence the level of pollutants by observing technological regulations
Acoustic influence	During work, stationary and technological equipment, machines and mechanisms are sources of acoustic pollution. To minimize the impact of acoustic pollution on employees of the plant, it is necessary to observe occupational health and safety measures when working at an enterprise with acoustic pollution. During the operation of the MBT plant, the level of technological noise at the border of the sanitary protection zone will not exceed 75 DB
Light, thermal and radiation pollution	Isolated cases of radioactively contaminated municipal items entering the MBT plant are possible. These can be municipal items from hospitals that use radiation for therapeutic purposes. To make such cases impossible, equipment for radiation control of garbage trucks should be installed in the control area of the landfill site following the requirements of DBN B.2.4-2-2005

Direction of influence	Impact characteristics
	A garbage truck that does not meet radiation control standards is removed to a separate site and unloaded. A search is underway for contaminated waste, which is removed for decontamination by special services (DSNS)
Flora and fauna	Impact on local fauna and flora is not expected
Technological risks/accidents that may affect public health	Since the processing of mixed municipal waste is accompanied by the formation of biogas, there is a high probability of self-ignition of the waste after 3 days of exposure. Therefore, the potential for spontaneous fires in the warm season should be taken into account. To manage this impact, it is necessary to ensure the availability of a sufficient number of water containers and fire-fighting equipment on the territory of the MBT plant, provide detailed training of workers in fire safety, limit access to the work area, provide workers with appropriate protective equipment (in particular, methane concentration detectors, etc.). Employees of the plant must strictly adhere to the rules of operation of the municipal waste sorting and processing facilities and technological regulations of the enterprise
Epidemiological impact on the population	The MBT plant is an indirect threat to the epidemiological situation. Thus, municipal waste can pose a threat directly to the workers of the enterprise and be a source of dangerous infections through local animals, such as dogs, rodents, birds, etc. To manage this influence, it is necessary to carefully follow the technological regulations of the enterprise. When leaving, specialized motor vehicles must pass a point for washing wheels and bodywork. Special sound and bioacoustics equipment is installed to scare away birds. Employees of the plant must be equipped with personal protective equipment and instructed in safety rules when working with municipal waste

CONCLUSIONS TO PART I

According to the results of Stage I of the study "Technical Feasibility Assessment, Financial Analysis and Feasibility Study of the System for the Separate Collection of Secondary Raw Materials", Part I "Development of the Feasibility Study for the Separate Collection of Secondary Raw Materials in the City of Uzhhorod", the following was obtained.

1) The **analysis of international and domestic experience in the management of municipal waste and the analysis of the existing practices of separate collection of waste and methods of their processing in Ukraine** revealed the existing advantages and disadvantages in this matter and made it possible to establish that the technologies for storing municipal waste at landfills or landfills were the most widespread in Ukraine (the least efficient method of waste management) and waste incineration (a less common method). The most common methods in EU countries are composting, mechanical-biological treatment and incineration waste

In addition, in the European waste management system various technological capabilities and processing processes optimally complement each other, which ultimately leads to effective waste management. Therefore, the experience of the EU regarding the refusal to bury municipal waste at municipal waste landfills and the use of new methods and practices of waste management is quite relevant for Ukraine. It is advisable at the initial stages of the development of the waste management system and its effective operation to adopt the experience of separate collection and sorting of waste, gradually adjusting and improving methods and practices and developing one's waste management system for the existing features of the territory of Ukraine.

One of the most important processes in the proposed concept of management solid waste at work is the process of sorting them by introducing a system of separate collection of municipal waste throughout the city, including valuable recyclable components (paper, cardboard, glass, polymer materials, metals). The organization of a separate collection of waste is one of the most promising ways to solve the problem of municipal waste. Based on the available initial data and local conditions, the creation and development of the main infrastructure facilities of the municipal waste collection system, which includes specialized municipal waste collection points, is planned in Uzhhorod; a container system for the separate collection of municipal waste (resource-valuable components) and a container system for the collection of mixed municipal waste (including underground containers). In addition, following the National Waste Management Strategy in Ukraine until 2030, the creation of a network of collection points for the reuse of furniture, municipal appliances, clothes and other goods that were in use, and waste collection centers for their repair for reuse is provided (primarily WEEE). Possibilities/variants for the installation of container sites of closed type and with underground containers were analyzed**, taking into account the location of underground networks in Uzhhorod and determining their estimated load**.

2) Currently, in Ukraine and selected oblasts, the implementation of projects based on various variants for the treatment of municipal waste, including mechanical and biological treatment, may face several risks that will lead to a delay in the implementation of the project or to its complete stop. Therefore, the issue was reviewed in the context of the formation of a safety basis for the implementation of waste management projects at the state, economic, social and technological levels within the framework of a factorial PEST analysis, based on the results of which the main risks were **determined implementation of projects for the construction (location) of the facility for processing (sorting) of secondary raw materials**, which may arise during the implementation of the project (including various technological variants). To establish effective enterprise management, it is recommended to implement ISO 31000 "Enterprise risk management system".

3) When **the feasibility (acceptability) of the implementation of the construction project for the processing (sorting) of secondary raw materials has been studied for the city of Uzhhorod,** by conducting a multifactorial analysis of various technological variants for waste treatment, evaluating various waste treatment technologies and the averaged morphological composition of municipal waste for Uzhhorod, it was established that the most acceptable technological variant according to the established criteria in the conditions of the city is the

introduction of mechanical and biological waste treatment. The implementation of the construction of the MBT plant will allow for an increase in the amount of extracted resource-valuable components of municipal waste and to obtain secondary raw materials of better quality.

4) as the main **technological schemes of various variants for the operation of the object of processing (sorting) of secondary raw materials for Uzhhorod**:

- A) sorting of municipal waste with the extraction of secondary raw materials; obtaining alternative fuel RDF/SRF (up to 30% of the total mass of waste), composting of bio-waste (up to 40% of the total mass) and landfilling of unsorted residue and inert waste (variant No.1);
- B) sorting of municipal waste with the extraction of secondary raw materials; anaerobic fermentation of bio-waste to obtain biogas (up to 40% of the total mass); landfilling of unsorted residue and inert waste (variant No.2);
- C) sorting of municipal waste with the extraction of secondary raw materials; stabilization of bio-waste (up to 40% of the total mass) and landfilling of unsorted residue and inert waste (variant No.3).

5) **The scheme of the location of the planned objects and structures of the object of processing (sorting) of secondary raw materials (MBT plant) for Uzhhorod** on the selected site is provided. It is advisable to provide for the allocation of construction phases. The first phase is the construction of a waste-sorting plant, the second phase is the bio-waste composting plant.

6) For the 3 main technological schemes of various variants for the operation of the object of processing (sorting) of secondary raw materials for Uzhhorod, **consolidated estimates of the cost of their implementation - construction (location) of the object of processing (sorting) of secondary raw materials** were obtained (according to the variants for completing the MBT plant):

- A) bio-waste composting (compost production) (variant No. 1).
- B) anaerobic fermentation of bio-waste (production of biogas and its utilization in a cogeneration plant) (variant No.2).
- C) stabilization of bio-waste (obtaining inert waste) (variant No. 3).

7) According to the results **of the assessment of the impact on the environment of various projects for the construction (placement) of the facility for the processing (sorting) of secondary raw materials in Uzhhorod**, it was established that during the operation of the MBT plant, various risks of impact on the environment are possible, and a general assessment by types and quantity was provided expected waste, emissions (discharges), water, air, soil and subsoil pollution, noise, vibration, light, heat and radiation pollution, as a result of the planned activity.

PART II.
FEASIBILITY STUDY OF THE MOST SUITABLE TECHNICAL SOLUTION FOR ORGANIC WASTE, SORTED MUNICIPAL AND COMMERCIAL GREEN WASTE MANAGEMENT IN UZHHOROD

CHAPTER I. ANALYSIS OF TECHNICAL SOLUTIONS REGARDING BIO-WASTE TREATMENT

1.1 Implementation of a bio-waste management system (municipal and commercial waste from green spaces and other biodegradable waste)

The system of urban and commercial bio-waste, including waste from green areas and other biodegradable waste management, includes a set of measures for their collection, transportation and treatment (recovery and disposal), respectively, at the created waste treatment facilities.

The choice of technical solutions for the management (collection, transportation and treatment) of bio-waste depends on many factors and must be carried out according to several criteria depending on local conditions (taking into account the natural and climatic conditions, sanitary conditions and quantitative and qualitative parameters of bio-waste components, sanitary and hygienic requirements, requirements for the use of the finished product, technical capabilities of waste treatment facilities, etc.), in addition, the technologies must have a positive implementation experience that will ensure effective and economically feasible management of bio-waste.

For high-quality preparation for treatment, bio-waste should not be mixed with other types of waste or materials with different properties, that is, collected separately. Separate collection of bio-waste (municipal and commercial waste from green spaces and other biodegradable waste) should precede the stage of their processing, which will further contribute to ensuring the efficiency of the entire subsequent processing process.

Models of separate collection of municipal waste (MW), including bio-waste, are formed depending on the accepted model of waste management, determined by the regional waste management plan in the region. The provisions of “Methods of Separate Collection of Municipal Waste” are used for the Separate Collection of Waste and its Implementation[54].

The creation of conditions for the separate collection of bio-waste and its implementation is carried out in the following stages:

- determination of the scope of bio-waste management services;
- carrying out calculations of the average daily and average annual generation of bio-waste in the composition of MW to determine the prospective volumes of obtaining raw materials after their treatment;
- identification of consumers of raw materials obtained from bio-waste, and/or substantiation of the need for the construction of special installations for the treatment of bio-waste in order to obtain raw materials;
- determination of the requirements of consumers of raw materials for the quality of bio-waste and the cost of accepting it for treatment;
- selection of a technological scheme for the separate collection of bio-waste;
- selection of types and calculation of the number of containers for bio-waste collection, purchase of containers;
- selection of a rational scheme for the location of containers and, if necessary, the construction of container sites;
- determination of the system and mode of transportation of bio-waste;
- selection of types and number of specially equipped vehicles for transportation of bio-waste.

Separate collection is implemented in stages, in particular at the first stage - by conducting experiments on the separate collection of bio-waste in separate areas of the settlement using different technological schemes to determine the most effective and acceptable for this settlement. It is important to pay constant attention to preserving the proper appearance and maintaining proper sanitary and technical condition of container sites and containers placed on them.

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

Taking into account the importance of separating bio-waste from the total amount of waste for further treatment, transportation of bio-waste to the treatment facility should be carried out with the help of specially equipped vehicles for the transportation of bio-waste, which requires the implementation of a system of organized separate removal of bio-waste.

Treatment of bio-waste consists of its recovery and/or disposal (including preparation) and depends on the accepted technological scheme of bio-waste collection. Recovery/disposal of bio-waste takes place at waste treatment facilities following the accepted processing technology (lists of operations for recovery/disposal of bio-waste are provided in the Law of Ukraine "On Waste Management"). Recovery/disposal of the existing volumes of bio-waste generated in the settlement is possible only if there is production capacity for their treatment.

Currently, the most common operation in Ukraine for the disposal of municipal and commercial bio-waste, including waste from green spaces and other biodegradable waste, is disposal in landfills and dumps of solid waste, which does not involve their treatment. Since bio-waste is generated and collected directly at the sites of generation regularly from early spring to late autumn and is one of the main fractions of MSW and constitutes a significant part of the total amount of MSW generated, its proper management will create great opportunities for its reuse, as well as will significantly reduce their mass at waste disposal sites. The introduction of a bio-waste management system using the best technologies and, accordingly, the most suitable technical solutions is very important from the point of view of ecology, economy and achieving appropriate levels of limiting their storage and accumulation, which will allow to partially solve the existing problems and threats related to municipal waste.

1.2 Selection of the bio-waste treatment method

Currently, biological, thermal, chemical, mechanical and mixed methods are used to treat bio-waste. Given the need to ensure environmental and energy security, the use of biological processing of bio-waste to obtain useful products (compost and biogas) is particularly relevant.

Considering the presence of a large share of bio-waste in the composition of solid waste, one of the priority areas in the development of the field of bio-waste management, including separately collected municipal and commercial waste from green spaces and part of bio-waste from mixed solid waste, in Uzhhorod is the use of biological treatment methods (aerobic composting and anaerobic fermentation), which make it possible to reduce the volume of waste with obtaining target products (including the return of part of organic materials for reuse) and to significantly reduce the amount of waste to be buried in landfills and landfills.

As of 2023, for the conditions of Uzhhorod, based on the analysis of the characteristics of the most common bio-waste treatment methods, 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.

Thus, the optimal method of management for 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 simpler, but with greater compliance with the requirements environmental safety and with the lowest level of capital investments and operating costs in comparison with alternative methods of waste treatment (waste incineration, anaerobic fermentation, disposal at landfills) is the composting method. If disposal at landfills takes 50-100 years, then composting takes 6-18 months, depending on climatic conditions. 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. The simplest variant for composting is the use of individual composters in private sites of individual buildings in the city (private sector houses).

At the initial stage of the implementation of the bio-waste management system in Uzhhorod, its treatment can be started with a relatively simple technical solution, for example, with centralized composting of separately collected urban 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 site 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 and simultaneously conducting powerful informational work with the population.

1.3 Basics of bio-waste composting process

1.3.1 Preparation of bio-waste for composting

Bio-waste delivered to the composting station is usually in a state that is not suitable for direct composting. Cut branches and shrubs, wood, cuttings, tree stump and trunk clippings, as well as grass, hay and leaves should be shredded before placing in compost bins to ensure optimal decomposition.

Many devices are used for such work, the main two types: high-speed machines – shredders or crushers (hammer crusher, hammer mill, cutting mills, etc.), and slow machines (one- or two-roll crushers, screw mills, etc.).

Usually, before composting, bio-waste is passed through an integrated sieve during unloading, so the output product contains a certain particle size in the range of 150-500 mm. As a rule, such material is very fibrous and has freshly broken surfaces to which microorganisms can easily adapt.

1.3.2 Management of the bio-waste decomposition process

Aeration of compost clamps piles with oxygen

Compost clamps that are not saturated with carbon dioxide should be provided with access to fresh air, which should be dispersed within the pile between turning operations. In the clamps that are not saturated with carbon dioxide, which is very important, it is necessary to pay attention to the correct ratio of the cross-sections and the mixture of materials (especially the volume of air cavities, temperature and controlled oxygen aeration), which guarantees the activity of the aerobic process in the clamp.

Adequate oxygen supply can be optimized with an additional aeration system in addition to regular overturning.

Artificial ventilation of compost clamps allows to creation of them in larger sizes, as a result, the territory is used economically. For a guaranteed active aerobic process, different aeration methods are used in the clamps (positive or negative aeration pressure, aeration controlled by temperature or oxygen, etc.).

The moisture level of compost clamp

Watering the clamps guarantees the maintenance of an optimal level of moisture and the strengthening of the decomposition process of bio-waste. Watering can be carried out manually or automatically directly when turning the clamp, which is a more efficient method since the moisture spreads to all the material in the clamp. The watering of stationary triangular clamps must be limited because water penetrates only to a certain depth of the clamp.

Turning/turning compost clamps

During the decomposition process, the air-water-soil ratio in compost clamps changes due to microbial decomposition and some natural causes. Local changes in the structure and distribution of moisture in the compost clamp appear. Due to the large weight of the material above it, the lower layer of the edge is compacted, and excess moisture accumulates at the bottom of the edge. To ensure constant and uniform conditions of decomposition of the entire clamp, it is necessary and important to turn it regularly. Fig. 1.1 shows an example of the use of a machine for turning clamps.

Figure 1.1 – The operation of the machine for turning over compost clamps
(source: https://tehnix.hr/en/)

As a result of overturning, the compaction of the material is weakened, which allows oxygen to penetrate the clamp. At the same time, the activity of microorganisms is stimulated, as a result of which the temperature rises. The penetration of a new dose of oxygen into the clamp prevents the appearance of an anaerobic zone and odor. During the inversion, the dry and wet zones are mixed and the humidity level is equalized.

Regular turning in the phase of intensive decomposition ensures that when mixing the inner and outer zones of the clamp, all particles are in the center of the clamp for a long enough period, and are exposed to high temperatures, which ensures disinfection and destruction of plant seeds.

Turning also ensures a higher level of homogeneity and quality of the compost. Due to the homogeneity of the material, the amount of screening decreases, and the amount of compost increases.

The turning of compost clamps is regulated by the decomposition process and the degree of compaction of the clamps. During decomposition, bio-waste is mineralized, its volume and weight change. Practically, the size and volume of the pores decrease in the clamp, reducing the oxygen saturation, which negatively affects the living environment of aerobic microorganisms and inhibits their activity. During stagnation, the temperature on the clamp drops.

The clamp should be turned no later than the temperature drops to 5°C during the day.

The number of turnings of the clamp depends on the type of material used, its structural stability, the selected size of the clamp, sedimentation of the clamp and the state of decomposition of bio-waste. Therefore, to determine the need for flipping, the following is used:

- the stage of intensive decomposition – the clamp is turned over 2-3 times a week;
- the stage of compost maturation – the clamp is turned 1-2 times a week.

To maintain a constant level of humidity in the compost clamp, it is advisable to cover the bins to avoid the effects of rain, wind, sun and heat. For this, special membranes for composting or translucent film are used.

Covering the clamp can be beneficial for maintaining high vapor levels and the release of organoleptic gases, the amount of which increases over time after inversion.

1.3.3 Refinement of finished compost

Sifting and screening are necessary to refine finished compost or soil and substrates made from compost.

Screening

Basically the resulting compost is not ready for sale immediately after decomposition, it must be sieved to obtain the required particle size of the batch or according to the buyer's request. For this purpose, there are various screening devices (Table 1.1).

Table 1.1 – List of devices used for screening compost and their applications

Device type	Application
Vibro sieve	Dry compost, stones and soil, gravel, sand
Drum sieve	Compost of normal humidity, soil, sand, gravel, various waste
“Star” sieve	Normally moist and under moistened compost, bark, peat, soil
Drum disc	Wet compost, soil, various waste
Rotary-flow sieve	Wet and wet compost, wet waste

Separation of pollutants

<u>Release of air</u>

Air separation, the so-called air-flow separation, is a mechanical sorting process with airflow. The sorting material is divided into two or more fractions depending on the shape and size of individual particles.

Air separators are classified depending on the direction of airflow into three groups - cross-flow separators (air passes over the material flow), counter-flow separators (airflow passes opposite to the material flow) and zigzag separators (air passes in the direction of flow several times). Cross-flow separators are most often used for composting.

Air separators can be used at two points in the composting process:

- during the preparation of input materials for composting and decomposition to remove light materials such as film (thin film) and plastic bags;
- when refining the finished compost to remove film residues, coarse particles remaining after the final screening, so that they can be returned to the composting process in the future.

Air separators are available both stationary and mobile and are usually used for the final screening of finished compost directly after equipment that removes large particles.

<u>Magnetic separator</u>

Metal particles are removed from the compost by a magnetic separator, which removes iron and metal debris from the material stream using an electric or permanent magnet. Many mobile devices (crushers, shredders, screeners, etc.) have such a separator in the form of a magnetic drum at the exit point of the conveyor belt or an upper magnet on the belt equipment. The ideal place for magnetic separation is the outlet section at the end of the belt, because the entire flow of material flows near the magnet, and this is where the best separation of metal particles from the flow will occur.

Centrifugal separator

Centrifugal separators are used to separate non-ferrous metals. Currently, they are widely used in composting, but they are important to obtain a pure final product since non-ferrous metals cannot be removed by sieving.

Stone and glass separators

Separators_of solid materials are needed to remove stones and glass from the compost. They work by exploiting the difference in elasticity and impact properties of hard materials compared to softer compost particles.

The compost goes into special separation drums, where a similar division takes place. In some cases, pneumatic concentrators are used to separate glass and stones.

There are several screening devices or air separators to remove stones from oversized particles in the final screening procedure. Rounded particles (stones, gravel, etc.) are separated using high-speed strip devices with rollers.

1.3.4 Measures to minimize emissions during composting

Reduction of odor

All composting stations emit a typical odor even with optimal process management. To minimize the smell, it is necessary to ensure rapid processing of the delivered material, inhibition of anaerobic processes, optimal control over the process, keeping the composting station in good condition, regular cleaning of roads, etc., taking into account meteorological conditions. It is important to use special devices and appropriate arrangements (for example, a steam condenser to reduce the formation of compost “smoke”, a system for spraying a concentrate that neutralizes the smell and a winder that covers the freshly turned clamps with a film (semi-permeable membrane), etc.).

Adjusting the noise level

A composting plant uses a large number of mobile devices (front loaders, shredders, screening machines, tipping machines) and/or stationary devices (ventilators, conveyors, mixers) for the biological treatment of bio-waste and can produce a high level of noise. Another source of noise is the traffic included in the operation of the composting station (import and export, internal traffic). In general, there is no way to prevent noise produced by machines and vehicles. Provisions on daily vehicle traffic and operating hours of the composting station should be agreed in advance with the local authorities and the population.

Minimization of emissions of microorganisms

Dust and airborne microorganisms can be released from the composting station during the delivery, decomposition, turning and packaging processes. To ensure a hygienically safe operation, appropriate measures must be provided for the technological process, construction and transport of equipment, as well as for the protection of personnel, such as:

- staff must wear masks when working with compost;
- machines must be equipped with dust protection;
- cabs of drivers of mobile cars must be equipped with appropriate filter systems;
- traffic routes must be cleaned of dust, and machines and equipment must be clean;
- it is recommended to take into account the direction of the wind and the environment when planning tasks associated with a high level of emissions;
- ventilation systems in buildings and protective aeration systems in mobile systems must be cleaned and regularly maintained following the manufacturer's recommendations and reviewed annually to ensure their proper functioning.

Collection and treatment of the allocated liquid

At the composting station following liquids can be:

- liquids from bio-waste that are composed;
- water from processing (water from irrigation or rainwater during open composting);

- condensate (with closed composting);
- wastewater from cleaning;
- wastewater from open storage, from roads and roofs.

If a large amount of liquid released by bio-waste or due to climatic conditions is expected, it is important to level the site accordingly to consolidate the collection of liquids and to ensure that the resulting liquid is collected and treated (use for wetting the compost clamps) or removed when not needed.

Prevention of gas formation

Carbon dioxide and other gases such as nitrous oxide (N_2O) and methane (CH_4) produced during microbial decomposition affect the environment. While the release of carbon dioxide is a natural by-product of microbial decomposition and is an unavoidable process, the release of methane and nitrous oxide (laughing gas) can be reduced with proper control of the composting process.

Methane emissions can be reduced with an appropriate C/N ratio and sufficient oxygen. A proper combination of input materials and an adequate volume of sidewall pores play the most important role. The smallest clamps and turning them frequently is an effective countermeasure. Significant emissions of nitrous oxide emissions occur during compost ripening and at temperatures below 45°C, but this can be reduced by creating large clamps and reducing turning.

1.4 Evaluation of different 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: closed and open. Table 1.2 shows the main difference between these systems.

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

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

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.

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 bio-waste treatment facility (composting station), 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 its planning and covering.

Table 1.2 – Advantages and disadvantages of open and closed composting systems

	Open systems	**Closed systems**
Advantages	- low 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)	- high investments

A comparative analysis of the following technical solutions for centralized bio-waste composting, possible for implementation and implementation in Uzhhorod, was carried out:

- closed composting system in tunnels (closed clamps);

- combined composting system in covered clamps (metal sheets, membrane with a metal frame);
- open system of composting in the clamps with aeration.

Composting in tunnels

One possible variant for closed composting systems is tunnel and closed-row composting, where the decomposing materials are stirred 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 also possible and sequential.

Compost tunnels have a process chamber for composting, closed in the upper part, and compost closed rows, the material is stored between two concrete walls without a roof (Fig. 1.2, *a*, *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. Closed rows can be up to 2.2 m with a non-aerated system and 3.5 m with an aerated system.

Figure 1.2 – An example of a composting system in a tunnel (*a*) and in closed rows (*b*)

Compost material is turned over by an automatic device moving along a tunnel or a closed row. 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 closed row is wide enough, a 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. Fig. 1.3 shows the scheme of the composting process in the tunnel.

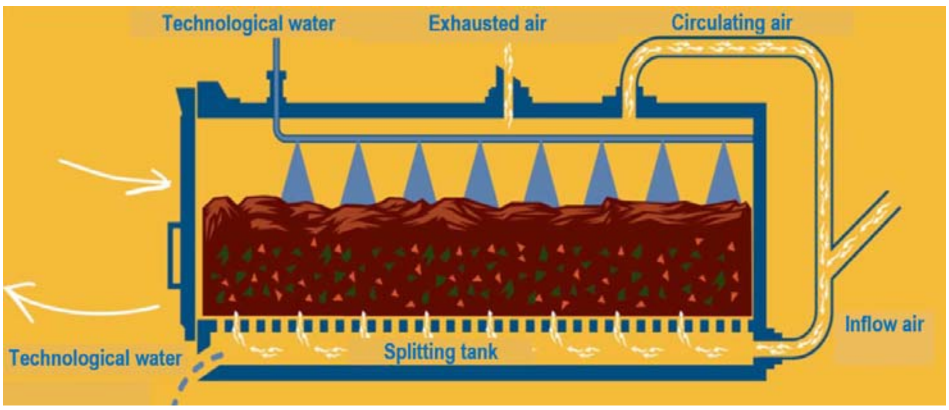


Figure 1.3 – Scheme of the composting process in the tunnel

Composting in covered clamps

Covered composting combines the advantages of open and closed composting systems, refers to methods of accelerated compost production (on average, the process takes 30 days), has various technical variants, is characterized by low processing costs and low construction costs with full control of emissions, as well as high-quality properties of compost.

One of the variants for technical execution is *composting in clamps covered with metal sheets* (Fig. 1.4). Table 1.3 shows the geometric characteristics of the design of the installation and the clamp of the bio-waste. Fig. 1.5 shows the diagram of the process of composting in covered clamps.

Figure 1.4 – An example of a covered clamps composting system (covered with metal sheets)

Table 1.3 – Design characteristics for covered clumps 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

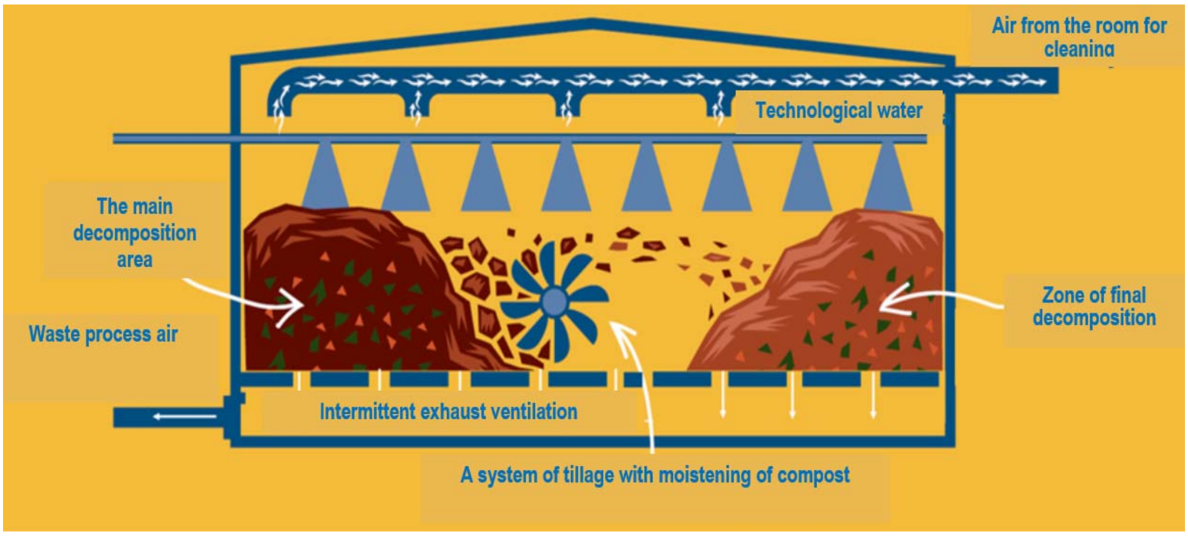


Figure 1.5 – Scheme of the composting process in covered clamps

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 m³/h per 1 ton of bio-waste.

For an active composting process, it is recommended to maintain the optimal humidity of the soil at a level not lower than 60%. In the case of a decrease in temperature in the middle of the edge, it should be moistened until optimal humidity is reached, by watering the edge (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.

Another variant of technical implementation – *composting in the clamps with a membrane* applied as protection against odor emission, occurs by installing a semi-permeable membrane on static blocks of composting units, which must be combined with a forced ventilation system (Fig. 1.6). 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 handling and periodic turning, this type of composting is generally not cost-effective.

Figure 1.6 – An example of a membrane composting system
(source: https://www.compost-systems.com/en/products)

Composting in the clamps with aeration

The simplest technical solution in terms of possible costs is the system of open composting in unreinforced clamps, where bio-waste is composted directly on the top layer of the soil (without soil compaction) (Fig. 1.7, *a*). However, in this case, special requirements regarding the location must be observed (for example, protection of groundwater).

The most common variant of the open composting system is composting in the clamps on a reinforced base (Fig. 1.7, *b*). 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).

Stacking of bio-waste is carried out, as a rule, by a forklift. The clamps have a height of 1.8 to 3.0 m. The shape of the clamps is possible: triangular, trapezoidal or flat.

The average duration of the decomposition process is approximately 10-60 weeks. Fig. 1.8 shows the variants of implementation of aeration in open composting systems at clamps. When laying in clamps with active aeration, the starting material should have an average particle size of the order of 1 cm, and when laying in clamps with passive (natural) aeration is 5 cm. Table 1.4 shows the geometric characteristics of the clamps.

a *b*

Figure 1.7 – An example of a composting system in unfortified (*a*) and fortified (*b*) clamps (source: https://www.compost-systems.com/en/products)

a *b* *c*

Figure 1.8 – Variants of aeration of the composting system in open clamps:
a – passive aeration due to heating ("smoky" effect); *b* – active aeration due to air supply through pipes; *c* – active aeration due to regular turning of the clamps

Table 1.4 – 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 edge, m	145.0

During composting of bio-waste with a triangular the shape of the clamps (Fig. 1.9) uses a specific "smoky" effect. Hot air from the clamp rises up, and fresh air is drawn in at the bottom by suction, which creates a natural flow of air through the clamp, which, in combination with a favorable ratio of the surface area to the volume of the clamp, ensures its effective aeration. The "smoke" effect only works with very bulky material, such as waste from pruning branches, and the height of the shoulder can reach 3 m. In the case of adding wet materials, such as organic fractions of waste or sewage sludge, the height of the shoulder should be limited to 1,5-2 m. Regular turning of the clamp prevents it from settling and forms air channels and also guarantees the looseness of the burr structure with a uniform flow of air through its core.

Optimal decomposition of compost material occurs in a short time. In addition to the advantage of increased edge aeration compared to a trapezoidal or flat edge, triangular edges have the advantage of selective sequential processing due to the small size of the edge. As a result, all the compost material collected during one week can be combined into a separate pile, and also processed separately from the material that appears during the next week. If you combine several weeks' worth of materials into a flat board, the boards that require flipping are moved, which also has a positive impact on the running costs of the bio-waste facility. Another advantage of the clamps in a triangular shape is the efficient drainage of rainwater. In practice, it can be seen that water penetrates only 20 cm, and a large amount of rainwater flows down the clamps.

Figure 1.9 – An example of the “smoky” effect in a composting system in the open clamps of a triangular shape (source: https://tehnix.hr/en/)

The edge in a triangular and flat shape has a more effective volume performance compared to the edge of a trapezoidal shape 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 active clamp aeration does not work in this case. If the clamp is not sufficiently supplied with oxygen, it is not properly turned over, then as a result, the composting time increases and 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 exposed, unprotected clamps, which can cause waterlogging and landslides. For this reason, controlled decomposition processes in a flat-shaped clamp are more difficult and require much more time for the material to break down than in a triangular-shaped clamp.

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

1.5 Recommendations regarding the introduction of composting bio-waste treatment in Uzhhorod

According to the results of the analysis and evaluation of various technical solutions of composting systems, it was established that composting is a flexible process that can be both simple and high-tech in implementation, however, it is one of the rather promising areas of handling bio-waste as a relatively simple and safe method of its treatment and can be considered as an environmental protection technology, in the process of which the destruction of bio-waste takes place, and the result of the process is compost, which can be used as fertilizer and material for stimulating the recovery of the soil layer, for the reclamation of damaged areas, urban green areas, parks, forests, etc., in addition, it can be a way to obtain free and natural and useful fertilizers for the public who have their lawns, gardens and sites, while reducing the amount and volume of accumulation waste from green areas and a part of bio-waste from mixed organic waste.

Biological methods of bio-waste treatment are effective from both ecological and economic considerations, their feature is the absence of the need for significant labor and material costs and the possibility of being applied both individually (directly in municipals) and centrally (for the entire settlement). With centralized composting, it is necessary to ensure a separate collection of urban and commercial waste from green areas and part of bio-waste from mixed waste, which will then be transported to specially equipped facilities for their treatment (composting stations).

To more widely implement the system of bio-waste management, it is necessary to ensure appropriate environmental education of the population to spread information about methods of ecologically safe and economically beneficial management of bio-waste and to introduce restrictive and stimulating measures at the state level.

Considering that there is an urgent need to implement modern bio-waste treatment technologies in Uzhhorod, the final choice of composting technology should be made according to several criteria depending on local conditions to ensure effective and economically feasible management of bio-waste to minimize its impact on the environment by reducing volumes of their accumulation. The formation of an effective system of municipal and commercial waste from green spaces and part of bio-waste from mixed waste management is one of the prerequisites for ensuring the ecological safety of the city's territories and implementing the principles of its sustainable development.

In general, the creation of a bio-waste treatment facility using the composting method should include the following stages:

- analysis of the material and resource base of municipal waste, the amount of compostable bio-waste;
- determination of volumes of compost and ways of its further implementation;
- determination of an available land site for the construction of a bio-waste treatment facility and organization of the composting process;
- obtaining and analyzing data on bio-waste and the location of the site for compliance with the requirements of current regulatory documentation;
- selection of composting technology, technical solutions and equipment, development of necessary technological processes and formulation of recipes for compost mixtures, in accordance with the needs of the city and the market;
- evaluation of existing alternatives and the choice of a rational technology, taking into account the available experience in this field;
- development of project-technological and other documentation of the bio-waste treatment facility for the possibility of implementing its construction and operation;
- putting into operation and ensuring sustainable functioning of the bio-waste treatment facility using the composting method;
- periodic assessment of activity results with appropriate adjustment if necessary in order to improve financial, environmental and other indicators.

1.6 Analysis of the possibility of cooperation in the field of waste management between communities

The goals and objectives of the field of waste management must be consistent with EU directives and the strategy for the development of this field in Ukraine. In the Transcarpathian region, including Uzhhorod, the goal is to cover all residents with an organized system of waste collection and removal, which should be cost-effective and ensure efficient collection and removal of solid waste. IP management must be carried out by state norms, standards and rules. One of the main directions of state policy in this area is to ensure the integrated use of material and raw materials and to promote the maximum possible removal of waste through the direct, repeated or alternative use of their valuable components.

Unresolved issues of waste management, including bio-waste, harm the ecological and social condition of the territory of territorial communities. New spontaneous landfills are constantly emerging, existing landfills do not meet modern environmental norms and standards, exhaust their potential, are overloaded, waste is often stored without sorting and disposal, access roads to landfills need repair, etc. Every year natural landfills cover larger and larger territories, which leads to an increase in the level of ecological danger. First, these are large areas of contaminated land that remain unusable for many years. Secondly, this situation leads to further pollution of the environment with poisonous substances and greenhouse gases. Thirdly, the potential for secondary use of resources is not used. The complex of problems related to environmental protection and public health requires a systematic approach.

Currently, there is limited experience with inter-municipal cooperation approaches between territorial communities in the field of waste management. Although there are examples of communities sharing waste management facilities, communities are generally working independently to implement their waste management systems. Cooperation in the field of waste management between the communities of the Transkarpathian oblast is very limited due to the existing big difference in the standards of providing such services to the population, in particular, that part of that lives in the mountainous area. In reality, many communities do not have waste collection services at all.

Attempts to organize a complex system of MW management based on cooperation, interregional cooperation and pooling of resources of local communities have not yet led to the desired results. However, the cooperation of territorial communities in any field is a tool thanks to which communities can attract additional funds and implement large projects that they cannot implement on their own, improve the quality of service provision and receive additional income.

Detailed planning, calculation of possible risks, drawing up of a contract and successful communication between communities are necessary for the successful implementation of the project. The stages of implementation of cooperation of territorial communities include:

- initiating the possibility of cooperation with potential communities;
- identification of potential areas of cooperation and joint projects;
- preparation of cooperation proposals and their submission for review and approval by the local council;
- beginning of negotiations with potential communities on cooperation and the formation of a commission for the preparation of a draft agreement on cooperation;
- creation of a joint commission on community cooperation to prepare a draft contract;
- approval of the draft contract;
- implementation of a joint project.

Communities can benefit from inter-municipal cooperation in the field of environmental protection management, which can include:

- joint environmental measures and information campaigns in communities;
- creation of an intercommunity municipal center for municipal waste management;
- purchase of joint additional equipment that will serve the settlements of several communities;
- creation of a joint utility company to increase the capacity of the waste management system, etc.

Currently, at the regional level, there is an understanding of the need for purposeful activity in this field, and assistance is provided to local authorities in solving the problem of waste management. The analysis of the current state of the system of waste management of each community is the first and most necessary step on the way to understanding the directions of further activities and solving the problem as a whole. All this creates the necessary prerequisites for the successful implementation of projects in this field to improve the efficiency of the municipal waste management system.

Gradually, appropriate conditions are being created for the maximum use of the advantages of cooperation between territorial communities in Transkarpathian Oblast. "Strategy of Waste Management in Transkarpathian Oblast until 2030"[55] provides that waste collection services will be organized at the district level. This will require the cooperation of local self-government bodies in planning, organizing and contracting for the provision of appropriate MSW management services. The creation of large regional landfills and waste treatment facilities is a more cost-effective solution compared to separate landfills that provide services within only one district.

[55] https://oda.carpathia.gov.ua/sites/default/files/imce/strategia_vidhody_2030.pdf

The spatial structure of settlements in the territory of communities, landscape and ecological features of the territories, the existing system of partnership between different communities, their financial and economic condition, mental characteristics of the population, etc., significantly affect the possibility of placing waste management facilities in certain territories. One of the problems of building new waste treatment facilities in Transcarpathia is the scarcity of land. In mountainous areas, it is almost impossible to find land sites that would meet construction and sanitary standards for such construction. When planning the waste management system in the region, it is assumed that waste will be transported from mountain settlements to lowlands, which causes additional social tension among the population of these areas. It is extremely difficult to obtain the consent of the population during public hearings according to the current legislation. Therefore, it is important to analyze the needs of communities and determine possible ways to solve existing problems. The most potential for cooperation is neighbouring territorial communities located in the same cluster and subregion. As of 2023, the Uzhhorod territorial community borders the Onokivska, Baranynska, and Kholmkivska territorial communities (Fig. 1.10).

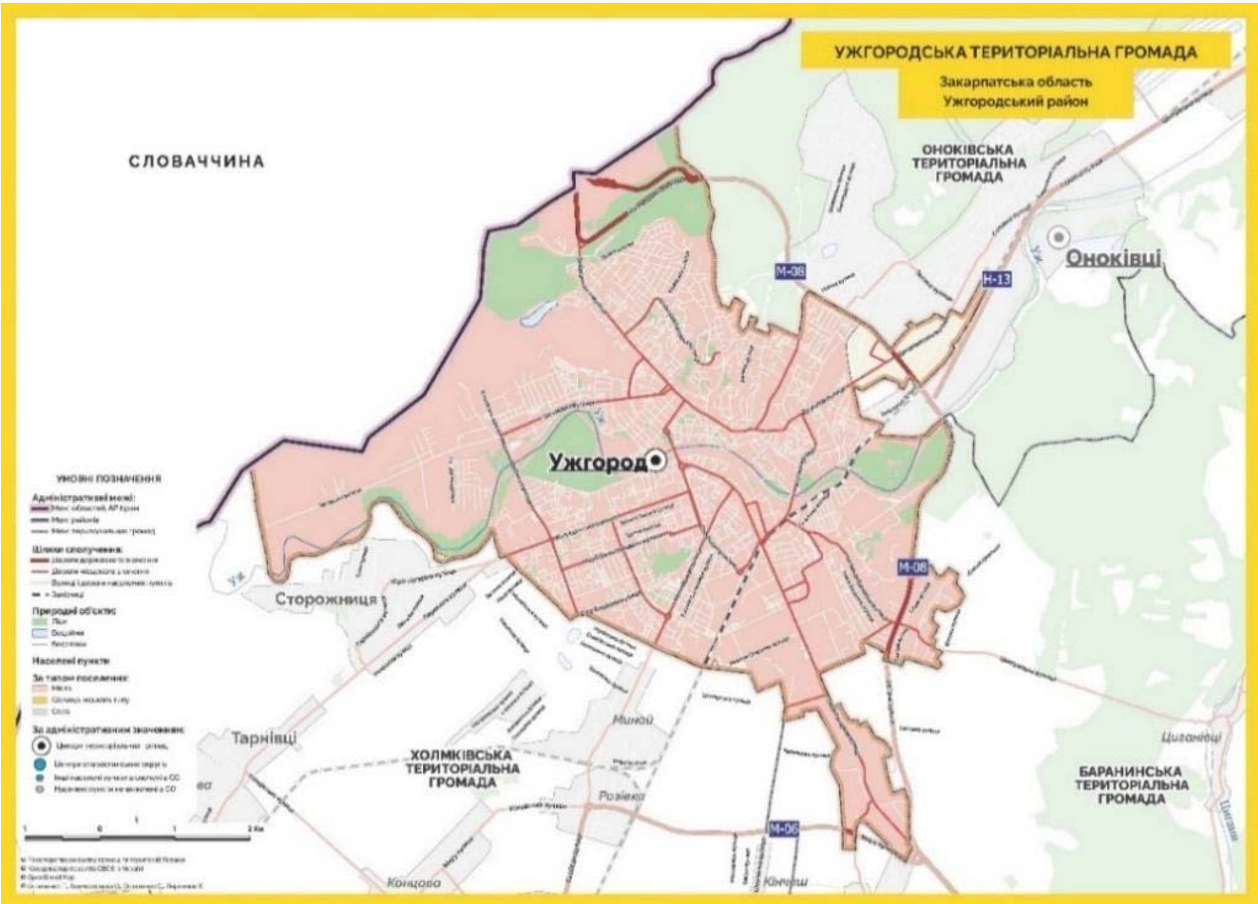


Figure 1.10 – Location of the Uzhhorod territorial community[56]

At the initial stage of implementation of the waste management system, neighbouring communities can be considered as a potential area of coverage of the service because the construction of a central waste treatment facility will be more favorable economically if the surrounding communities are served. It is necessary to conduct a detailed analysis of alternative variants for planning a rational model of the municipal waste management system within each of the territorial communities, while the boundaries of interaction should cover a sufficient amount of resources and optimally use the advantages of close mutual location.

[56] http://surl.li/dlogs

Some components of the waste management system have the potential to generate income. However, the waste management system as a whole will have costs that will have to be paid by residents/legal entities and territorial communities of the region. The cost to residents/legal entities and territorial communities will be minimized if the revenues from the profitable components of the waste management system are retained by the public sector and used to offset the costs of other components. The formation of cooperation initiatives of territorial communities is very important for increasing the efficiency of waste removal costs.

Several benefits can be achieved through greater and better cooperation in waste management, including:

- dissemination and harmonization of knowledge and experience;
- introduction of a new quality of services for citizens;
- improving the quality of service;
- more efficient use of vehicles and equipment;
- increasing economies (due to scale) by jointly concluding a contract for the maintenance of territories;
- increasing opportunities for the introduction of technologies favorable to the environment;
- diversification/distribution of costs/risks on the way to implementing a joint initiative.

These approaches will not only reduce the amount of waste disposal and its negative impact on the environment but will also provide an opportunity to obtain secondary raw materials, increase the amount of resource recovery, create a potential sales market for enterprises of neighbouring territorial communities, ensure the collection and removal of waste in the most economically feasible way and ensure sustainability waste management systems in the territory of Uzhhorod.

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

2.1 Basic conditions for the location of bio-waste treatment facilities by the composting method

Bio-waste treatment facilities (sites and composting facilities) can be built throughout the area, but it is advisable to locate them mainly near the places where the relevant waste is generated. Sites cannot be placed on slopes of more than 10%, near valleys, and reservoirs. It is desirable to locate sites and facilities for composting near transport highways to organize the removal and sale of composting products, the entrances and exits should be suitable for the access of trucks. As with the construction of most bio-waste processing facilities, 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[57] the sanitary and protective zone must be at least 300 m.

2.2 Determination of the available locations of the bio-waste treatment facility by composting method in Uzhhorod

For the possibility of implementing a bio-waste management system in Uzhhorod, one of the steps parallel to the implementation of the system of separate collection of urban and commercial waste from green spaces and part of bio-waste from mixed waste is to determine the place available for the location of the bio-waste treatment facility, with the territory, necessary for the placement of composting facilities and structures (composting station) following existing conditions.

At the beginning of implementation, the composting station will be designed for the treatment of bio-waste obtained as a result of its separate collection in separate containers (or bags) in Uzhhorod, which are the main raw materials for the composting station and are delivered from the storage sites for processing by special vehicles by the business entity in the field of waste management. In the future, when determining the location, it is advisable to take into account the prospect of a gradual increase in processing capabilities by expanding the list of waste that is accepted by the composting station for treatment, adding separately collected other municipal and commercial waste that has the greatest suitability for composting, and creating an opportunity to accept bio-waste from neighbouring communities for achieving the required level of target indicators determined by the National Waste Management Strategy in Ukraine by 2030[58].

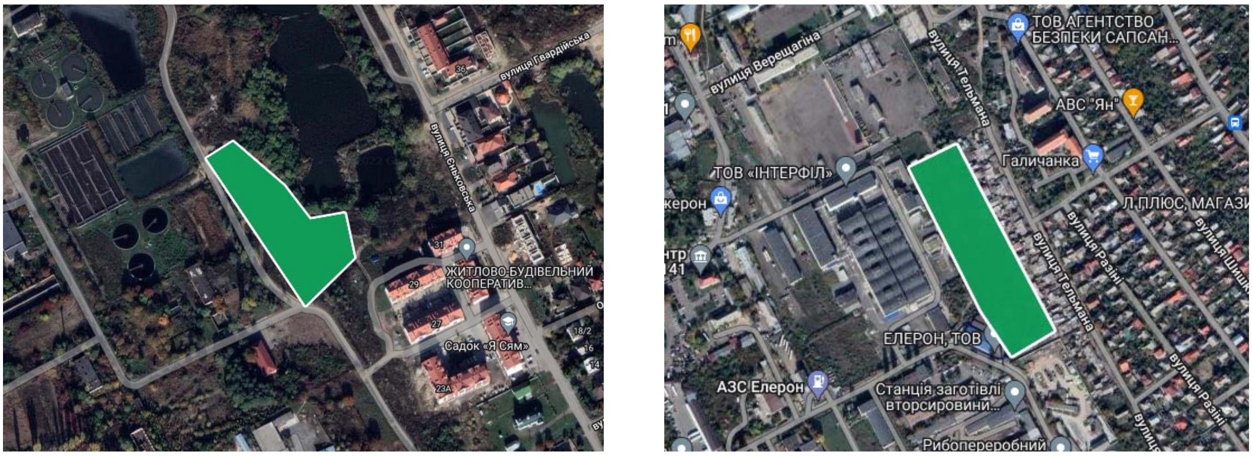
2.2.1 Site for placing a bio-waste treatment facility

It is recommended to accept the area of the land site for the location of the bio-waste treatment facility (composting station) following the requirements of GBN B.2.2-35077234-001[59]. In the future, the area of the land site for construction will be up to 1 ha, excluding administrative and municipal buildings (depending on the technical decision). The boundaries are determined by the dimensions of the site of the composting station, which is surrounded by a fence around the perimeter.

The 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 on the territory of the city:

- 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*).

[57] DSP 173-96 "State Sanitary Rules for Planning and Development of Settlements" // http://surl.li/hivnz
[58] https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80
[59] GBN V.2.2-35077234-001:2011 "Enterprises for Sorting and Processing Solid Municipal Waste. Requirements for Technological Design"



– *the territory of the site*

a *b*

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

Site No. 1 in the west it borders the treatment facilities of the centralized water drainage system of Uzhhorod, in the south - with the housing and construction cooperative "Ozerniy Kray", in the east - with an unnamed reservoir, in the north - with wasteland. The site is free from buildings, there are no green areas. The site is not used. Located on the right bank of the city. The topography of the site is flat. The site has an irregular shape. Territorially, the planned site No. 1 for composting is located within the city of Uzhhorod. To the west, at a distance of approximately 700 m, is the state border of Ukraine with Slovakia.

Site No. 2 from the north borders the territory of the emergency and rescue unit of Uzhhorod and wasteland, from the east - with residential buildings and a store of building materials, from the north – LLC "Eleron" (gas station) and the recycling station "Proektna, 3", from the west – LLC "Interfil" (the company specializes in the production of cosmetic products, decorative cosmetics and municipal goods). The site is free from buildings, there are no green areas. The site is not used. Located on the left bank of the city. The topography of the site is flat. The configuration of the site is rectangular, and has the correct shape. In terms of territory, the planned site No. 2 for composting is located within Uzhhorod. In the western direction of the site, at a distance of approximately 800 m, there is an old quarry.

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), processing (composting) area (75%) and other areas (10% of the area). The width of the access roads is 5 m; the passage between the compost rows is 1.2 m.

The bio-waste composting station includes:

- department for preliminary examination of raw materials (mixtures) (for inspection of incoming material and removal of impurities, grinding, crushing, sieving, etc.);
- aeration department (for saturating raw materials with oxygen and releasing carbon monoxide);
- composting process department – depending on the technology variant – tunnels, covered or open clamps (implementation of the intensive decomposition phase and the maturation phase);
- 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 sites composting).

A 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 handling 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 clamp-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 (leachate) 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 clamps and maneuvering machines for turning clamps should be provided.

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

Commercial compost storage area composting station is intended for 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 clamps 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).

2.3 Architectural-planning and constructive solutions of the bio-waste treatment facility

The main planning decisions of the construction being designed (composting station) are determined by the following factors:

- availability of a building-free site for construction on the territory of the city;
- technological solutions.

The planned composting station consists of:

1. Sorting equipment locations.
2. Areas for composting on the clamps.
3. Block of premises for auxiliary technical purposes.
4. External spatial metal structures for fastening technological equipment.

Options for the location of the building are in the western (site No. 1) or southeastern (site No. 2) part of the territory of Uzhhorod. The main facade of the building is located in the north.

Projected passageways are used for technological and fire-fighting maintenance of the station. A sidewalk with a width of 1.25 m has been designed for the passage of workers from the entrance to the passageways.

The planned passageway is located on the southwest clamp of the enterprise's territory.

The necessary area of the territory of the composting station, depending on the selected technical solution, is equal to 0.67 or 0.77 ha.

The pre-station zone is located at the entrance from the southwestern part of the construction site. An open platform for passenger automobile transport is designed depending on the accepted number of employees according to DBN B.2.3-5[60] and DBN B.2.5-15[61].

There are temporary buildings on the construction site of the composting station, which are to be dismantled in the future. Green vegetation on the site is preserved.

The territory of the station is surrounded by a fence made of corrugated board 1.6 m high.

All technological equipment of the station is located under the roof of quickly assembled and disassembled structures.

As an example, it can be "LLENTAB" structures in the form of bent-bearing arches made of high-quality steel. The product is certified by UkrSEPRO and has permits for use in Ukraine. Structures can be disassembled, moved and assembled in a new location with 100% preservation of the quality of the new structure.

The building of the composting station is designed from lightweight metal structures. Steel structures consist of cold-bent profiles with the use of bolted connections. Cold-bent profiles are made by rolling or on special bending machines. Hot-dip galvanized steel in rolls is used. Individual elements are connected with M12 class bolts.

The size of the building is 60 × 24 m. We will take LLENTAB profile frames (or similar) as a basis. The main forms of LLENTAB profiles are Z-profiles (roof and wall girders), C-profiles (columns, trusses, frame elements), and H-profiles (upper and lower truss belts). Mounting holes are punched in all elements during their production (see Fig. 2.2).

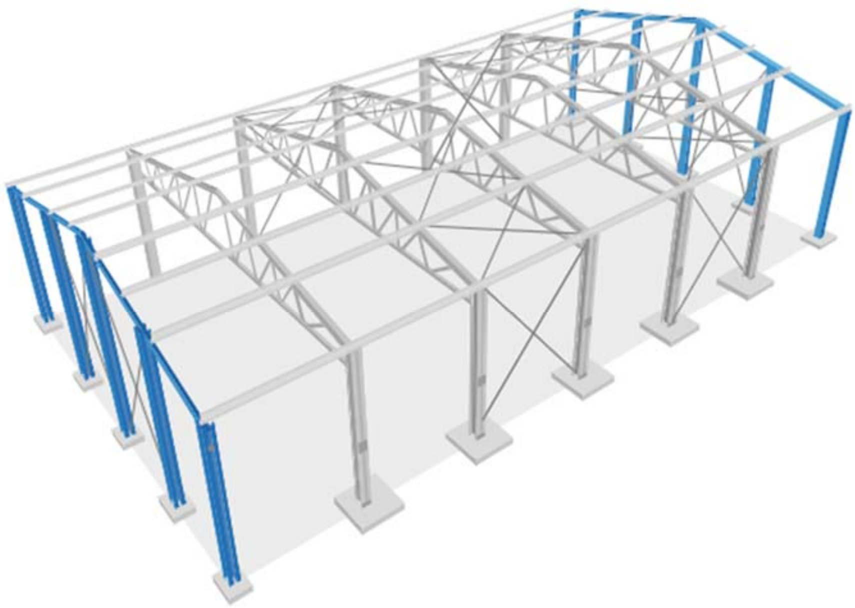


Figure 2.2 – Two-slope structural scheme with a load-bearing end wall (LLENTAB technology)

Columns are made of C-shaped profiles of the 2xC type. LLENTAB 2xC170 profile: 3-6 mm thick.

Construction of the LLENTAB coating. Trusses perform a head-bearing function for the roof. Truss elements form the upper and lower belts, connected by braces. Most often, belts are made from profiles in the shape of an "omega" or a double C-profile. Braces – from a single C-profile. Belts can be installed at different angles. The slope of the upper belt determines the resulting slope of the pavement.

LLENTAB wall joists. Purlins are a secondary wall structure that is attached to the columns. They are a system of horizontal profiles that perceive wind loads acting on wall corrugated boards or sandwich panels. As a rule, purlins are designed in the form of uncut beams. The weight of the enclosing structure is transferred to the foundations or foundation beams.

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[60] DBN B.2.3-5:2018 "Streets and Roads of Populated Areas" // http://surl.li/nlkpa

[61] DBN V.2.2-15:2019 Buildings and Structures. Residential Buildings. Substantive Provisions. With Amendment No. 1

LLENTAB roof trusses. Roof purlins are a secondary bearing structure of the covering, which is attached to the trusses of the building. These profiles perceive the vertical load acting on the roof. Girders are designed in the form of uncut beams. They are part of the roof reinforcement and free the upper belt of the truss from loss of stability. Z-profiles are most often used as roof purlins.

The modular configuration allows you to add new sections to increase the length of the station area. The advantage of the structures, in the case of acceptable soil conditions, is that there is no need to build foundations for spans up to 40 m wide. The structures have a 30-year guarantee.

Organization of terrain and drainage of surface wastewater

The organization of the relief of the site must be carried out taking into account the relief of the area, the markings of existing roads, the minimum volume of earthworks and the reliable drainage of rainwater from the planned structure.

Preparation of the territory – backfilling from local soil to project marks with the planning of the surface of the site.

Drainage of surface wastewater from the territory of the station is carried out along the planned surface of the road surface with a minimum slope of 0.05 on the existing road.

Block-module equipment for wastewater treatment

The installation of block-modular local wastewater treatment plants (WWTP) for the treatment of industrial and municipal wastewater generated at the composting station is planned. Block-module units are designed for deep biological treatment of wastewater with a volume of up to 25 m³/day.

For the operation of the composting station, we envisage block-modular treatment facilities of the BIOTAL BP2R type (or similar in capacity) (see Fig. 2.3).

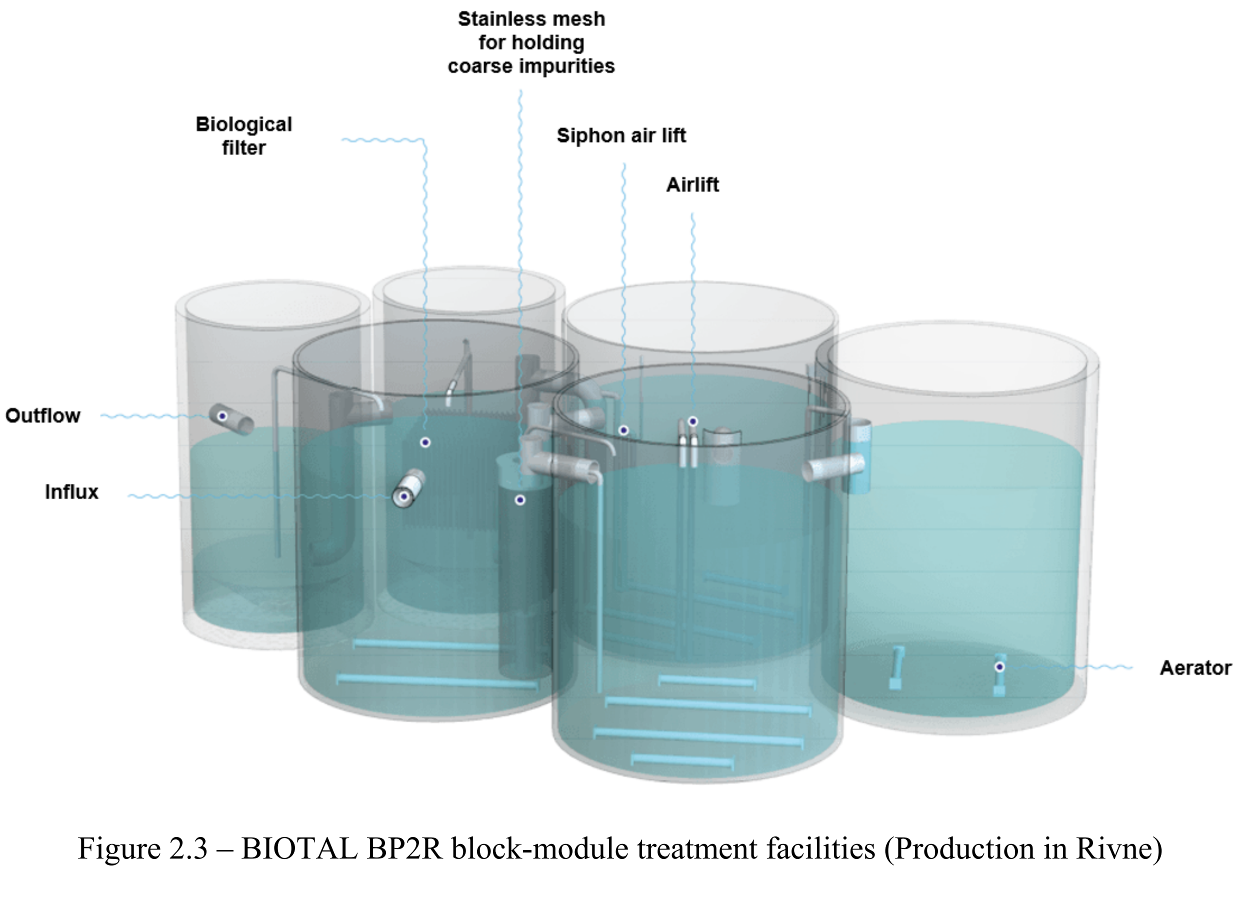

Figure 2.3 – BIOTAL BP2R block-module treatment facilities (Production in Rivne)

The project envisages the placement of LWWTPs with a design capacity of 8 m³/day. The dimensions of the building are a width of 4.5 m, a length of 6 m, and a depth of 3 m.

Installation of structures takes place on a common reinforced concrete slab, on which six reinforced concrete wells are installed. Polypropylene bioreactors of type SBR2 and SBR3 are placed in two wells. Aeration systems and sewage pumps are installed in the well of the receiving chamber. A sludge capacity is provided for the accumulation of excess activated sludge. In the well of the biofilter, the loading of the biofilter and the circulation airlift are mounted. Disinfection of treated wastewater is provided in the contact tank.

The BIOTAL installation consists of a receiving chamber (RC), at the entrance of which a mesh is provided for the retention of coarse impurities, a three-stage SBR reactor, an aerated circulating self-washing biological filter (BF), a contact tank (CT) and a sludge tank-aerobic stabilizer of excess activated sludge. In this case, microorganisms work effectively in each aeration tank, between which there is no competition since their different groups work effectively within narrow limits of the concentrations of pollutants, which decrease during the cleaning process, along with the movement of wastewater from RC-D to CT, that is, the water is treated in stages.

In the BIOTAL installation, the hydraulic connection between RC-D and the first SBR reactor, between the second and third SBR reactors, between the third SBR reactor and the biofilter-thin-layer settling tank (BF-TV), as well as between the biofilter-thin-layer settling tank and the contact tank, periodically is interrupted by the program by turning off the devices that provide this connection. Hydraulic communication is carried out between PK-D and SBR-1 – supply pumps, SBR-1 and SBR-2 – hydraulic flow, SBR-2 and SBR-3 – hydraulic flow or reverse airlifts, between SBR-3 and BF-TV – controlled siphon, siphon airlift, or pumps, and finally, between BF-TV and RC – hydraulic flow.

In the process of stepwise movement of purified wastewater from zone to zone, purification takes place step by step in 6-8 phases within the framework of one of 5 programs, moreover, in economic modes, the composition of phases changes - purified wastewater is not pumped out and excess activated sludge is not removed.

The BIOTAL system has three sludge systems: in RK-D, in a three-stage reactor SBR and BF-TV and is carried out by four-circuit recirculation of reverse activated sludge – from SBR-2 to SBR-1, from SBR-3 to RC, from SBR -3 in SBR-1, with BF-TV and with CR in RC. This construction of the technology made it possible to keep the trimul system in balance, since the pumping of wastewater during the treatment process from RC to SBR-1, from SBR-3 to BF-TV and from BF-TV to CR takes place after settling cycles, respectively - in RC, SBR- 3 and BF-TO, with partial mixing of sludge from these structures in the recirculation process before settling cycles.

Wastewater treatment at the BIOTAL installation takes place in the following order:

1 – wastewater that has just arrived at the installation is pre-treated in the receiving chamber-denitrifier;

2 – wastewater entering the installation in the previous cycle is treated in the first and second SBR reactors;

3 – in the third SBR reactor, wastewater that arrived at the installation two cycles ago is treated;

4 – in a biological filter-thin-layer settling tank, wastewater that was treated three cycles ago is processed;

5 – in the contact tank, wastewater that arrived at the installation four cycles ago is treated. During this process, treated wastewater is gradually moved from the first to the last stage of LWWTP treatment, by periodically hydraulically connecting these stages with the help of hydro-automatic devices or pumps.

Landscaping and greening

The project envisages a site for staff recreation, as well as a site for smoking.

Asphalt concrete paving with a width of 1 m is planned along the perimeter of the building.

Roads are covered with asphalt concrete. Driveways, sidewalks and playgrounds are limited by curbs.

To ensure normal sanitary and hygienic conditions on the territory of the construction site, the greening of areas free from construction is planned by:

- planting decorative trees;
- sowing lawns with perennial grasses.

When planting new trees, up to 50% of plant soil is added. When arranging lawns, a layer of vegetable soil with a thickness of 0.15 m is added, and when arranging flower beds – 0.20 m.

Technological transport and equipment

The existing roads and driveways of the territory of the composting station provide technological and fire protection maintenance of the facility. The width of industrial driveways is assumed to be 3.5 m.

Equipment and vehicles of serial production are used to prepare compost. Technological equipment of the composting process: this is a system of conveyors, a hopper, shredding equipment for shredding biowaste, biodrums (or biothermal chambers, pits, sites or stacks), shredding equipment for shredding compost with a magnetic separator, a grab crane (examples of the equipment used are shown in Fig. 2.4, 2.5).

Bio-waste must be sent to the area of laying the clamps with a bulldozer, the filler can be delivered by tractor carts or dump trucks.

The clamp must be formed and mixed with a bulldozer, grab crane, or special equipment (for example, PND-250 continuous loader, SZU-20 mixer-loader, converted spreaders of organic fertilizers: PTR-10, RZHT-10 or MZHT-10, RSP fodder mix dispenser – 10, etc.).

In the absence of a plate feeder, the unloading of compost into the crusher can be carried out with a grab crane.

The design of the working body of the grab crane must correspond to the geometric shape of the bottom of the hopper accumulator.

If the density of bio-waste and compost is less than 0.2 t/m³, the grab bucket should be six- or eight-lobed, in the case of a higher density – two-jaw. It should be taken into account that the density of the material during the composting process increases from 0.2 t/m ³ to (0.6-0.8) t/m³. The following indicators can be roughly accepted:

- after the first month of composting – 0.45 t/ m³;
- after the second – 0.6 t/m³;
- after the third-fourth – 0.7 t/m³.

Figure 2.4 – Belt conveyor for compost

Figure 2.5 – A.TOM 5300 compost shredder

See Annex G for the plan of the composting station with an example of the location of the planned main departments, objects and structures.

2.4 Determining the parameters of the main processes of the bio-waste treatment facility using the composting method

2.4.1 Formation of the aeration regime in the clamp

In the periods between stirrings, fresh air enters the clamp thanks to convection, the so-called pipe effect. Heated and rich in CO_2 air in the clamp tends to evaporate upwards, and colder and fresher air enters its place, mainly from the clamps at the base of the clamp (Fig. 2.6). Therefore, a higher quality compost mixture can be obtained when the temperature difference between the inside of the clamp and the outside air is more significant and the ventilation in the clamp is more intense.

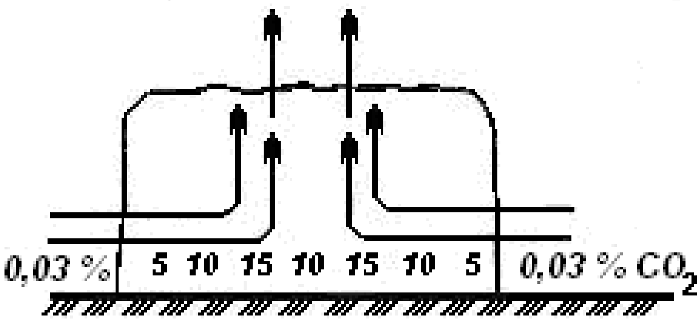

Figure 2.6 – Pipe effect in the clamp

In the summer period, a sufficiently strong tube effect is not created in the clamp and therefore anaerobic nuclei are formed.

To maintain a good pipe effect in the clamp, its width is reduced during each mixing.

The outer layer on the periphery of the burr, especially on its clamps, is usually dry, and it does not create conditions for the development of microorganisms. For this reason, this area remains cold. Directly behind the outer layer, the most favorable conditions for the development of thermophilic actinomycetes are created. Due to strong aeration, fermentation in this zone proceeds quickly and the material almost “burns out”. A dry (humidity less than 50%), very pale layer is formed, which is called the “burnt” zone of the edge. Such material becomes poor in terms of nutrients.

In contrast to these very well-aerated zones, air access to the base of the board is usually insufficient and humidity is high. Under these conditions, processes similar to butyric acid fermentation take place. The temperature here does not exceed 40°C-45°C; the so-called anaerobic core is formed.

In the middle, that is, in the center of the compost pile, the most favorable conditions for fermentation are created. In a zone where there is a sufficient amount of air and optimal humidity, the temperature quickly rises to (55-65)°C. It is here that thermophilic microorganisms multiply. This is the so-called brown compost zone – the “white burning zone”. In wide clamps and during long-term composting, two more composting zones are distinguished - overheating zones, located in the upper corners of the section of the clamp along its length. In these zones, the temperature often reaches (72-82)°C.

A few days after the formation of the compost pile, the compost mixture settles, and the pile becomes approximately 50 cm lower, as a result of which the density of the mass increases and the access of oxygen to the center of the pile decreases. As a result of the evaporation of water during the fermentation process, the moisture content of the material also decreases. As a result, the fermentation conditions deteriorate and the need to stir the clamp arises. In the optimal case, the mixing of the edge should be carried out in the following way: the material of different zones should be loosened and well-ventilated, water should be added, as well as suitable mineral additives should be added and the edge should be formed again; at the same time, the clamp zones should be placed as follows: the clamp parts of the clamp are made of the material that was in the brown zone (“white burning zone”), the dry areas of the old clamp, which have burned out, are placed at the base of the new clamp, and the anaerobic “core” - in the most favorable zone, that is, in the center of the new edge, and finish the edge with material from the old brown zone (Fig. 2.7). The new edge should be formed (10-20) cm narrower than the old one to improve the air regime in it.

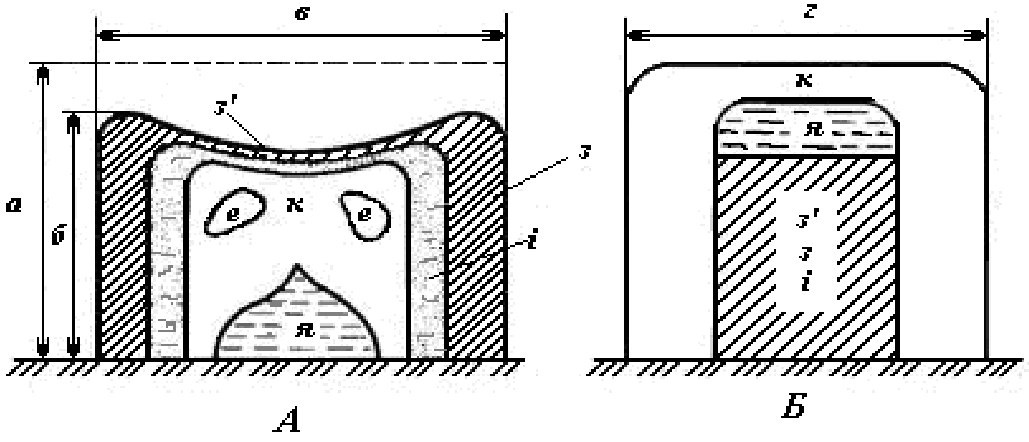

Figure 2.7 – Zoning in the compost heap
A – cross-section of the old clamp; *B* – cross-section of the new clamp, in which the zones of the old clamp are placed accordingly: *з* – dry and cold zone; *з'*– cold and sometimes wet zone; *i* – burnt (pale) zone; *к* – brown (most favorable) zone; *я* – anaerobic (smelling) nucleus; *e* – burnt zone; *a* – the height of the clamp immediately after its formation; *b* – the height of the clamp before its next mixing; *c* – the width of the old clamp; *d* – the width of the new edge (slightly less than the width of the old one).

2.4.2 Storage of finished compost

After the completion of the composting process, the material must be reloaded with a grab into the receiving hopper of the sorting and crushing department, and then with the plate feeder of the hopper – to the screen with the diameter of the sieve holes 60 mm.

Ready compost must be sent to the consumer or a storage area.

The width of the clamp, m, during storage, is determined by the formula:

$$A= \frac{L_k - 2c - d}{2}, \tag{2.1}$$

where L_k – the span of the crane, m;

c – distance from the track to the edge, m;

d – the width of the passage between the clamps, m.

The length of the clamp at a slope angle of 45° is determined by the formula:

$$B = \frac{K_1 \cdot П_{міс}}{\left(a - h_{cp}\right) \cdot h_{cp} \cdot \gamma_{cp}}, \tag{2.2}$$

where K_1 – the coefficient that takes into account the backfilling of the edges with inert material (K_1 =1.07);

$П_{міс}$ – monthly productivity of the site, t;

a – clamp width, m;

h_{cp} – average height of the clamp, m;

γ_{cp} – average density of bio-waste in clamp, t/m³.

2.4.3 The procedure for determining the proportions of components for preparing a compost mixture based on bio-waste

The compost mixture must be balanced simultaneously for nutrients and moisture with a relative estimate *of the* corresponding mass quantities of organic material according to the formula:

$$s = \frac{M_{ow}}{M_{oCN}}, \tag{2.3}$$

where M_{ow} – the mass amount of organic material (as a moisture absorber) to balance the humidity of the mixture, t;

M_{oCN} – the mass amount of organic material (as an energy component) to balance the mixture in terms of nutrients.

M_{ow} should be determined as follows:

$$M_{ow} = \frac{M_г (W_г - W_{см})}{W_{см} - W_o}, \tag{2.4}$$

where $W_г$, W_o are, respectively, the moisture content of the organic substance of bio-waste and the organic substance of the additive, %;

$W_{см}$ – technologically specified moisture content of the compost mixture, %;

M_g – the mass amount of organic matter.

In turn, M_{oCN}, determined by the formula:

$$M_{oCN} = \frac{kM_{г}(100 - W_{г})}{100 - W_{o}}, \quad (2.5)$$

where k is a correction factor that takes into account the content of biogenic nutrients in organic material, it must be calculated according to the formula:

$$k = \frac{N_{г}k_{CN} - C_{г}}{C_{o} - N_{o}k_{CN}}, \quad (2.6)$$

where $N_{г}$, N_{o} – respectively, nitrogen content in the dry matter of organic matter and in organic material, %;

C_{g}, C_{o} – respectively, the carbon content in the dry matter of organic matter and in organic material, %;

k_{CN} – the optimal ratio of carbon and nitrogen for the effective life activity of microorganisms.

If $s < 0.9$, the mixture must be balanced for moisture by moistening the mixture during mixing of the components with the introduction of water by mass amount, which is determined by the formula:

$$M_{в} = \frac{M_{oCN}(W_{см} - W_{o}) - M_{г}(W_{г} - W_{см})}{100 - W_{см}}, \quad (2.7)$$

where $M_{в}$ the mass amount of water for wetting the mixture.

If $s > 1.1$, balancing of the mixture by moisture should be carried out before mixing the components by introducing dried recycling compost with preliminary determination of its moisture content, the mass amount of which should be determined according to the formula:

$$M_{рк} = \frac{M_{г}(W_{г} - W_{см}) - M_{oCN}(W_{см} - W_{o})}{W_{см} - W_{рк}}, \quad (2.8)$$

where $M_{рк}$ is the mass amount of dried recycling compost, t;

$W_{рк}$ – moisture content of dried recirculation compost, %.

In the range of values $0.9 < s < 1.1$, no additional components can be introduced, because the mixture is considered balanced.

It is possible to check the technologically specified humidity of the prepared mixture taking into account the determined mass proportions of the components:

– in case of moistening of the compost mixture:

$$W_{cm} = \frac{M_{г}W_{г} + M_{oCN}W_{o} + M_{b}100}{M_{см}}, \quad (2.9)$$

– in case of introduction of recycled compost or structural component:

$$W_{cm} = \frac{M_{г}W_{г} + M_{oCN}W_{o} + M_{pk}W_{pk}}{M_{см}}. \quad (2.10)$$

2.4.4 Determination of the moisture content of the compost mixture

To calculate the amount of water needed to create and maintain the humidity of the compost mixture at the level of 60% of the full moisture capacity, you need:

- determine the total moisture content of the compost mixture,
- calculate the amount of water that must be added to ensure humidification up to 60% humidity from the full moisture capacity.

The total moisture capacity must be determined in metal tubes with a diameter of 70 mm and a height of 140 mm, the lower end of which is covered with a metal mesh with holes of 0.25 mm in diameter, on which filter paper is placed.

A monolith of the compost mixture should be cut with a special drill, squeezed out of the drill with a piston, transferred into a metal tube with a mesh and weighed on technical scales. Then place the tube in a porcelain cup and pour water up to the (30-50) mm mark.

The complete saturation of the compost mixture with moisture should be checked by daily weighing, for which the tube with the compost mixture should be removed from the vessel with water, carefully wet the excess moisture with filter paper and weighed. Obtaining close results of the previous and subsequent weighing (the difference is no more than (0.05-0.12) g) indicates the establishment of a constant mass. After that, the compost mixture should be transferred from the tube to a porcelain cup, mixed thoroughly and (10-15) g taken from different places to determine the moisture content. The weighted part of the compost mixture should be placed in a tared glass jar and the mass of the jar with the compost mixture to the nearest 0.01. Then the open box should be placed in a drying cabinet and the compost mixture should be dried at a temperature of (100-105)°C to a constant mass. The biomass should be weighed for the first time after 6 hours of drying, subsequent weighing should be carried out every 2 hours until a constant weight.

The total moisture capacity, *TMC*, must be calculated according to the formula:

$$TMC = [\,(в - c)/(c - a)\,] \cdot 100, \quad (2.11)$$

where a – the mass of the empty bag, g;

$в$ – weight of the box with the compost mixture before drying, g;

c – is the mass of the box with the compost mixture after drying, g.

The total moisture content for each sample of the compost mixture should be determined three times. Then it needs to find the amount of water needed to saturate the compost mixture to 60% of the full moisture content. For example, if the total moisture content of the compost mixture is 38.8%, then 60% of it is 23.2%, so during experiments to saturate the biomass to 60% of the total moisture content, 232 g/ml of water should be added for each kilogram of dry biomass.

CHAPTER III. COMPARATIVE ANALYSIS OF POSSIBLE BIO-WASTE MANAGEMENT OPTIONS IN UZHGOROD

3.1 Comparative financial analysis of possible variants for handling bio-waste in Uzhhorod

A comparative financial analysis of possible variants for the implementation and implementation of bio-waste management including sorted (separately collected) municipal and commercial waste from green spaces and part of bio-waste from mixed municipal waste (MSW) received in Uzhhorod was conducted for the next three of technical solutions for centralized treatment of bio-waste by composting at a composting station:

- variant 1 (V1) – closed bio-waste composting system in tunnels;
- variant 2 (V2) – a combined bio-waste composting system in the clamps covered with a membrane with a metal frame;
- variant 3 (V3) – an open system of bio-waste composting in clamps with natural aeration.

The introduction of a system of centralized composting of separately collected bio-waste in Uzhhorod will require investments in the preparation of the site and in processing equipment sufficient to process up to 1,600 tons of bio-waste per year. Table 3.1 shows the indicators of the master plan of the composting station according to various technical solutions for bio-waste treatment.

Table 3.1 – Indicators of the general plan of the composting station according to various technical solutions for the treatment of bio-waste

No.	Characteristic	Unit	Project indicator		
			V1	V2	V3
1	Land area (need)	ha	**0.67**	**0.67**	**0.77**
2	Area of the composting facility	ha	0.08	0.08	0.12
3	Commercial compost storage area	ha	0.10	0.10	0.12
4	Area of highways and paved roads	ha	0.32	0.32	0.36
5	Landscaping area	ha	0.17	0.17	0.17

The estimated cost of construction works of a composting station 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[62]. The price may be specified when local conditions are established. The salary fund is based on the average salary in the Transcarpathian region, taking into account the accepted number of staff at the composting station.

3.1.1 Financial analysis of the technical solution for treatment bio-waste according to variant 1

Table 3.2 shows the approximate staff list of composting station workers.

Table 3.3 shows the electrical energy balance of the composting stations. Table 3.4 shows the technical indicators of the composting station.

Table 3.5 shows the necessary investment (capital) costs for the construction of a composting station.

[62] 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

Table 3.2 – Approximate staff list of composting station employees according to variant 1

No.	Position	Number of workers, persons
1	Head of the site	1
2	Operator	3
3	Receiver	1
4	Repair worker	1
	In total	**6**

Notes: the functions of the operators include the formation of edges, compliance with the ratio of the components of raw materials for composting and laboratory studies of the main indicators, monitoring the quality of compost.

Table 3.3 – Electric energy balance of the composting station according to variant 1

No.	Name	Number, MW/year	The cost of electricity	
			Tariff, UAH per kW	Sum, million hryvnias
1	The total need for the use of electricity per year	24.0	1,803.49	0.043

Notes: The calculation was made based on the tariff from 31/07//2023 for the 2nd class of enterprises, namely 1,803.49 UAH per 1 kW. According to the calculation, the total use of electricity for the enterprise will be 24 MW per year at a load calculation of 1.6 thousand t/year.

Table 3.4 – Technical parameters of the composting station according to variant 1

No.	Indicator	Value
1	Production capacity of the composting station, t/year	1,600
2	Number of working shifts/hours	1/8
3	Number of working days	250
4	Number of working hours per year	2,000
5	Amount of bio-waste that can be processed, t/year	1,600
6	The area of the site, which is necessary for the composting station, ha	0.67
7	The number of working personnel, persons	6
8	Terms of construction of composting station facilities, months	12

Table 3.5 – Investment (capital) costs for the construction of a composting station according to variant 1

Name of expenses	Estimated value,	
	million hryvnias	million euros
Capital costs for the construction of composting station facilities	6.4	0.159
Including expenses for construction and installation works	1.6	0.040
Costs for design and authors, technical supervision	1.3	0.032
Total	**7.7**	**0.191**

Notes: as of July 31, 2023, the euro to hryvnia exchange rate was accepted at 40.26 hryvnias for 1 euro

3.1.2 Financial analysis of the technical solution for processing bio-waste according to variant 2

Table 3.6 shows the approximate staff list of composting station workers.

Table 3.7 shows the electrical energy balance of the composting station; Table 3.8 shows the technical indicators of the composting station.

Table 3.9 shows the necessary investment (capital) costs for the construction of a composting station.

Table 3.6 – Approximate staff list of composting station employees according to variant 2

No.	Position	Number of workers, persons
1	Head of the site	1
2	Operator	3
3	Receiver	1
4	Repair worker	1
	Total	**6**

Notes: the functions of the operators include the formation of edges, compliance with the ratio of the components of raw materials for composting and laboratory studies of the main indicators, monitoring the quality of compost.

Table 3.7 – Electric energy balance of the composting station according to variant 2

No.	Name	Number, MW/year	The cost of electricity	
			Tariff, UAH per kW	Sum, million hryvnias
1	The total need for the use of electricity per year	16.0	1803.49	0.029

Notes: The calculation was made based on the tariff from 31/07//2023 for the 2nd class of enterprises, namely 1,803.49 UAH per 1 kW. According to the calculation, the total use of electricity for the enterprise will be 16 MW per year with a load calculation of 1.6 thousand t/year.

Table 3.8 – Technical parameters of the composting station according to variant 2

No	Indicator	Value
1	Production capacity of the composting station, t/year	1,600
2	Number of working shifts/hours	1/8
3	Number of working days	250
4	Number of working hours per year	2000
5	Amount of bio-waste that can be processed, t/year	1,600
6	The area of the site, which is necessary for the composting station, ha	0.67
7	The number of working personnel, persons	6
8	Terms of construction of composting station facilities, months	12

Table 3.9 – Investment (capital) costs for the construction of a composting station according to variant 2

Name of expenses	estimated value,	
	million hryvnias	million euros
Capital costs for the construction of composting station facilities	6,10	0.152
Including expenses for construction and installation works	1.53	0.038
Costs for design and copyright, technical supervision	1.20	0.030
Total:	**7.30**	**0.182**

Notes : as of July 31, 2023, the euro to hryvnia exchange rate was accepted at 40.26 hryvnias for 1 euro

3.1.3 Financial analysis of the technical solution for processing bio-waste according to variant 3

Table 3.10 shows the approximate staff list of composting station workers.

Table 3.11 shows the electrical energy balance of the composting station. Table 3.12 shows the technical indicators of the composting station.

Table 3.13 shows the necessary investment (capital) costs for the construction of a composting station.

Table 3.10 – Estimated staff list of composting station employees according to variant 3

No.	Position	Number of workers, persons
1	Head of the site	1
2	Operator	3
3	Receiver	1
4	Repair worker	1
	Total	**6**

Notes: the functions of the operators include the formation of edges, compliance with the ratio of the components of raw materials for composting and laboratory studies of the main indicators, monitoring the quality of compost.

Table 3.11 – Electric energy balance of the composting station according to variant 3

No.	Name	Number, MW/year	The cost of electricity	
			Tariff, UAH per kW	Sum, million hryvnias
1	The total need for the use of electricity per year	3.20	1803.49	0.006

Notes: The calculation was made based on the tariff from 07/31/2023 for the 2nd class of enterprises, namely UAH 1,803.49 per 1 kW. According to the calculation, the total use of electricity for the enterprise will be 3.2 MW per year at a load calculation of 1.6 thousand t/year.

Table 3.12 – Technical parameters of the composting station according to variant 3

No.	Indicator	Value
1	Production capacity of the composting station, t/year	1,600
2	Number of working shifts/hours	1/8
3	Number of working days	250
4	Number of working hours per year	2000
5	Amount of bio-waste that can be processed, t/year	1,600
6	The area of the site, which is necessary for the composting station, ha	0.77
7	The number of working personnel, persons	6
8	Terms of construction of composting station facilities, months	12

Table 3.13 – Investment (capital) costs for the construction of a composting station according to variant 3

Name of expenses	estimated value,	
	million hryvnias	million euros
Capital costs for the construction of composting station facilities	4.48	0.111
Including expenses for construction and installation works	1.12	0.028
Costs for design and copyright, technical supervision	1.00	0.025
Total:	**5.48**	**0.136**

Notes : as of July 31, 2023, the euro to hryvnia exchange rate was accepted at 40.26 hryvnias for 1 euro

3.1.4 Comparative financial analysis of various technical solutions for bio-waste processing

Table 3.14 shows the comparative financial analysis of the possible realization and implementation of three variants for bio-waste, including sorted (separately collected) municipal and commercial waste from green spaces and part of bio-waste from mixed municipal waste (MSW) management received in Uzhhorod.

Table 3.14 – Comparative financial analysis of various variants for bio-waste management in Uzhhorod (as of the start of operation of the composting station, 2025)

No.	Characteristics of indicators	Unit	V1	V2	V3
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 processing 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 processing bio-waste (45% of item 1)	t/year	640	640	640
5	Installation capacity of composting station equipment	kWh	15	10	2
6	Volumes of electricity consumption per year (item 5 and item 1)	kW/year	24,000	16,000	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	6.40	6,10	4.48
10	Capital costs for the purchase of machines and mechanisms	million hryvnias	8.96	7.68	6.72
11	Capital costs for design, copyright and technical supervision	million hryvnias	1.3	1,2	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 drainage	million hryvnias/year	0.008	0.008	0.008
13	Operating costs for maintenance	million hryvnias/year	0.133	0.133	0.133
14	Operational costs for the operation of machines and mechanisms	million hryvnias/year	0.398	0.398	0.398
15	Operating expenses for wages (including deductions for social events)	million hryvnias/year	1,2	1,2	1,2
16	Operating costs for electricity	million hryvnias/year	0.043	0.029	0.006
17	Operating 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

No.	Characteristics of indicators	Unit	V1	V2	V3
19	**Total Capital expenditure**	**million hryvnias**	**16.66**	**14.98**	**12,20**
20	**Total Operating expenses**	**million hryvnias/year**	**2.05**	**2.04**	**2.02**
22	**Cost of commercial compost**	**hryvnias/ton**	**3210.00**	**3188.13**	**3152.19**
23	Bio-waste treatment level indicator	%	85	85	85
24	Indicator of the level of waste disposal	%	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**	**884.00**	**875.25**	**860.88**

According to the results of a comparative financial analysis of the possible variants for the implementation and implementation in Uzhhorod of technical solutions for the management of bio-waste, including sorted (separately collected) municipal and commercial waste from green areas and part of bio-waste from mixed waste received in Uzhhorod, following can be assumed:

- the indicator of the level of bio-waste processing according to all variants of technical processing solutions is 85%, accordingly, the level of waste disposal is reduced to 15% due to the extraction of bio-waste;
- depending on the chosen variant of the technical solution for processing bio-waste, the costs of composting at the beginning of the project implementation will be approximately from 860.88 to 884.00 UAH/t (without taking into account the planned profit);
- lower costs for composting require the simplest technical solution for bio-waste processing – an open system of composting in landfills with natural aeration;
- the costs of composting according to any variant of the technical treatment solution directly depend on the volume of treated bio-waste and can be gradually reduced accordingly when the volume of bio-waste treatment increases, including by accepting the permissible volume of bio-waste from neighboring communities and the possibility of selling the finished compost for the purpose of making a profit (revenue from retail sales of products can be up to 0.64 million hryvnias/year).

CONCLUSIONS TO PART II

According to the results of the work on Stage II of the study "Evaluation of Technical Possibilities, Financial Analysis and Technical and Economic Justification of the System for the Separate Collection of Secondary Raw Materials", Part II " Feasibility Study of the Most Suitable Technical Solution for organic waste, sorted municipal and commercial green waste management in Uzhhorod" **it is possible to draw the following conclusions:**

1) the system of handling urban and commercial bio-waste, including waste from green areas and other biodegradable waste, includes a set of measures for their collection, transportation and processing (recovery and disposal), respectively, at the created waste treatment facilities. For high-quality preparation for processing, bio-waste should not be mixed with other types of waste or materials with different properties, that is, collected separately. Separate collection of bio-waste should precede the stage of its processing, which will further contribute to ensuring the efficiency of the entire further processing process;
2) one of the priority directions in the development of the field of bio-waste management, including separately collected urban and commercial waste from green spaces and part of bio-waste from mixed municipal solid waste, in Uzhhorod is the use of biological treatment methods (anaerobic fermentation and aerobic composting), which allow to reduce the amount of waste with obtaining target products (including the return of part of organic materials for reuse) and to significantly reduce the amount of waste that is subject to disposal in landfills and landfills;
3) based on the characteristics 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 for the conditions of the city of Uzhhorod due to the presence of special requirements for the operation of such installations and the high costs of implementation and further operation. However, in the long term, when establishing the economic feasibility of implementing the method of anaerobic fermentation of bio-waste, it is possible;
4) as of 2023, the optimal method of handling separately collected bio-waste for implementation in Uzhhorod is simpler, but with greater compliance with environmental safety requirements and with the lowest level of capital investments and operating costs compared to alternative methods of waste treatment – the composting method;
5) despite the simplicity of the composting method, its implementation requires compliance with the relevant requirements for the process and monitoring (preparation of bio-waste, step-by-step management of decomposition (aeration of the clamps, maintenance of the humidity level, harrowing of the clamps), refining of the finished compost (sieving and separation of impurities), implementation of measures to minimize various emissions (odor, noise, microorganisms, liquids, gases);
6) taking into account that the range of composting technologies is extremely wide and covers from simple to technically complex and with precise management, a comparative analysis of three possible technical solutions for centralized bio-waste composting was carried out for implementation and implementation in Uzhhorod:
   - closed composting system in tunnels (closed rows);
   - combined composting system in covered clamps (metal sheets, membrane with a metal frame);
   - open system of composting in the clamps with aeration;
7) the introduction of a system of centralized composting of separately collected bio-waste in Uzhhorod will require investment in the construction of a composting station with a capacity of 1,600 tons of bio-waste per year , calculations have established an approximate staffing list of employees, the balance of electrical energy, technical indicators of the composting station and necessary investment (capital) costs for its construction according to various technical solutions;

8) based on the results of a comparative financial analysis of possible variants for the implementation and implementation in the city of Uzhhorod of technical solutions for handling bio-waste , including sorted (separately collected) municipal and commercial waste from green areas and part of bio-waste from mixed waste received in Uzhhorod, it was found that, depending on the selected variant of the technical solution for the treatment of bio-waste, the costs of composting at the beginning of the implementation of the project will be approximately from 860.88 to 884.00 UAH/t (without taking into account the planned profit). For comparison, composting costs in EU countries are 1,098-2,562 UAH /t (30-70 EUR/t), the simplest technical solution for bio-waste processing requires lower composting costs – an open composting system in landfills with natural aeration;
9) cooperation of territorial communities in any field is a tool thanks to which communities can attract additional funds and implement large projects that they cannot implement on their own, improve the quality of service provision and receive additional income. Detailed planning, calculation of possible risks, drawing up of a contract and successful communication between communities are necessary for the successful implementation of the project. At the initial stage of the implementation of the waste management system, neighbouring communities can be considered as a potential area of coverage of the service, because the construction of a waste treatment facility will be more favorable economically if the adjacent communities are served. It is necessary to conduct a detailed analysis of alternative variants for planning a rational model of the municipal waste management system within each of the territorial communities, while the boundaries of interaction should cover a sufficient amount of resources and optimally use the advantages of close mutual location;
10) the costs of composting according to any variant of the technical treatment solution directly depend on the volume of processed bio-waste and can gradually be reduced accordingly with an increase in the volume of bio-waste treatment, taking into account the presence of a large share of bio-waste in the composition of municipal waste, including, due to the acceptance of the permissible volume of bio-waste of neighbouring communities and the possibility of selling ready-made compost for profit (revenue from retail sales of products can be up to 0.64 million hryvnias/year).

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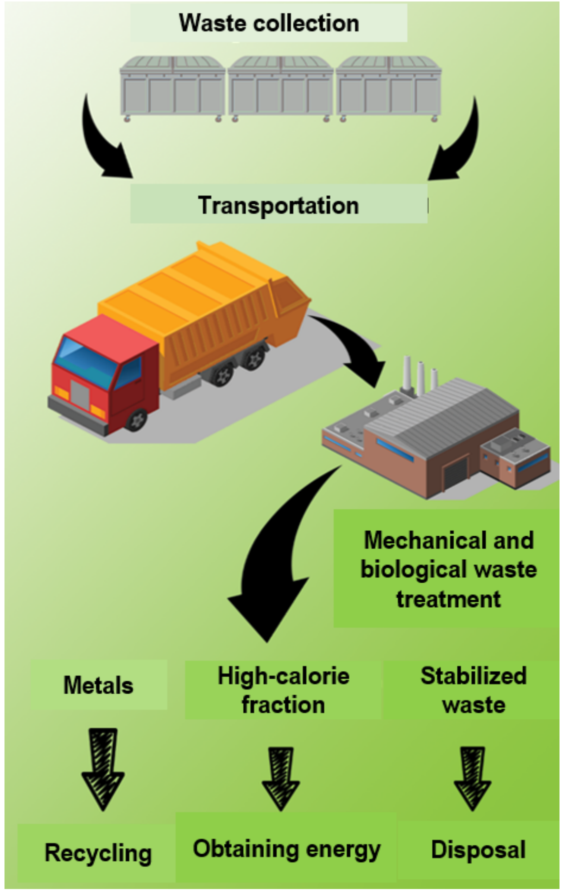
45. "On the approval of the List of hazardous properties and instructions on the control of cross-border transportation of hazardous waste and their utilization/removal". Order of the Ministry of Natural Resources of Ukraine dated October 16, 2000 No. 165.
46. Decree of the Cabinet of Ministers dated November 8, 2017 No. 820-r "On the National Strategy for the Management of Solid Municipal Waste in Ukraine."
47. "Methodological recommendations for determining the morphological composition of solid municipal waste", approved by the order of the Ministry of Housing and Agriculture of Ukraine dated February 16, 2010 No. 39.
48. SOU ZhKH "Technology of processing of organic matter contained in municipal waste", approved by the order of the Ministry of Housing and Agriculture of Ukraine dated 30.03.10 No. 78.
49. "Methodical recommendations for the organization of collection, transportation, processing and disposal of municipal waste", approved by the order of the Ministry of Housing and Agriculture of Ukraine dated 07.06.10 No. 176.
50. "Rules for determining norms for the provision of services for the removal of municipal waste", approved by the order of the Ministry of Housing and Rural Affairs of Ukraine dated 30.07.10 No. 259.

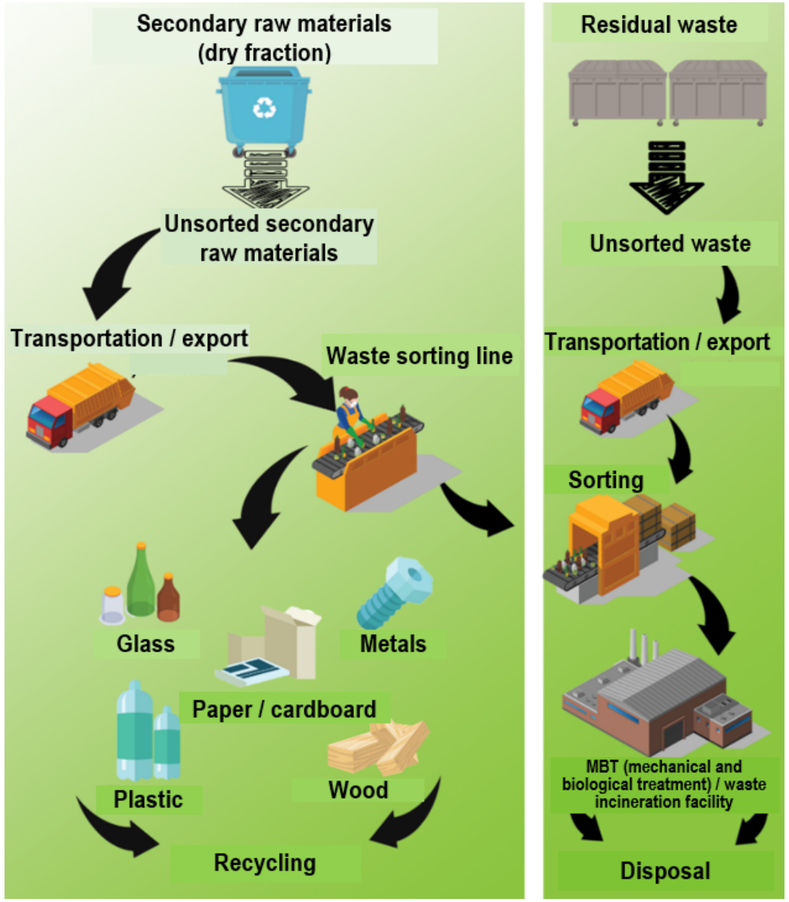
51. “Rules for the operation of municipal waste landfills”, approved by the order of the Ministry of Construction of Ukraine dated 01.12.2010 No. 435.
52. “Municipal waste” Biogas from municipal waste landfills, used in cogeneration plants”, approved by the order of the Ministry of Housing and Agriculture of Ukraine dated 12.31.10 No. 484.
53. “Municipal waste” The technology of processing waste plastics, paper and cardboard, which is part of solid municipal waste” was approved by the order of the Ministry of Housing and Agriculture of Ukraine dated 31.12.10 No. 485.
54. “Municipal waste” Technology for processing glass waste, which is part of solid municipal waste”, approved by the order of the Ministry of Housing, Commune and Agriculture of Ukraine dated 31.12.10 No. 486.
55. “Recommendations for the development of technological maps for the maintenance of green spaces”, approved by the order of the Ministry of Housing and Communal Affairs of Ukraine dated 24/11/08 No. 364.
56. “Methodical recommendations for the accounting of green spaces in populated areas of Ukraine”, approved by the order of the Ministry of Construction of Ukraine dated November 22, 2006 No. 386.
57. “Methodology for determining the amount of financing for the maintenance of 1 hectare of green spaces”, approved by the order of the Ministry of Construction of Ukraine dated 09.01.07 No. 2.
58. “Regulations on the monitoring system of green areas in cities and towns of the urban type of Ukraine, approved by the order of the Ministry of Housing and Rural Affairs of Ukraine dated August 4, 2008 No. 240.
59. Reporting form No. 1 (annual) “Report on the green economy” and Instructions for filling out reporting form No. 1 (annual) “Report on the green economy”, approved by the order of the Ministry of Housing and Agriculture of Ukraine dated 24.12.08 No. 401.
60. “Methodology for determining the replacement value of green spaces”, approved by Order No. 127 of the Ministry of Housing and Rural Affairs of Ukraine dated May 12, 2009.
61. DBN B.2.2-12:2019 Planning and development of territories.
62. DBN V.2.4-2-2005 Solid municipal waste landfills. Basic design provisions (Am. No.1, Am. No.2).
63. DBN B.2.2-5:2011 Improvement of territories (am. No.1, No.2, No.3).
64. DSTU-NB B.2.2-7:2013 Guidelines for arranging container sites.
65. DSTU EN 1501-1:2019 Garbage trucks and their lifting devices. General technical and safety requirements. Part 1. Rear-loading garbage trucks (EN 1501-1:2011 + A1:2015, IDT).
66. DSTU-N B V.1.1-27:2010 Building climatology.
67. DSTU 8727:2017 Sewage sludge. Preparation of organo-mineral mixture from sewage sludge.
68. DSTU 8476:2015 Containers for municipal waste. General technical requirements.
69. DSTU EN 15359:2018 Solid renewable fuel (SRF). Technical characteristics and classes (EN 15359:2011, IDT).
70. State sanitary norms and rules for maintaining the territories of populated areas. Approved by the order of the Ministry of Health of Ukraine dated March 17, 2011 No. 145.
71. State sanitary rules for the planning and development of settlements. Approved by Order No. 173 of the Ministry of Health of Ukraine dated 19.06.96.
72. GBN V.2.2-35077234-001:2011 Buildings and structures. Solid municipal waste sorting and processing enterprises. Requirements for technological design.
73. On the approval of the Methodological recommendations for the formation of public opinion regarding environmentally safe management of municipal waste, approved by the order of the Ministry of Housing and Communal Affairs of Ukraine dated February 16, 2010 No. 38.
74. On the approval of the Rules for the maintenance of residential buildings and adjacent territories, approved by the State Committee of Ukraine on Housing and Communal Affairs dated May 17, 2005 No. 76.
75. Rules for the maintenance of green spaces in populated areas of Ukraine. Approved by Order No. 105 of the Ministry of Construction, Architecture and Housing and Communal Services of Ukraine dated April 10, 2006.

ANNEXES

ANNEX A.
DOMESTIC WASTE MANAGEMENT VARIANTS (INCLUDING SEPARATELY COLLECTED SECONDARY RAW MATERIALS) IN UZHHOROD

Variant “Mechanical-biological treatment of residual waste”	
Technological scheme	**Description**
 	**Waste collection**: municipal waste is collected independently by municipals in the form of mixed residual waste (secondary raw materials are collected in separate containers) using designated containers (according to DSTU 8476:2015) or bags. For this purpose, mobile containers for waste of the KMP class 2-4 type and for small volumes – bags or bags are suitable, which can also be used for a planned and yard waste collection system. **Waste transportation:** as a rule, removal of all collected waste is carried out by one of several possible specially equipped garbage collection vehicles. There are garbage trucks with rear, front and clamp loading in various modifications, which are selected taking into account the actual local conditions. The same vehicles (garbage collection trucks) carry out the removal of waste to mechanical and biological treatment facilities. The shorter the waste transportation distance, the higher the efficiency of the entire system. **Waste treatment:** waste is treated at a mechanical-biological treatment facility using mechanical and biological processes to reduce the weight and volume of waste, as well as stabilize it for transportation to the waste disposal site. Metals and high-calorie fractions are separated from the waste stream by mechanical methods. Biological processes (rotting or fermentation) ensure the drying and biological decomposition of waste, contributing to their stabilization. Depending on the technological model, either stabilized waste (during mechanical-biological treatment) that is transported to the waste disposal site, or stabilized secondary fuel (during stabilization treatment) is formed at the output. The obtained secondary raw materials are returned to the relevant industrial enterprises, and the stabilized and residual waste is removed to landfills for safe waste

<table>
<tr><th colspan="2">Variant “Separate collection of secondary raw materials (in one container)”</th></tr>
<tr><th>Technological scheme</th><th>Description</th></tr>
<tr><td>



</td><td>

Collection: a separate collection of secondary raw materials allows to significantly reduce the volume of waste that enters the places of their removal. The so-called containers “dry fraction (secondary raw materials)” represent an acceptable and inexpensive system for collecting various types of secondary raw materials. According to its principle, this system involves the collection of two fractions of waste: 1) dry secondary raw materials and 2) residual mixed waste.

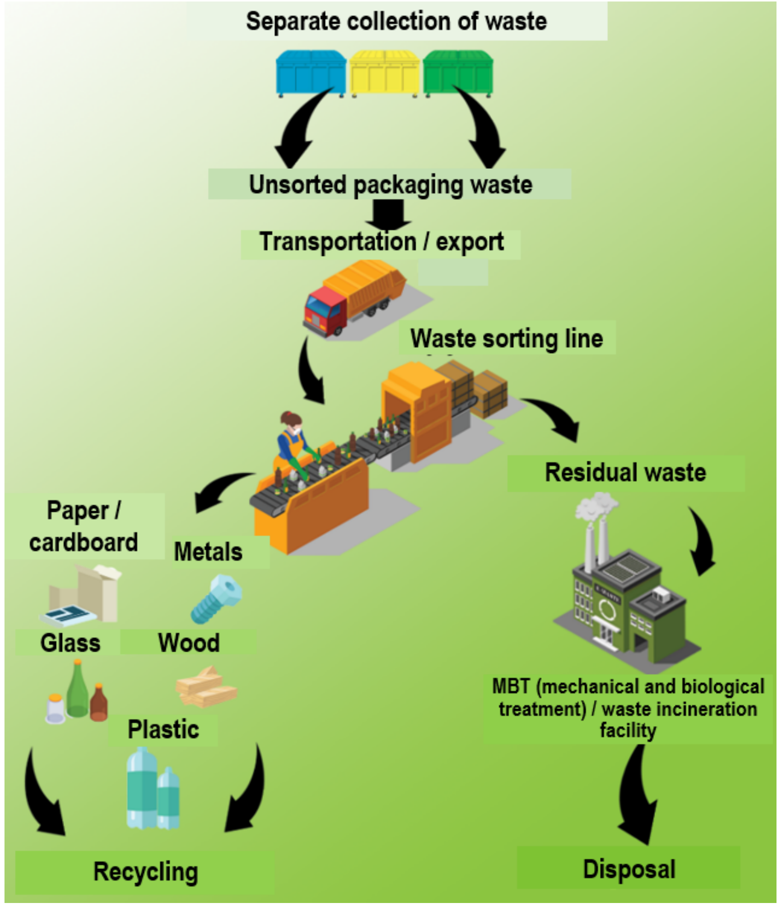
Different containers can be used for collecting secondary raw materials, for example, mobile containers for waste of the type KMP or KSS of classes 1-4 according to DSTU 8476:2015, bags or bags. It is also possible to use special storage containers.

As a rule, **transportation of recyclable materials takes place in garbage trucks with rear or clamp loading.** At the same time, it is advisable to take the recyclables directly to the sorting line by garbage trucks.

Treatment: on the sorting line (located in the MBT plant), waste is separated into different fractions using various mechanical and manual processes, as well as partially or fully automated sorting operations. The most important fractions include scrap glass, waste paper/cardboard, wood, ferrous metals, non-ferrous metals and plastic materials. Depending on the market demand, fractions of waste paper, and ferrous and non-ferrous metals can be subjected to additional sorting by grades.

Treatment of residual mixed waste is carried out using all technological stages of MBT.

</td></tr>
</table>

<table>
<tr><th colspan="2">Variant “Separate collection of secondary raw materials (in separate containers)”</th></tr>
<tr><th>Technological scheme</th><th>Description</th></tr>
<tr><td>


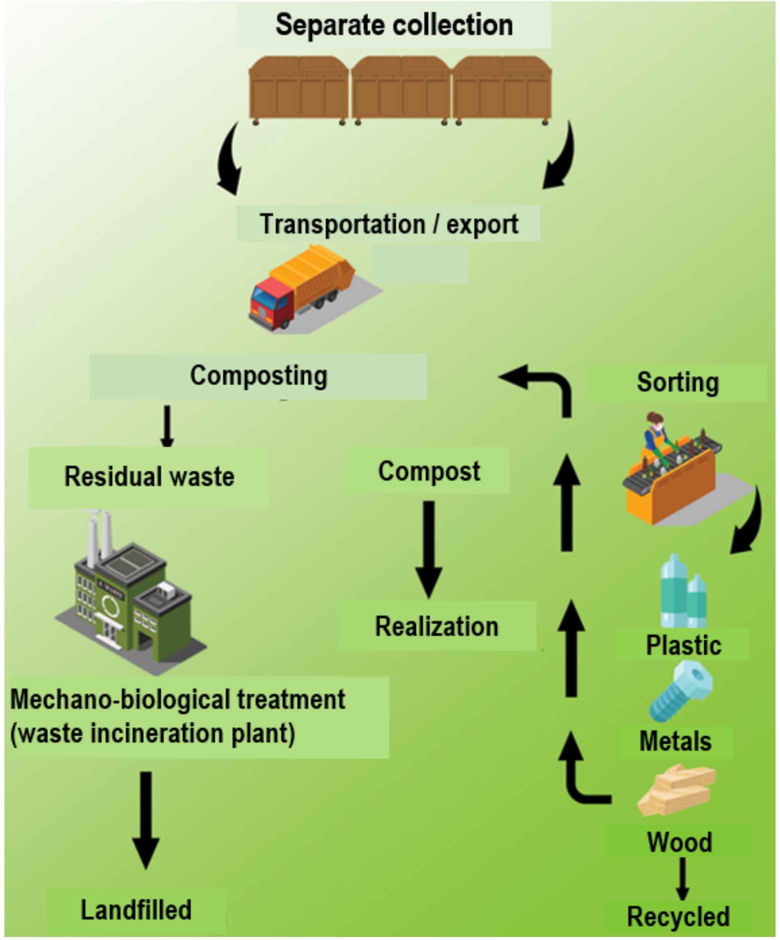
</td><td>

Collection: separate collection of secondary raw materials allows a significant reduction in the volume of waste that goes to disposal sites. Different containers can be used for collecting secondary raw materials, for example, mobile containers for waste of the type KSP or KSS of classes 1-4 according to DSTU 8476:2015, bags or bags. It is also possible to use special storage containers.

Transportation: Recyclables are usually transported in rear- or clamp-loading garbage trucks, sometimes front-loading. Large container systems and containers for waste collection are transported by special vehicles, which are equipped with the appropriate chassis and lifting and unloading devices. The model of the garbage truck is chosen depending on local conditions. At the same time, it is advisable to take the recyclables directly to the sorting line by garbage trucks.

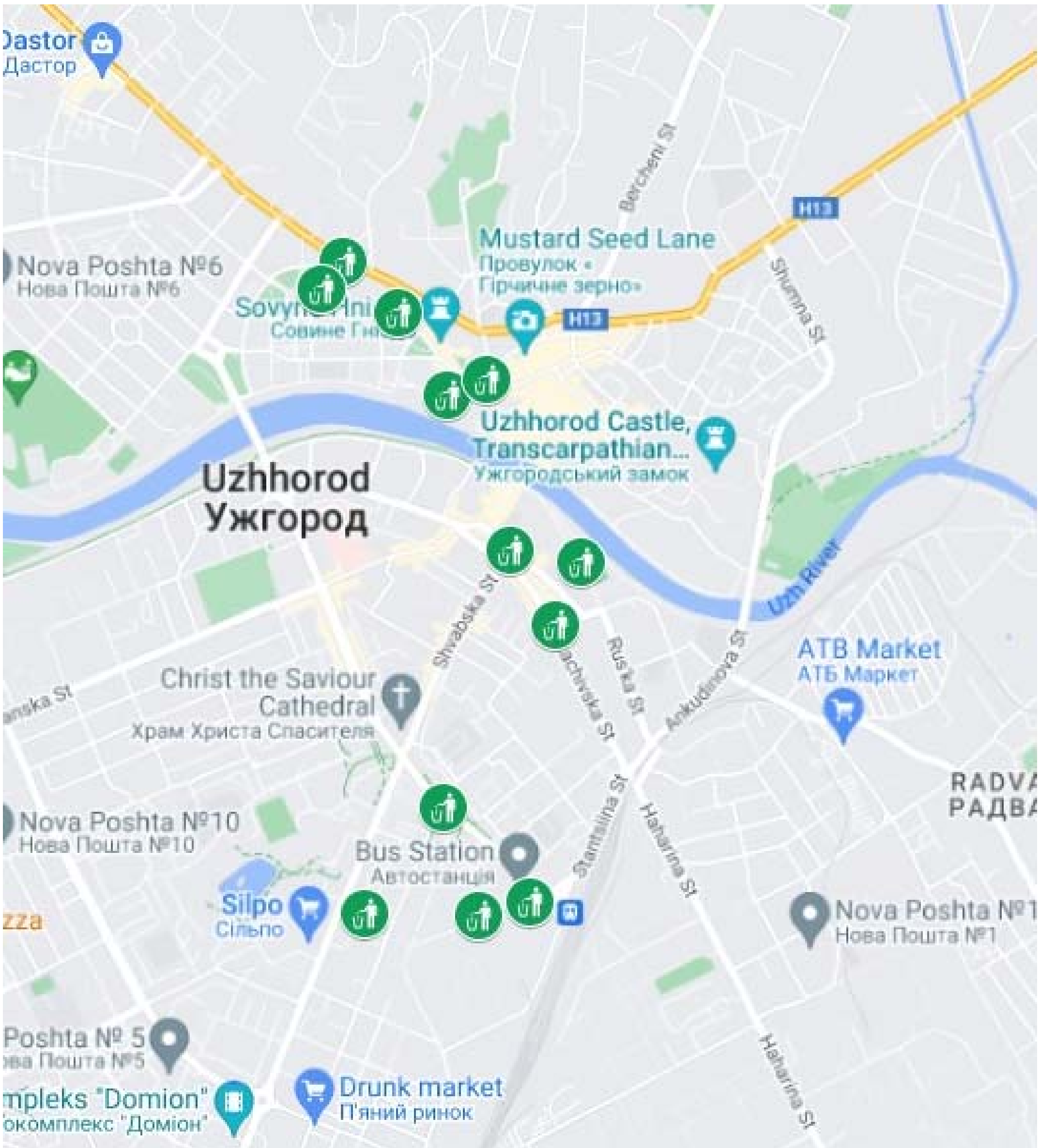
Treatment: on the sorting line (located in the MBT plant), waste is separated into different fractions using various mechanical and manual processes, as well as partially or fully automated sorting operations. The most important fractions include scrap glass, waste paper/cardboard, wood, ferrous metals, non-ferrous metals and plastic materials. Depending on the market demand, fractions of waste paper, ferrous and non-ferrous metals can be subjected to additional sorting by grades.

Treatment of residual mixed waste is carried out using all technological stages of MBT.
</td></tr>
</table>

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:** as a rule, removal of collected bio-waste takes place by garbage trucks with rear or clamp 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.
SYSTEMS OF UNDERGROUND CONTAINERS
FOR THE COLLECTION OF MUNICIPAL WASTE

Recommended installation locations of underground containers on the territory of Uzhhorod[63]



 – the place of installation of the underground container

63 http://surl.li/latyb

ANNEX C.
VARIANTS OF INSTALLATION OF CONTAINER SITES WITH UNDERGROUND CONTAINERS, TAKING INTO ACCOUNT THE LOCATION OF UNDERGROUND NETWORKS IN UZHHOROD

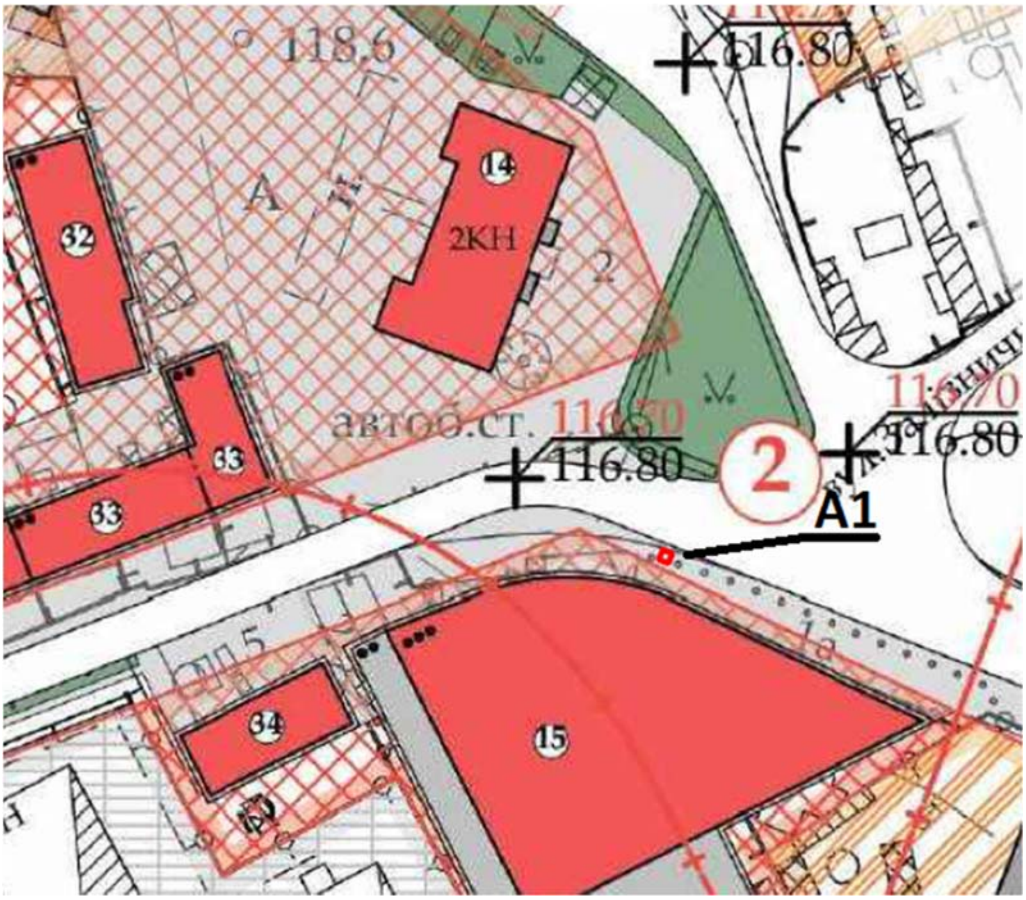


Figure C.1

Figure C.2

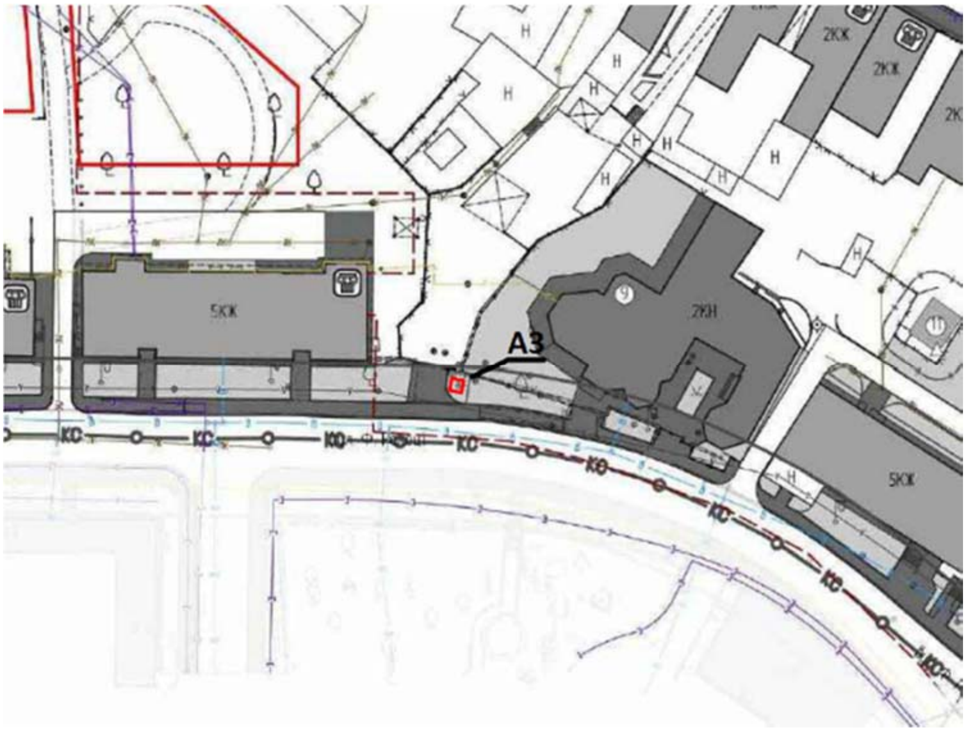


Figure C.3

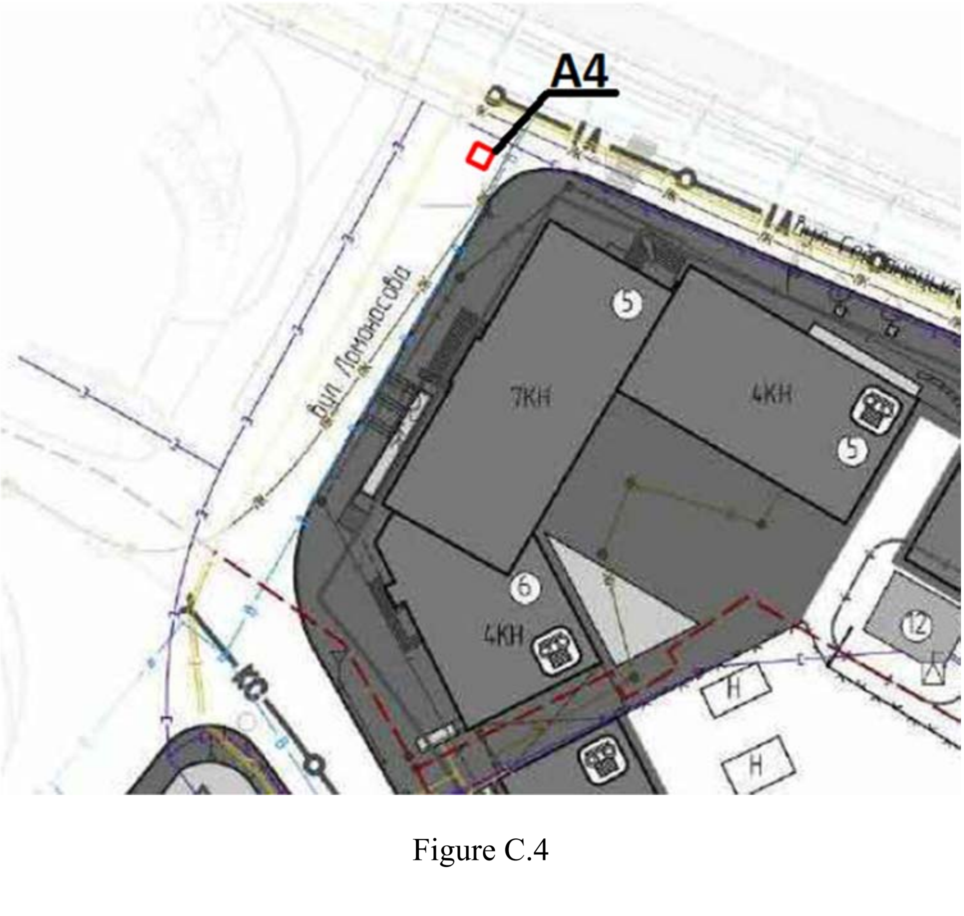


Figure C.4

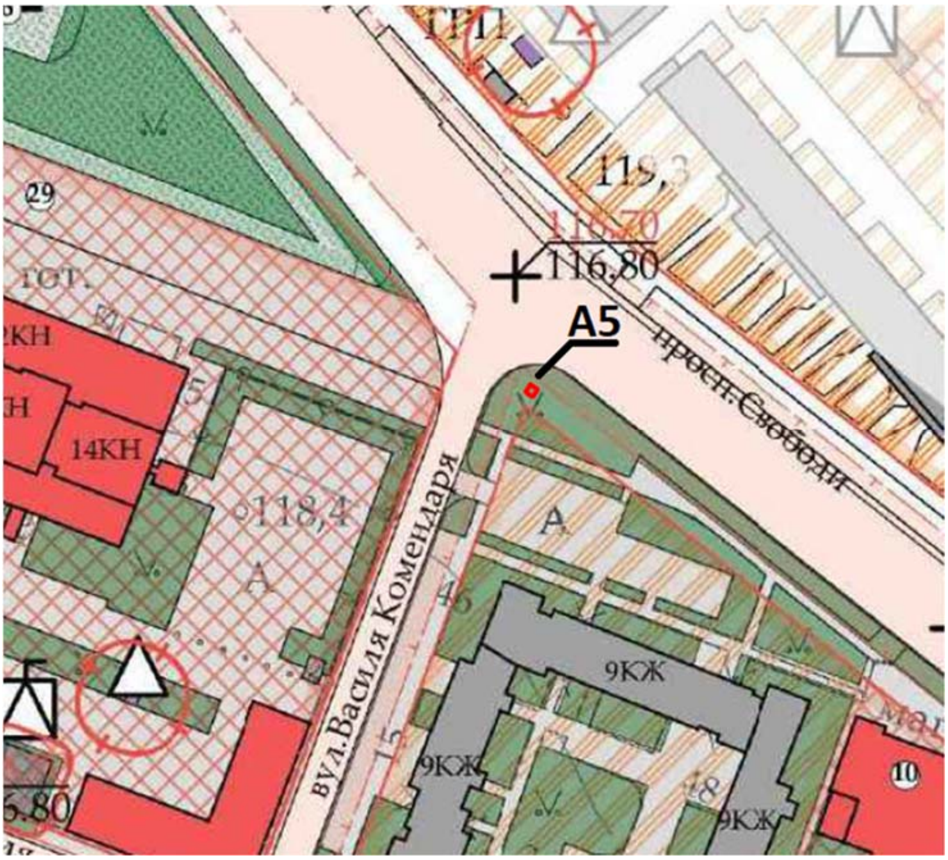


Figure C.5

Figure C.6

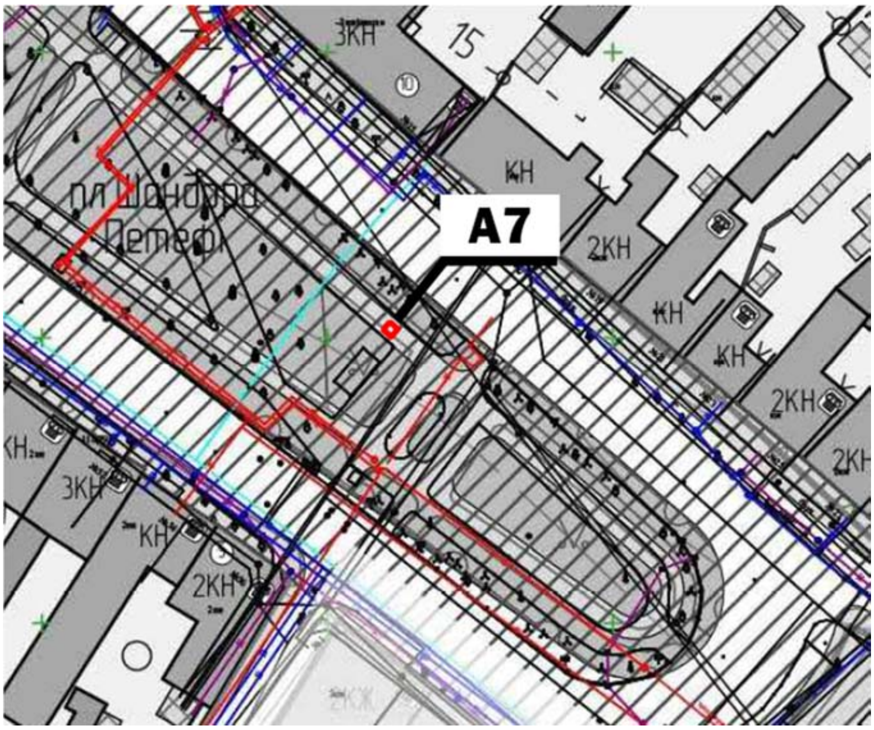


Figure C.7

Figure C.8

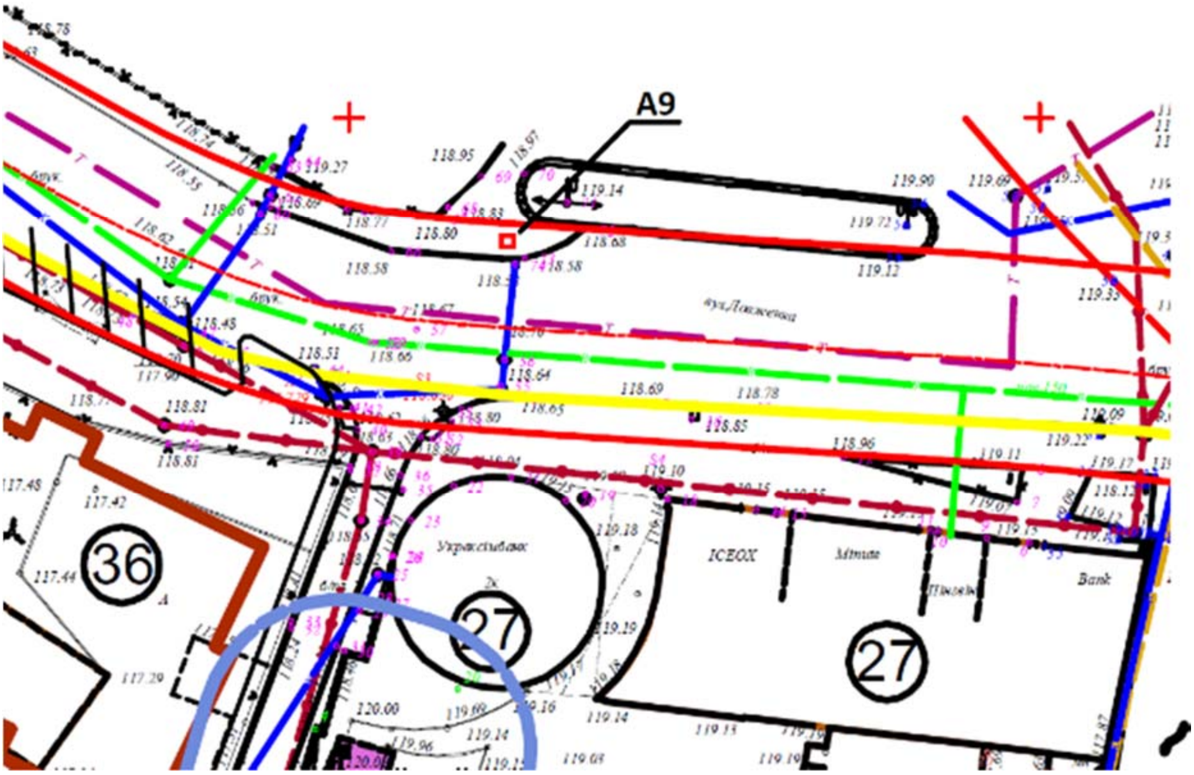


Figure C.9

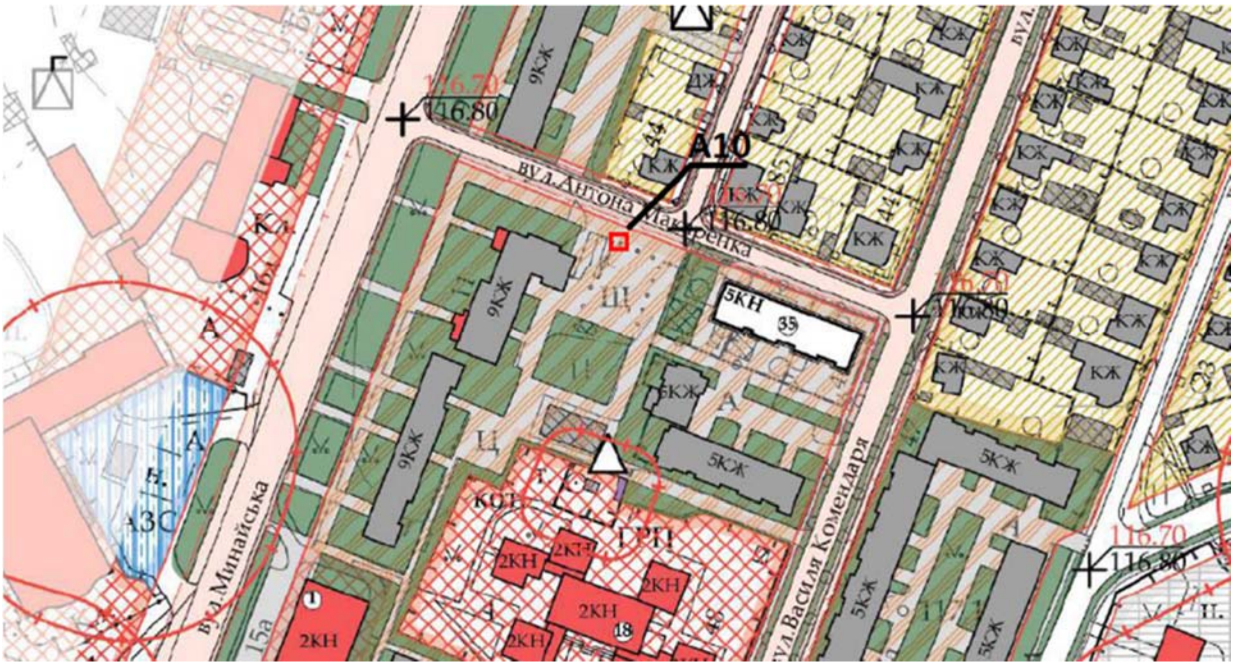


Figure C.10

Figure C.11

Figure C.12

ANNEX D.
COMMERCIAL PROPOSAL FOR THE INSTALLATION OF UNDERGROUND MUNICIPAL WASTE COLLECTION POINTS (CONTAINER SITES WITH UNDERGROUND CONTAINERS)

КФ-СІСТЕМС™

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www.kf-systems.com.ua

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вул. Бориспільська, 9 , корпус 4
ЄДРПОУ 40729819

<u>№ 72/4-7 від 05.06.2023 р.</u>

Т.в.о. директора
ДП «Науково-дослідний та конструкторсько-технологічний інститут міського господарства»
Голюк М.Г.

03035, м.Київ,
вул. Митрополита Василя Липківського, 35

Шановна пані Марино!

Дякуємо Вам за проявлений інтерес до нашої компанії.

Компанія «КФ-СІСТЕМС» більше семи років працює на ринку управління відходами, та є єдиним в Україні виробником автономних підземних контейнерів для побутових відходів.

На сьогоднішній день «КФ-СІСТЕМС» позиціонується як виробник, у якого завжди є в наявності повний спектр продукції для найвимогливіших покупців.

«КФ-СІСТЕМС» постійно розширює ринки збуту та прагне до максимального задоволення споживчого попиту. Плануючи дії на ринку, ми зацікавлені в стабільній роботі з тими операторами, які володіють мобільними ресурсами для постійного покращення благоустрою та екологічного стану міста.

У відповідь на Ваш запит, надаємо комерційну пропозицію на влаштування підземних пунктів збору сміття і побутових відходів по об'єкту

- Підземні контейнери KF:

Стандартна сміття-приймальна колонка Габарити ДхГхВ, мм (790x724x975)

Збільшена сміття-приймальна колонка Габарити ДхГхВ, мм (1060x990x983)

Перевагами таких контейнерів є:

- Об'єм контейнера 5м3 при необхідній площі 3,4м2;
- Наявність системи моніторингу наповненості;
- Наявність системи безпеки (під час розвантаження контейнера, чаша залишається закритою, що унеможливлює падіння людини всередину);
- Наявність системи пожежогасіння (при піднятті температури всередині контейнера спрацьовує вогнегасник);
- Санітарна зона 20м може бути скорочена;
- Наявність педалі для відкриття барабану (чисті руки);
- Відсутня необхідність підведення електроживлення (усі системи контейнера працюють від сонячної батареї);
- Відсутня необхідність підведення/встановлення водовідведення та дренажів;
- Відсутність доступу до пересортування сміття третіми особами (бомжі);
- Повна відсутність або незначний запах;
- Турбота про екологію (закрита система, литий з/б приямок, немає контакту з ґрунтом).

Технічні характеристики контейнера:

- **Об'єм контейнера для побутових відходів - 5 м^3**
- **Матеріал - сталь гарячого цинкування**
- **Габарити підземної частини контейнера, м:** Д=1,85хШ=1,85хГ=2,63
- **Габарити сміттє-приймальної колонки, м:** Д=0,79хШ=0,724хВ=0,975
- **Вантажопідйомність до 2,0 т.**

Найменування	Кількість, шт.	Ціна, з ПДВ, грн.	Сума, з ПДВ, грн.
Підземний контейнер для сміття зі стандартною сміття-приймальною колонкою 50л, 5м3	12	280 000,00	**3 360 000,00**

*Ціни вказані на умовах EXW-Київ, вул. Бориспільська, 9, Україна, відповідно до правил Інкотермс 2010.

У комплект поставки підземного контейнера об'ємом 5м3 входить:

- Залізобетонний приямок (виготовляється з бетону класу С25/30 за міцністю на тиск, W6 – за водонепроникністю, F100 – за морозостійкістю)*;
- Металевий оцинкований контейнер зі сміття-приймальною колонкою;
- Система безпеки (під час розвантаження контейнера, чаша залишається закритою);
- Наземна частина збору сміття;
- Підіймальний механізм;
- Система GPS-навігація за місцем знаходження;

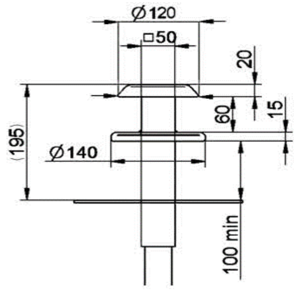
- Система моніторингу заповнення та температури;
- Система пожежогасіння.

Підземний контейнер обладнаний автономною системою моніторингу, яку живлять сонячні панелі. Система моніторингу передає дані про рівень заповнення контейнера на сервер, що дозволяє завчасно спланувати вивантаження сміття.

В конструкції контейнера також міститься вогнегасник який спрацьовує в разі пожежі, а система моніторингу передає дані про пожежу на сервер.

Система вивантаження контейнера:

- контейнер із системою KINSHOFER (для вивозу необхідний спецавтомобіль обладнаний насадкою KINSHOFER для грибної системи)



<u>**Всього комерційна пропозиція складає – 3 360 000,00 грн. з ПДВ.**</u>

В комерційну пропозицію не входить вартість розробки проектно – кошторисної документації.

Вартість доставки 12 комплектів в м. Ужгород **– 180 000,00 грн. з ПДВ** (додатково за необхідності даної послуги).

Можливий варіант монтажу обладнання силами спеціалістів ТОВ «КФ-СІСТЕМС» за рахунок Замовника (додатково за необхідності даної послуги).

Шефмонтажні роботи за 1 контейнер – **5 000 грн. з ПДВ** (додатково за необхідності даної послуги).

<u>**На всю продукцію надається гарантія:**</u>

- <u>***60 місяців на металеві частини конструкції від наскрізного прогнивання;***</u>
- <u>***120 місяців на залізобетонну частину конструкції;***</u>
- <u>***12 місяців на технічні засоби диспетчеризації конструкції.***</u>

<u>**Термін виготовлення – протягом 45 календарних днів з моменту отримання авансу**</u> *(пов'язано з технологічним процесом виготовлення з/б приямків для підземних контейнерів)*

<u>**Умови оплати – аванс 70%, доплата по факту виготовлення 20%, доплата після відвантаження 10%.**</u>

Користуючись нагодою пропонуємо Вам ознайомитись із контейнерами для роздільного збору відходів нашого виробництва.

Контейнер використовується для роздільного збору та сортування твердих відходів таких як: скло, пластик, папір.

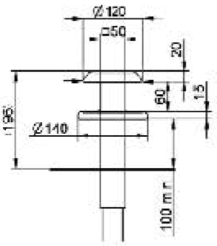
Технічні характеристики:

- Об'єм контейнера – 2,5м^3.
- Контейнер виконано із склопластикового вогнестійкого матеріалу.
- Товщина стінки контейнера – від 5 мм. до 7 мм.
- Вага контейнера – 90 кг, вантажопідйомність до 780 кг.
- Габаритні розміри –D=1750мм H=1570мм
- Отвір для завантаження сміття D=300мм (за необхідністю може бути змінено)

Сміттєвий контейнер призначений для роздільного сортування відходів.
Створений за концепцією нижнього розвантаження і його зовнішній вигляд дозволяє оптимально використовувати місце збору.

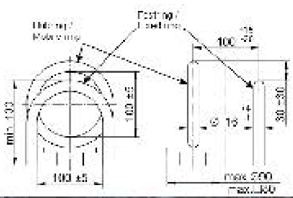
Система вивантаження контейнера може бути двох типів:
Перший тип - контейнер із системою KINSHOFER (для вивозу необхідний спецавтомобіль обладнаний насадкою KINSHOFER для грибної системи)

mushroom system for containers



Другий тип - контейнер із петлевою системою піднімання (для вивозу необхідний спецавтомобіль обладнаний гідравлічним підйомним краном)

ring system for containers





Найменування	Кількість, шт.	Ціна, грн з ПДВ	Сума, грн з ПДВ
Склопластиковий контейнер з грибковим зачепом/кільцевим зачепом (ДЗВІН)	1	27 300,00	27 300,00

- Контейнери мають естетичний зовнішній вигляд.
- Мають малу питому вагу і високу питому міцність.

- Стійкі до ультрафіолетового випромінювання, хімічного і біологічного впливів, високих та низьких температур (витримує температури від -40 °С до 60 °С протягом довгого часу).
- Гладка поверхня запобігає налипанню відходів на стінках бака.
- Контейнери водонепроникні.
- Можлива опція - комплектація системою диспетчеризації та моніторингу наповненості.

Колір контейнера та система вивантаження – за бажанням Замовника.

На всю продукцію надається один рік гарантії.
Термін виготовлення – протягом 30 календарних днів.

Також, можлива розробка будь-яких урн, контейнерів, сортувальних станцій чи інших металоконструкцій за дизайн-проектом Замовника.

З надією на плідну та взаємовигідну співпрацю.

Директор **Сергій МЕЛЬНИКОВ**

Віталій Кондратенко
050-384-65-28

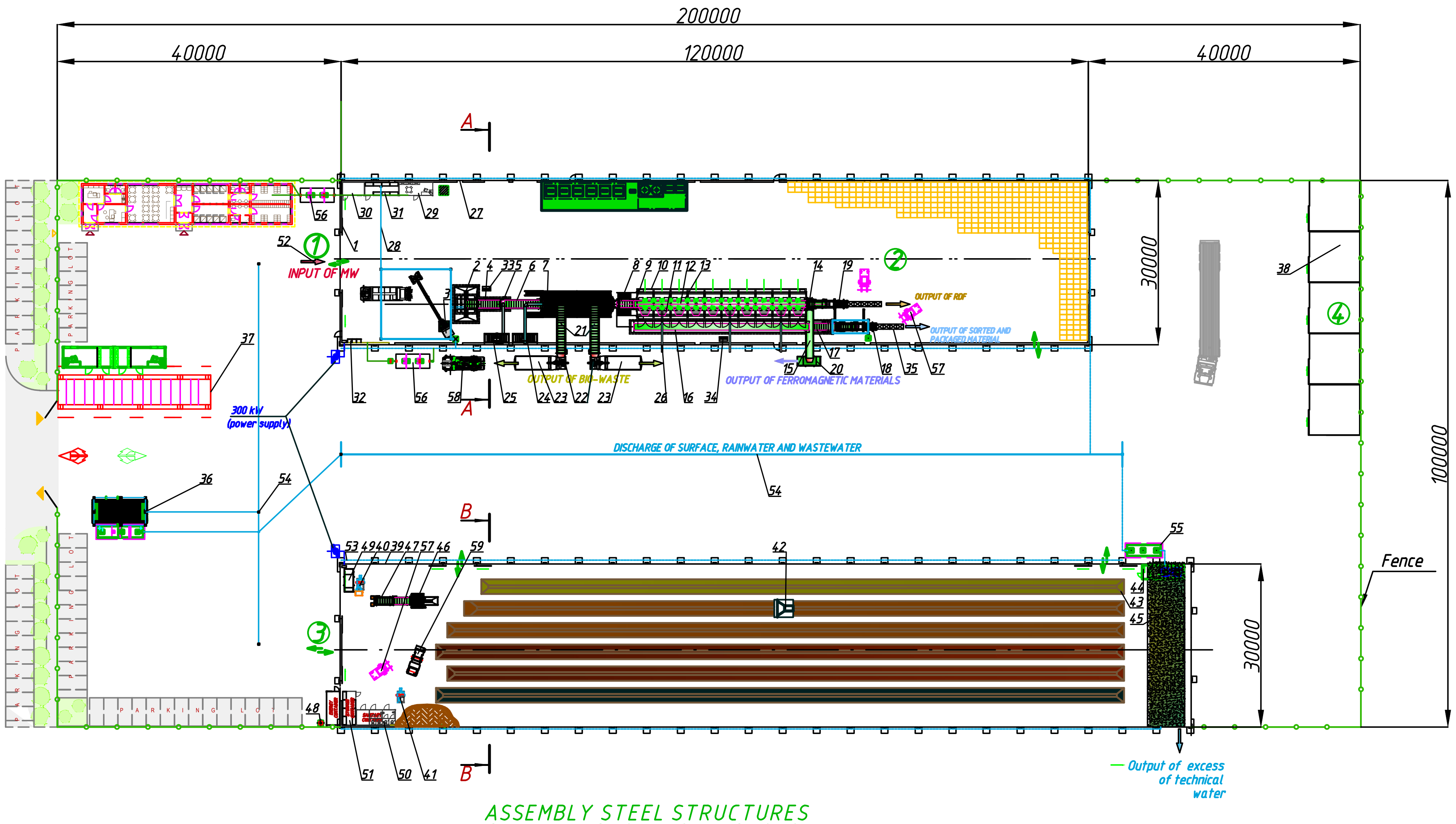
ANNEX E.
COST OF SECONDARY RAW MATERIALS

Table E.1 – Average sales prices of secondary raw materials (as of August 2023)

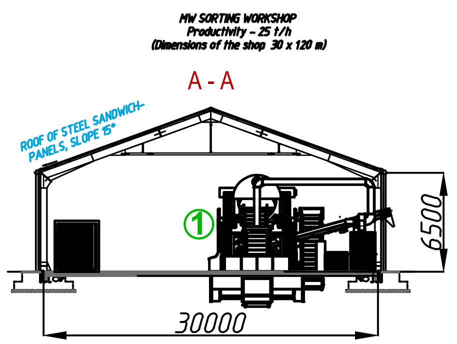
	Product type	Price, UAH per ton
1	PET bottle transparent	19,580.00
2	PET bottle blue	13,700.00
3	PET bottle green	12,000.00
4	PET bottle brown	10,540.00
5	PETF oil	7,670.00
6	PET bottle mixed	16,290.00
7	Cullet transparent	3,000.00
8	Cullet green	1,800.00
9	Low pressure film	7,000.00
10	Aluminum scrap	37,000.00
11	MS-7B	3,000.00
12	MS-5B	3,000.00
13	Colored LDPE	18,000.00
14	HDPE 2 grade + stretch	19,000.00

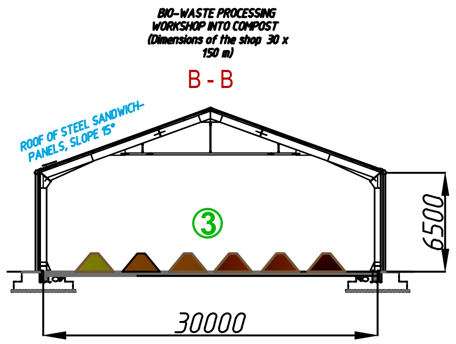
ANNEX F.
PLAN OF THE MECHANICAL AND BIOLOGICAL TREATMENT PLANT

PLAN OF THE MBT PLANT



ASSEMBLY STEEL STRUCTURES OF WORKSHOPS





Conditional designations of premises

1. MUNICIPAL WASTE SORTING WORKSHOP
2. PRODUCTION LINE, SHREDDING AND PRESSING OF RDF
3. BIO-WASTE PROCESSING AND COMPOST PRODUCTION WORKSHOP
4. RECYCLING YARD FOR COLLECTION OF BULKY WASTE

External dimensions of the MBT plant 2.0 ha (200.0 x 100.0m)
Production capacity of the MBT plant 25 t/h
Based on the materials of Tehniks (Croatia). Patent P20110260A

Explanation of premises and equipment

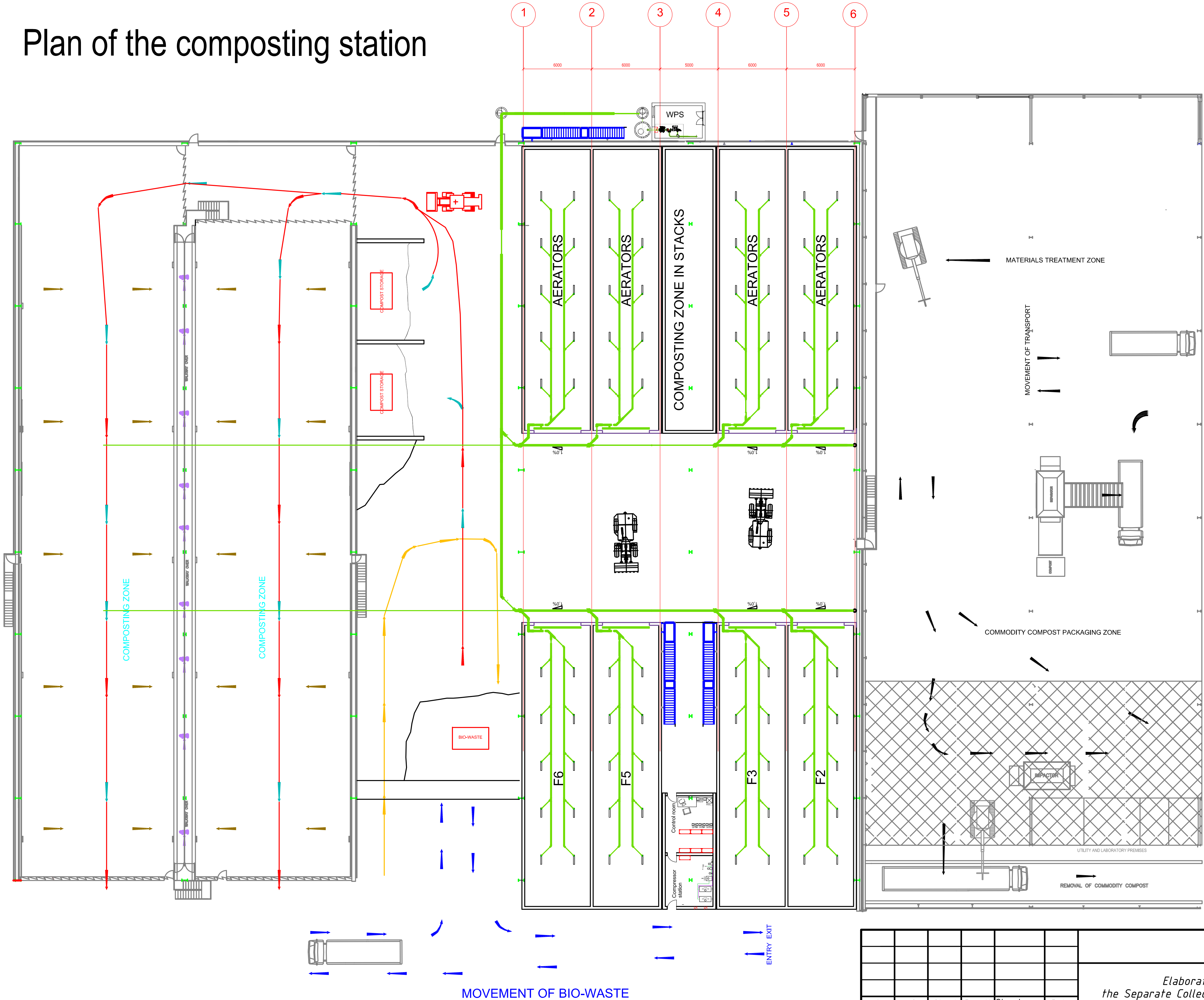
No.	Name of premises and equipment
1	Retractable gates for vehicle entry/exit
2	Screw conveyor
3	Crane for manipulation and feeding mixed communal and bulky waste
4	Feeding ribbed conveyor
5	Bag spreader
6	Receiving and feeding ribbed conveyor
7	Utility rotary separator
8	Lifting ribbed conveyor
9	Entrance door
10	Container sorting plant with air conditioning and ventilation
11	Zone of fresh air supply to the sorting cabins
12	Conveyor with a smooth surface
13	Sorting boxes with a folding bottom
14	Magnetic separator
15	Feed conveyor with a smooth surface
16	Receiving floor conveyor with a smooth surface
17	Lifting ribbed conveyor for filling the automatic press
18	Automatic press-packer for secondary raw materials
19	Automatic press packer for RDF
20	Utility container
21	Feed rib conveyor for bio-waste
22	Shredder for feeding bio-waste to the container
23	Containers for collecting bio-waste
24	Pipeline for intake of harmful air from the communal rotary separator
25	Filter plant
26	System of ventilation and conditioning of cabins for sorting
27	Ventilation holes for supplying fresh air
28	Channels for collecting waste water and other liquids
29	Container for line control and technological process control
30	Sanitary container
31	Container with cabinets for staff
32	Main distribution and control switchboard
33	RO facility control panel
34	Line control panel for automatic feeding
35	Output line of sorting and packing material
36	Transport disinfection zone
37	Weighing station of the complex for the processing of mixed solid waste
38	Containers for bulky waste
39	Body of the bio-waste processing plant
40	Shredder for coarse waste
41	Ecocomposter
42	Device for treatment of bio-waste
43	Compost stack
44	Control and automation point
45	Technical water
46	Fine-fraction rotary separator
47	Feed rib conveyor for bio-waste
48	Water connection
49	Electrical control panels of the bio-waste processing workshop
50	Sanitary container of bio-waste processing workshop
51	Storage container of the waste processing workshop
52	Traffic direction
53	Link for connecting the workshop to the power supply
54	Surface and wastewater discharge channel
55	Plant for pumping waste water
56	Local treatment facilities
57	Forklifts
58	Vehicles for import and export of waste
59	Tractor for working with compost

Am.	Q.	Sheet	Doc. No	Signature	Date	10/31.05.23
						Elaboration of a Feasibility Study (FS) for the Separate Collection of Secondary Raw Materials in Uzhhorod
Developed		Nebesna		[signature]		MBT plant — Stage: FS; Sheet: 1; Sheets: 1
N. control		Satin		[signature]		Plan, sections A-A; B-B S 1:1000 — SE NDKTI MG city Kyiv

A3 format

ANNEX G.
PLAN OF THE COMPOSTING STATION

Plan of the composting station



						10/31.05.23			
						Elaboration of a Feasibility Study (FS) for the Separate Collection of Secondary Raw Materials in Uzhhorod			
Am.	Q.	Sheet	Doc. No	Signature	Date				
Developed		Nebesna				Composting station	Stage	Sheet	Sheets
							FS	1	1
N. control		Satin				Schematic plan	SE NDKTI MG city Kyiv		

A2 format