MINISTRY OF FOREIGN AFFAIRS
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Mykolaiv
city on the wave

Assistance to the Development of the Mykolaiv Masterplan

Municipal waste management
Municipal waste treatment options, Report Final

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COWI

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List of Abbreviations

CAPEX	Capital Expenditure
EBRD	European Bank for Reconstruction and Development
FS	Feasibility study
IMC	Intermunicipal cooperation
LA	Legal acts
LLC	Limited liability company
MBT	Mechanical biological treatment
MCA	Mykolaiv City Administration
MFA	Danish Ministry of Foreign Affairs
MW	Municipal waste
MWM	Municipal waste management
MWMP	Municipal waste management plan
NERCEP	National Commission for State Regulation in the Field of Energy and Utilities
OPEX	Operational Expenses
PET	Polyethylene terephthalate
PPP	Public-private partnership
RDF	Refuse Derived Fuel
RWMP	Regional waste management plan
SES	Sanitary epidemiological service
SRF	Solid Recovered Fuel
UAH	Ukrainian Hryvnia
UC	Utility Company
WEEE	Waste from electrical and electronic equipment
WtE	Waste to Energy

1 Introduction

This report has been developed within the framework of the project “Technical advice to the Danish Ministry of Foreign Affairs regarding Mykolaiv - Denmark partnership” financed by the Danish Ministry of Foreign Affairs (MFA). The project, which has been entrusted COWI, is a framework contract, which, among others, includes assistance to the Mykolaiv City Administration (MCA) in developing the Mykolaiv Masterplan in close cooperation with an Italian company, One Works. Box 1-1 below provides information about COWI's contribution to the masterplan.

Box 1-1 COWI's contribution to Mykolaiv Masterplan in a nutshell

Mykolaiv Masterplan, which has been requested by the Mayor of Mykolaiv City, has a time horizon till 2050. It provides a compass for actions to be taken by the Mykolaiv City to ensure that it will develop into a thriving city attractive to its citizens and business community.

COWI and One Works assist Mykolaiv City Administration in developing the masterplan. In this work, COWI focuses on three sectors:

- Water and wastewater
- Energy, including power, district heating and renewable energy sources
- Solid waste management.

Mykolaiv City Administration meets every week with COWI and One Works to ensure proper coordination.

COWI has established a project organization consisting of a project management team and three sector teams of professionals, each headed by a Discipline Leader. Three sectoral Focal Points are responsible for monitoring cross-cutting activities, ensuring coordination between the parties and maintaining consistency in the deliverables.

To enhance transparency in the development of the Mykolaiv Masterplan, given its significant public interest and exposure, COWI has established three sector-specific Sounding Boards inviting all potentially interested parties to take part in these.

The principal audience for this report comprises the Mykolaiv City Administration (MCA) and One Works, given their central roles in the realization of this vision.

The report contains description and comparison of different municipal waste (MW) treatment options from technical and economical point of view and taking into account affordability of population. Besides the current chapter the report includes:

Chapter 2 describes the consultant's methodology for choosing diverse waste treatment options, provides applied forecasts for demographic developments and municipal waste generation and refers to the available data, data limitations, and applied assumptions

Chapter 3 presents waste treatment scenarios considered for the horizon until 2050, covering recyclables, organic and green waste, as well as mixed waste generated in the city

Finally, **Chapter 4** describes the existing system of setting tariffs and presents an affordability analysis based on the dynamics of income generation of the population projected until 2050.

2 Methodology, assumptions and calculation approach

This chapter provides a description of the methodology applied by the consultant for selecting various waste treatment options, assessing forecasts for demographic developments and municipal waste generation. Finally, it references the available data, data limitations, and applied assumptions.

2.1 Description of general methodology

To identify proper waste treatment options, an analysis of the technical and indicative aspects of treatment options has been conducted.

Applied methodology includes the following steps:

- Forecast[1] of MW generation based on the analysis of current data and assumptions
- Forecast of population dynamics
- Definition of material flow changes for the planning period based on MW composition, data from the MW generation forecast, and population forecast
- Definition of material flow changes with the application of basic assumptions on MW collection coverage growth, MW separate collection coverage growth, etc.
- Definition of material flow changes for the defined scenarios of MW treatment options and final targets that could be achieved under defined scenarios
- Definition of indicative costs for the MW treatment options based on the consultant's experience in FS development and operation facilities in EU countries
- Calculation of indicative weighted average tariffs for the MW management system for each scenario based on the application of indicative costs.
- Affordability analysis based on the forecast data on average revenue per person per year and calculated average weighted tariffs
- Based on the analysis data, the capacity of proposed facilities has been identified

All calculations are grounded in available official data, forecasts provided by experts, or, in the absence of data, determined by expert assumptions. The list of applied assumptions is detailed in Chapter 2.3.

The scope for choosing treatment options for application in Mykolaiv city and the comparative analysis is based on:

- EU requirements and practices

[1] All forecasts for this investigation are done for the horizon of 2050

- Requirements of the legislation of Ukraine, including documents on strategic planning for the MW management sector

- Necessity to achieve established targets, as outlined in the National Waste Management Plan until 2030 and the National Waste Management Strategy until 2030 (recycling, landfilling, etc.)

The following limitations and warnings have been considered:

- Affordability of the population: For the affordability analysis, an average EU practical limitation has been applied, where the payment for the MW management service should not exceed more than 1.0 – 1.5% of the average income per person per year.

- Investments return: A simplified return of CAPEX has been incorporated into the tariff

One aspect of this investigation is that projects are interconnected chronologically and are inserted into the calculation model gradually, stage by stage. Therefore, it is possible to define the achievable targets for the last year of the calculation period, which is the year 2050, when all measures will be implemented, and all facilities will be commissioned.

The following has been excluded from this analysis and investigation due to the absence of data, but it is highly recommended to be considered during the next stages:

- The frames of the RWMP: Typically, RWMP establishes targets for the oblast, defines clusters for MW management, the amount of MW that should be treated within each cluster, and defines future MW treatment infrastructure with its capacities. As of November-December 2023, the RWMP for Mykolaiv oblast has not been drafted, making it impossible to consider the aforementioned frames. It is recommended to clarify estimations of facility capacities (defined within this report) after the RWMP defines the clusters for MW and the amount of MW generation in each cluster

It is strongly recommended that representatives from the city participate in the development of the RWMP to ensure that technical solutions proposed by the RWMP align with the options defined for Mykolaiv city[2]

- Only indicative financial estimation has been done. FS calculations have been outside the project scope, but they could be conducted in the next stage during FS development to clarify the results of indicative costs and consider possible changes of capacities related to RWMP development

- The approach doesn't cover the defining of land plot areas for the MW treatment infrastructure, which could be done within FS. Only the area for the landfill is calculated

[2] This cooperation is foreseen in the PIP on waste in the enabling project STEP 1 "Support to development Municipal Waste Management Plan for Mykolaiv"

2.2 Forecasts

For Waste Management (WM) planning, it is crucial to take into account future changes related to WM generation as well as changes in the population.

2.2.1 Population

The scheme for sanitary cleaning in Mykolaiv city includes a population forecast, projecting population growth in the coming years from 470,011 people in January 2022 to 481,186 in 2028, 498.0 thousand people in 2038, and 507.7 thousand people in 2041. However, this forecast does not account for the negative population dynamics from 2015 (494,763 people) to 470,011 on January 1, 2022 (Statistical Service Data). The positive growth in the forecast is attributed mainly to mechanical growth resulting from an increase in the number of job opportunities and the expansion of residential construction.

It's important to note that this forecast doesn't consider the negative impact of the war. Between 2022 and 2023, there was a movement of people from Mykolaiv to other countries or regions of Ukraine (outflow), while an influx of people from the occupied territories of Kherson oblast took place. The latest available data for the city is for February 1, 2022 (before the war started), and according to this data, the population in Mykolaiv city is approximately 469,545 people.

Correction of the forecast is deemed impossible, given that the latest available data on the State Statistical Service website (https://www.ukrstat.gov.ua/) is for January and February 2022, which predates the onset of the war. Furthermore, there is no official data from open sources regarding casualties resulting from the war.

The most recent publications concerning the population forecast provide a general outlook for Ukraine. According to Ella Libanova, the director of the Institute of Demography and Social Research named after M. V. Ptukha at the National Academy of Sciences of Ukraine, "perhaps as of January 1, 2023, the population of Ukraine was 28-34 million people. The assessment was carried out throughout Ukraine within the country's borders as of January 1, 2022. The main share of this variation is due to the uncertainty surrounding migration. In this case, the forecast estimate of the population of Ukraine on January 1, 2030, within the borders as of January 1, 2022, may be 24 - 32 million people.

Considering the absence of a positive population dynamic for Ukraine in other relevant investigations, and in light of the information provided, the population figure as of February 1, 2022 (469,545 people) has been used for the entire planning period in the calculation of Municipal Waste (MW) generation.

2.2.2 Waste generation

Municipal Waste (MW) generation growth is correlated with the well-being of the population and GDP growth. For the purposes of this study, the amount of MW generation per capita is considered to be 309 kg/year. The assumption is made that MW generation grows at a rate of 0.2% for every 1% increase in GDP. The forecast results, as presented in the figure below (Figure 2-1), indicate that MW generation for the year 2050 will be approximately 153,000 tonnes, with a corresponding MW generation rate of 328 kg per capita.

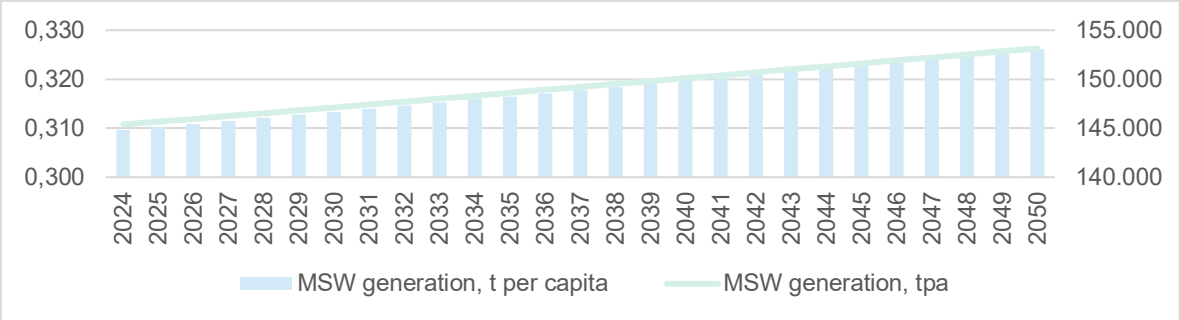

Figure 2-1. MW generation forecast for Mykolaiv city

Based on the Municipal Waste (MW) generation forecast, the changes in the quantity of recyclables until 2050 have been determined. The potential content of recyclables, including paper, cardboard, metals, glass, and plastics, for the year 2050 is estimated to be about 34,363 tons. The amount of organic waste is projected to be around 76,030 tons (Table 2-1).

Table 2-1 Forecast of WM material flow by individual components, 2025 – 2050

Waste category	%	2025	2030	2035	2040	2045	2050
MSW generation, tpa, including:		145,670	147,133	148,610	150,102	151,609	153,131
• Organic waste	50%	72,325	73,051	73,785	74,526	75,274	76,030
• Paper and cardboard	8%	11,319	11,432	11,547	11,663	11,780	11,898
• Polymers, including	8%	11,187	11,300	11,413	11,528	11,644	11,760
• PET	24%	2,647	2,674	2,700	2,727	2,755	2,783
• Glass	6%	8,230	8,313	8,396	8,481	8,566	8,652
• Metals	1%	1,952	1,972	1,991	2,011	2,032	2,052
• Textile	5%	6,759	6,827	6,896	6,965	7,035	7,105
• Wood	3%	4,676	4,723	4,770	4,818	4,867	4,916
Hazardous waste as part of MSW	0%	277	280	282	285	288	291
Bones, skin, rubber	3%	4,691	4,738	4,785	4,833	4,882	4,931
Tetra Pak	1%	1,209	1,221	1,233	1,246	1,258	1,271
Unsorted residue	10%	13,853	13,992	14,133	14,275	14,418	14,563
Bulky waste	2%	2,200	2,222	2,244	2,267	2,289	2,312
Waste electronic and electrical equipment	0.2%	335	338	342	345	349	352
Smal fraction (fines)	5%	6,657	6,724	6,791	6,860	6,929	6,998
Recyclables content, total		*32,688*	*33,017*	*33,348*	*33,683*	*34,021*	*34,363*

Source: Calculated by the consultant based on MW composition data and forecast for MW generation

2.3 Existing data and assumptions

The current situation, which has been thoroughly detailed in the report titled "Municipal Solid Waste: Existing Situation, Report (January 2023)" has been adopted as the conceptual basis, taking the data from 2023 as the baseline for further considerations. It includes:

- Population for 01.02.2022: 469,545 persons
- MW generation: 144,800t (919,800 m^3) or 309 kg per capita for basic 2022 year
- Population coverage by MW collection service: 63%

- MW landfilling: 99,9%
- MW composition: data provided by the city – results of investigations (see Report “Municipal Solid waste. Existing situation”)

Following main assumptions have been used for the calculations:

- MSW generation growth: 0,2% per 1% GDP growth
- Coverage by MSW collection: 5% per year increasing from 2024
- Coverage by separate collection: basic 0,5%; 5% per year increasing from 2024
- Separate collection efficiency: 80%
- Maximum organic waste separate collection coverage: 50%
- Output of clean compost: 30%
- RDF production: 30% from input waste flow
- Residuals after incineration:15%

3 Waste treatment scenarios

This chapter presents waste treatment scenarios that the consultant has considered, along with arguments for selecting some of them for inclusion in the Priority Investment Program (PIP) for the waste sector. The PIP, encompassing short-, mid-, and long-term investments, as well as enabling projects, forms the core of the roadmap aiming to achieve the targets set by Vision-2050 for municipal waste management in Mykolaiv.

With Ukraine recently granted the status of a candidate country for accession to the European Union, the initial consideration for selecting waste treatment scenarios focused on the waste hierarchy principle, aiming to prioritize recycling and minimize the amount of residual waste destined for landfilling. This hierarchy serves as the cornerstone of EU waste policies and legislation, as outlined in the EU Waste Framework Directive (Directive 2008/98/EC).

According to the Directive on waste 2008/98/EC and Directive 1999/31/EC the following targets has been established:

- the preparing for re-use and the recycling of municipal waste shall be increased to a minimum of 65 % by weight.

- amount of municipal waste landfilled is reduced to 10 % or less of the total amount of municipal waste generated (by weight).

- reduce the biodegradable waste landfilled to 35 % of that produced in 2015.

Scenarios for achieving the targets in line with the Vision-2050 have been drafted taking into account 2 factors:

- The system could be as close as possible to achieve EU targets on waste management as well as correspond with targets established by Ukrainian legislation and policy documents;

- The system should be feasible for the population

The following subchapters present waste treatment scenarios for various waste fractions:

- Chapter 3.1 Recyclables
- Chapter 3.2 Organic and green waste
- Chapter 3.3. Mixed waste

The selection of waste treatment scenarios will influence both the volume and composition of waste destined for landfill. At this stage, establishing a clear picture and choosing a specific set of treatment options for various waste types is not feasible. Therefore, several options have been considered to estimate the required capacity of the new landfill (Ch 3.5).

3.1 Recyclables

To conserve resources, reduce energy consumption, and decrease the volume of waste sent to landfills the consultant have included recycling of waste to all considered scenarios. Both EU and Ukrainian legislation require separate collection of MW with different recycling targets.

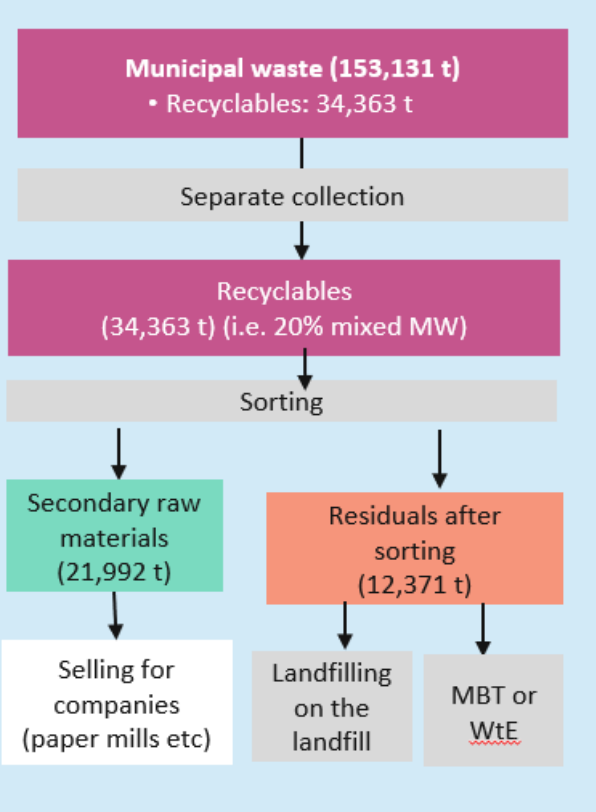

Figure 3-1 Treatment of recyclables

Recycling will include separate collection of recyclables, with subsequent sorting within the sorting line. Recyclable secondary raw materials will be sent to processing companies and residual waste will be disposed to the landfill as described in Figure 3-1 above.

Based on the data for MW content for 2050, the potential content of recyclables is estimated to be about 34,363 tonnes. The output of recyclables will depend on:

- Efficiency of MW separate collection
- Technical aspects of the sorting line construction (clean MRF)

The consultant's calculation is based on the assumption that the increase in separately collected municipal waste (MW) will be about 5% per year, and the proportion of containers with separately collected recyclables could be up to 20% of nonrecyclable waste. This technical solution will allow achieving a 14% recycling rate for MW in total.

The separate collection of MW will be developed step by step. The maximum input flow of separately collected MW will be about 5,077 tons in the year 2026, 10,050 tons in the year 2029, 20,176 tons in the year 2035, and 30,544 tons in the year 2041.

This increase should be considered during the planning of the sorting line capacity to ensure that the sorting line will operate at full capacity without overcapacity.

Main advantages/disadvantages for the sorting of mixed and separately collected MW described in Table 3-1

Table 3-1 Advantages/disadvantages for the sorting of mixed and separately collected MW

Sorting of mixed MW	Sorting of separately collected MW
• Captured recyclables are lower quality and there is lower price for selling them; • Lover amount of recyclables captured with the highest OPEX for electricity etc taking into account that whole mixed waste amount should go through the sorting line	• Higher output of recyclables with the better quality and better selling price; • Lower capacity is needed, so lower CAPEX and OPEX is expected

3.2 Proposed technical options for organic and green waste

Based on data for MW composition for 2050 potential content of organic waste is about 76,030 tonnes. Two following options for treatment of organic waste have been considered:

- Composting (Figure 3-3);
- Anaerobic digestion (AD)

The Figure 3-2 below visualise material flow of composting of organic and green waste.

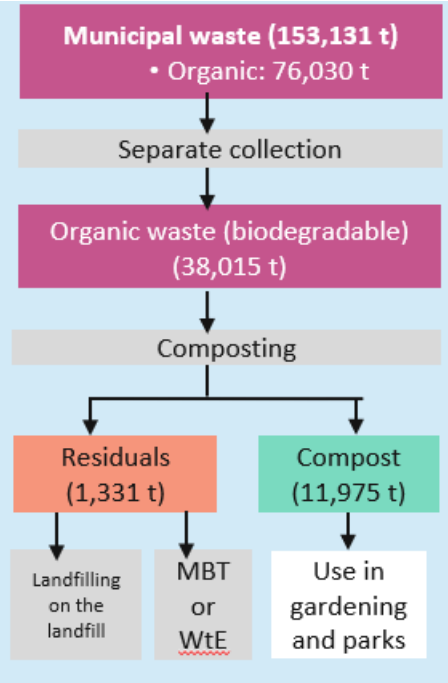

Figure 3-2 Material flow for composting of organic and green waste

Both options yield maximum positive results when organic and green waste are separately collected at the source of generation. This practice ensures the purity of the input flow and the resulting output products. Additionally, it is worth noting that Anaerobic Digestion (AD) is more technically sensitive for implementation.

The proposed scenario involves composting organic waste, and its implementation should align with the separate collection of organic waste.

Based on the experience in the EU, where currently not all countries have successfully implemented separate collection of organic waste, it is assumed that for Mykolaiv City, the

maximum coverage by organic waste separate collection could be 50%, assuming an annual growth rate of about 5%. This means that the maximum capacity of the composting plant could be 37,863 tons in 2025.

Furthermore, the introduction of biowaste separate collection requires the establishment of a separate tariff for this service, which could potentially increase the overall municipal waste (MW) management tariff. Financial aspects must be taken into consideration, and more detailed calculations can be conducted within the Municipal Waste Management Plan (MWMP) development process.

The remaining 50% of organic waste contained in municipal waste (MW) will be in bins together with mixed waste and will also require treatment.

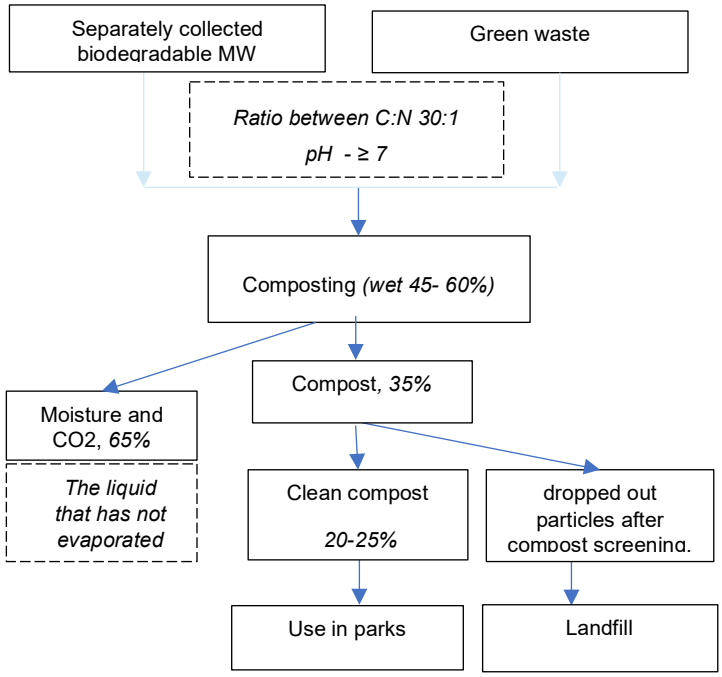

Figure 3-3. Technical scheme of composting

3.3 Proposed technical options for mixed waste

For the mixed waste treatment, consultant considered the following two options:

- Mechanical-Biological Treatment (MBT) with RDF production (with incineration either cement plant or boilers) and biostabilisation
- Direct incineration in incineration Plant

The two scenarios are further described in Chapter 3.3.1 and 3.3.2.

It should be noted that MCA is exploring the development of a new system for the treatment of MW and has engaged SE "Scientific-Research and Design-Technological Institute of Urban Economy" to undertake the development of a "Technical and Economic Feasibility Study for the new

construction of a Municipal Waste treatment complex in Mykolaiv City[3]". According to the Terms of Reference (ToR), the institute is tasked with creating a Feasibility Study (FS) for the MW treatment facility. This includes considering various technical options, providing a detailed cost comparison, and defining the facility's capacity. The FS is anticipated to be finalized by the end of March 2024.

It is important that findings of that project will be taken into consideration in future work.

3.3.1 MBT scenario

MBT of mixed waste is used for treatment of waste before landfilling and stabilisation of organic content. MBT typically includes the following components:

- Mechanical treatment – intended to sort out recyclables, combined with drying materials to produce RDF/SRF

- Biological treatment – could be anaerobic digestion or biostabilisation to treat organic waste as a part of mixed MW. Within the AD the biogas could be produced with further using in a combined heat and power (CHP) plant to produce electricity and heat. With the biostabilisation no positive output products is produced.

Considering MBT with biostabilisation and RDF/SRF production is proposed it is recommended to look into following options for further using of RDF/SRF:

- Using in cement kiln. There is a cement plant JSC Yugcement (operator - PRJSC Dyckerhoff Cement UA) within 37 km from Mykolaiv city. For further development of this option negotiations with Cement plant of SFT specification will be needed.

- Using RDF/SRF in boilers for the district heating system (option recommended by the city for considering).

There is a list of technical aspects that should be taken into account before choosing an option for further using of RDF/SRF:

- Additional chemical analysis of the waste is required.

- Estimation of calorific value of RDF/SRF

- The technical assessment the tolerable concentrations such as of moisture, sulphur, chlorine in the SRF

- Cleaning system for air emissions. For the end of 2024 Ukrainian legislation regarding system of measurement of air emissions and the list of substances for measuring as well as some limit values for them is in noncompliance with EU requirements. EU approach allows having more strict control on air emissions to prevent possible negative impact. In this regards option with cement plant is better regarding the high temperatures and circulation system

- Using fuel from waste also requires a permit for waste treatment

[3] https://prozorro.gov.ua/tender/UA-2023-10-26-010324-a

It is estimated that potential input of mixed waste for the MBT could be 94,455 tonnes in 2050. This also includes residuals after sorting of separately collected recyclables.

General material flow for MBT scenario with RDF production is described in Figure 3-3 and Table 3-1.

The final decision regarding MBT technology should be based on assessment of economic parameters of the project, local priorities and possibilities of commercial use of MBT final product that could be done during preparation of FS. In the case of MBT scenario an agreement on RDF specification with cement plant will be needed. Based on already existing experience on this issue, this might be recommended depending on final SRF[4].

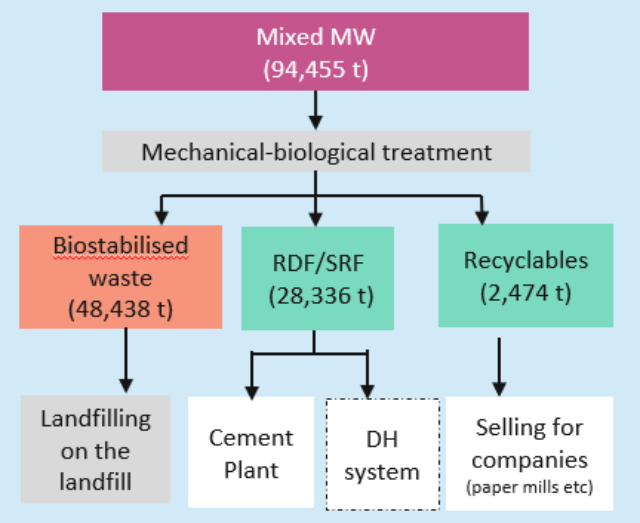

Figure 3-4 Material flow for MBT

scenario

3.3.2 Incineration scenario – waste-to-energy

For waste incineration scenario foresee construction of WtE plant. Material flow for incineration scenario is shown in the Figure 3-5.

Potential input of mixed waste for the cement plant could be 94,455 tonnes in 2050. This also includes residuals after sorting of separately collected recyclables. Assumed residuals after incineration is about 14,168 tonnes.

Advantage of incineration (WtE) is a significant reduction of MW landfilling. At the same time the main challenge related to treatment after incineration of fly ash and other residuals that could be classified as hazardous waste (see Category 19 01 Of the National List of waste[5] (19 01 05*, 19 01 07*, 19 01 10*, 19 01 11*, 19 01 13*, 19 01 15* etc). Hazardous waste requires specific treatment at additional costs.

[4] ISO/TR 21916:2021(en) Solid recovered fuels — Guidance for the specification of solid recovered fuels (SRF) for selected uses https://www.iso.org/obp/ui/en/#iso:std:iso:tr:21916:ed-1:v1:en
[5] https://zakon.rada.gov.ua/laws/show/1102-2023-%D0%BF#Text

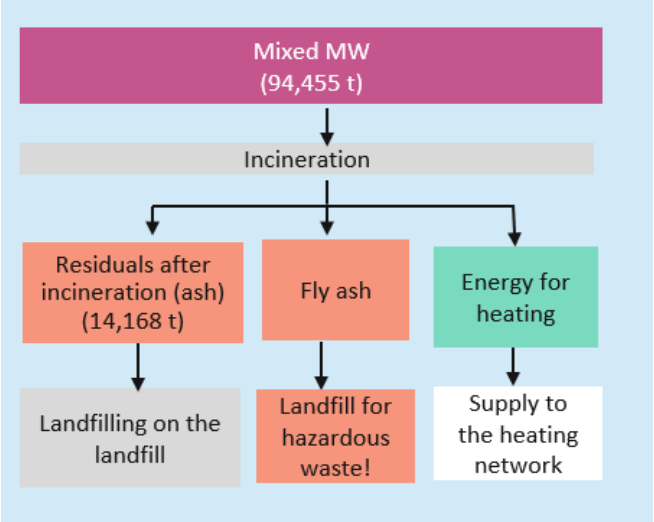

Figure 3-5 Material flow for waste-to-energy scenario

Other technical aspect which should be taken into account is possibility to use produced heat during whole year including summertime.

General material flow for incineration scenario with RDF production described Figure 3-4 and Table 3-2.

Table 3-2 Material balance for mixed MW treatment options scenarios (estimation for 2050)

Mixed MW treatment options	MW input		Recyclables (sorting)		RDF/SRF		Landfilling	
	tpa	%	tpa	%	tpa	%	tpa	%
MBT (RDF/SRF production + biostabilisation)	94,455	100	2,474	3%	28,338	Up to 30%	48,438	51%
Incineration scenario (WtE)	94,455	100	-	-	-	-	14,168	15%

3.3.3 Material flow analysis and achievable targets for proposed scenarios

Comparison of technical indicators shows that sorting of separately collected MW and composting of separately collected MW will ensure up to 24% of MW recycling. Within the scenario with MBT option recycling rate could be increased by 3%, recovery rate (% used RDF fuel) could be up to 19% and the landfill rate will be about 32%, 26% considered as mass loses during composting and biostabilisation of organic waste. Within the scenario with WtE plant option recovery rate could be up to 52% (in case of efficient using of energy), the landfill rate will be about 9%, 16% considered as mass loses during composting and biostabilisation of organic waste.

The material balances for two scenarios in 2050 are illustrated in Figure 3-6 and Figure 3-7.

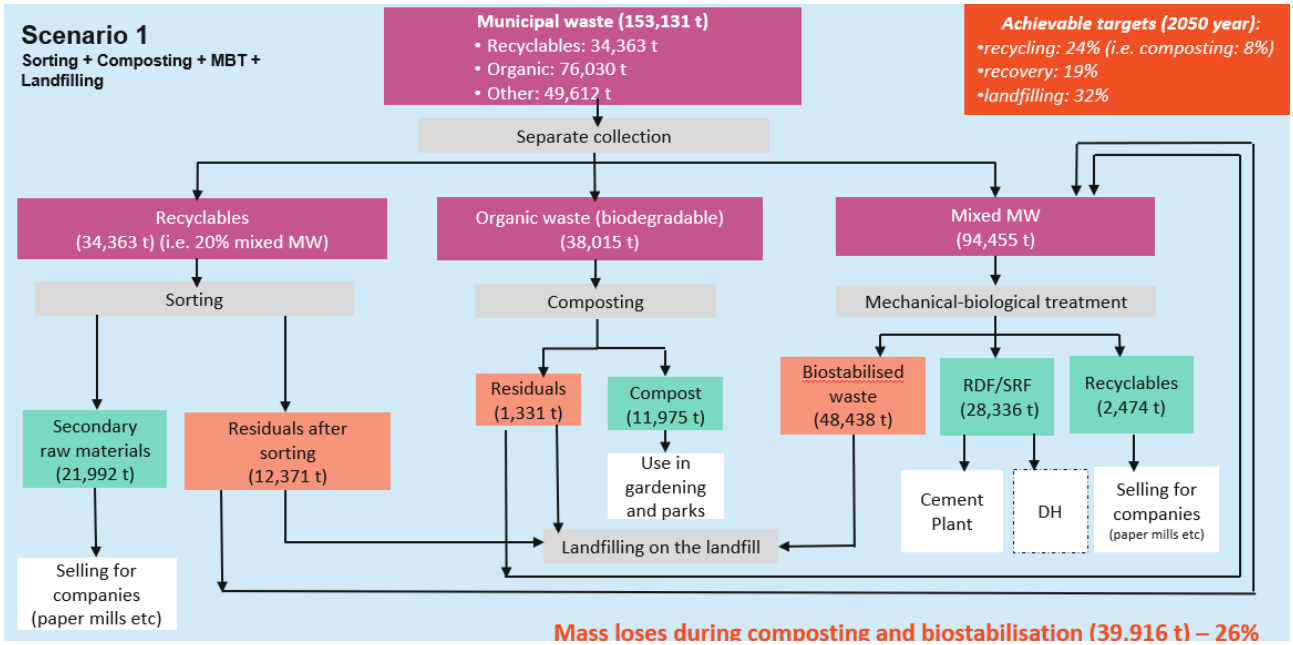

Figure 3-6. Scenario #1 Sorting + composting + MBT for mixed waste + landfilling

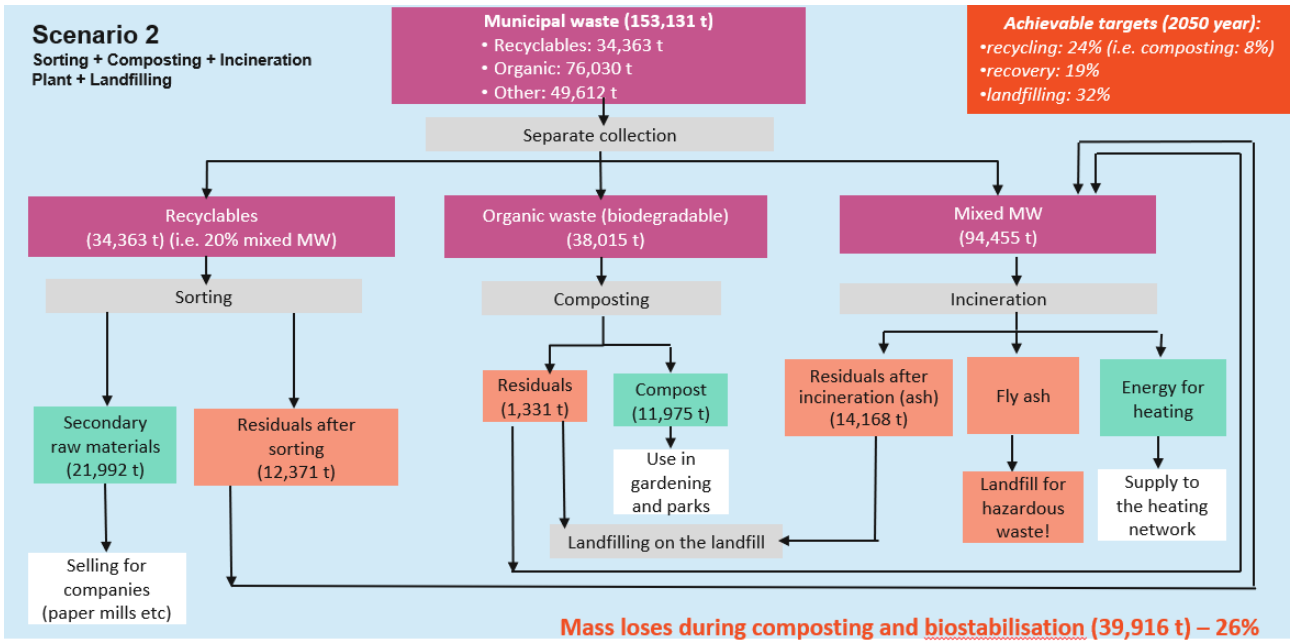

Figure 3-7. Scenario #2 Sorting + composting + WtE for mixed waste + landfilling

3.3.4 Indicative complex assessment of considered options

To draw a conclusion, financial aspects should be taken into account. The indicative CAPEX for each option, as well as the indicative average weighted tariff, are presented in Table 3-3 below. Scenario 1 is less attractive for the landfilling rate but is cheaper. Scenario 2 is more attractive for the landfilling rate reduction but is more expensive.

Table 3-3. MW management scenarios summary

Name	Type of waste	Capacity, tpa	Other parameters	Indicative tariff and payments for population	Targets achieved	CAPEX, mln EUR (indicative)
Scenario 1 Sorting + composting + MBT for mixed waste + landfilling						
Sorting plant	Separately collected recyclables	Up to 33,000	Reduction of capacity by 3 times for 1st stage is recommended	Tariff for management service – 9,662 UAH/t (including VAT for 2032) 641 UAH/person/month or 253 UAH/households/ month* (including VAT) 1.7% form average income (for 2032**)	Recycling – 24% Recovery – 19% Landfilling – 32%	~0.75
Composting plant	Biodegradable waste	Up to 36,000	Input is 50% of organic waste content in MW			~1.5
MBT with RDF production + biostabilisation	Mixed MW	95,000 – 100,000	30% RDF			~34.0
New landfill+ rehabilitation& closure of existing landfill	Mixed MW + other non-hazardous waste	145,000 + 20%	High – 15 m, operation- 20 years (3 cells), area – 24 ha (with other waste – 30ha)			~30.0 – 35.0 ~29.0
Scenario 2 Sorting + composting + WtE for mixed waste +landfilling						
Sorting plant	Separately collected recyclables	Up to 33,000	Reduction of capacity by 3 times for 1st stage is recommended	Tariff for management service – 13,221 UAH/t (including VAT for 2032) 347 UAH/person/month or 877 UAH/households/ month* (including VAT) 2.4% form average income (for 2032**)	Recycling – 24% Recovery – 52% Landfilling – 9%	~0,75
Composting plant	Biodegradable waste	Up to 36,000	Input is 50% of organic waste content in MW			~1,5
Incineration plant	Mixed MW	95,000 – 100,000	Fly ash treatment is a challenge			~up 130.0
New landfill+ rehabilitation& closure of existing landfill	Mixed MW +other non-hazardous waste	*145,000 + 20%*	With a decrease of MW landfilled the operation time of the landfill will be extended			~30.0 – 35.0 ~29.0

Source: calculated by expert

* There is 2.53 persons per one household

** Affordability to the 2032 done as Forecast of income per household provided by EBRD is only till 2032. This estimation could be considered as possible as for the 2032 estimated that all Facilities will be already launched in operation

Details of calculation tariffs described in chapter.....

Both scenarios will not allow achieve established by EU targets on MW recycling and reducing of the landfilling (Table 3-4). But it could be chieved in long term perspective in case of proper income growth of population and covering by biodegradable waste separate collection 100% of population which has not been implemented yet by all EU countries for the 2024.

Table 3-4 Comparison between targets which could be achieved by proposed scenarios of MW management (estimation for 2050) and targets established by EU Directives

Mixed MW treatment options	Recycling rate		Recovery rate		Landfilling rate	
	%	Year	%	Year	%	Year
Scenario #1 Sorting + composting + MBT for mixed waste (RDF/SRF production + biostabilisation) + landfilling *	24%	2050	19%	2050	32%	2050
Scenario #2 Sorting + composting + WtE for mixed waste + landfilling **	24%	2050	52%	2050	9%	2050
Directive 2008/98/EC	65%	2035	-	-	10%	2035
Law “On waste management”	10% 20% 25% 30%	2025 2030 2035 2040	-	-	-	-

* Mass loses during composting and biostabilisation about 26%s from total

** Mass loses during composting about 16% from total

3.4 Planning of the landfill capacity

Development of the municipal waste management system in Mykolaiv envisages the construction of a new landfill. Landfill capacity was forecasted for the following 4 scenarios:

1. Waste disposal without waste minimization measures excluding non-hazardous industrial waste
2. Waste disposal without waste minimization measures including non-hazardous industrial waste
3. Waste disposal with waste minimization measures excluding non-hazardous industrial waste
4. Waste disposal with waste minimization measures including non-hazardous industrial waste

Expected waste disposal is shown in the Table 3-5

Table 3-5.Expected waste disposal on the landfill and landfill parameters

Name of indicator	MSW landfilling			Total landfilling with industry waste		
	Without waste minimization measures*	With waste minimization measures		Without waste minimization measures	With waste minimization measures	
		MBT scenario	Incineration scenario		MBT scenario	Incineration scenario
Capacity, tpa	153,000	48,500	14,000	191,250	58,200	16,800
High, m	15	15	15	15	15	15
Area, ha*	26	8	3	32	10	3
Operation time, years	20	20	20	20	20	20

* Area of the landfill will be adjusted during the development of design documentation.

It’s quite important to make all hydrogeological investigation for the land plot for a new landfill.

4 Affordability analysis

Affordability is a key element in planning a MW management system. Any project should be financially recoverable. The primary source of income for any MW management project is the tariff for MW management services, which is converted into payments from the population for the services provided.

The main data used for analyses is:

- macroeconomic data forecast for Ukraine from 2022-2032,
- household income and expenditure data in Mykolaiv for each of 10 income deciles in UAH for 2018-2021 (drafted by financial experts of COWI),
- average household size in Mykolaiv for 2018-2022,

The macroeconomic data for 2022-2032 is provided by European Bank for Reconstruction and Development (EBRD) whereas the other data is provided by the municipality of Mykolaiv.

4.1 Population revenue forecast

The critical issue for MW management sector is an affordability issue because cost recovery depends on the established and paid in time tariff on MW management service, including MW recycling. To understand the level of affordability, which will limit possibilities in MW treatment technology, the level of population income is analysed, and the proper forecast has been developed. In recent years, the Mykolaiv has seen an annual increase in the average monthly nominal wage, and as a result - an increase in disposable income and total resources per household.

Table 4-1 Nominal income growth 2022-2032 (pct.)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Nominal income growth	-10.2 %	15.8%	10.2%	12.4%	13.4%	15.5%	15.5%	13.4%	13.4%	11.3%	11.3%

In the analyses the nominal income growth rate projects the households' nominal expenditure for the years from 2022-2032.

Baseline data for household nominal income for 2018-2021 has been considered for each of 10 deciles. For 2022-2032 - the data has projected for each decile using the nominal income growth rate.

The average household income for each decile is given in Table 4-2.

The Table 4-2 shows that the income is not increasing consistently for every increase in the income decile. This is because the household incomes are based on average incomes per capita, and that the average household size differs between the deciles. The average household size tends to be larger for smaller income deciles than for higher income deciles.

Table 4-2 The average household income per each decile (1,000 UAH per month)

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Average household	8.8	10.4	10.6	11.9	10.7	12.4	13.7	15.4	17.4	20.1	23.2	26.3	29.9	33.3	37.0
1st decile	6.0	5.2	5.2	6.7	6.0	7.0	7.7	8.6	9.8	11.3	13.0	14.8	16.8	18.6	20.8
2nd decile	5.5	6.8	6.4	7.9	7.1	8.2	9.0	10.2	11.5	13.3	15.4	17.4	19.8	22.0	24.5
3rd decile	6.3	7.8	9.3	9.6	8.7	10.0	11.1	12.4	14.1	16.3	18.8	21.3	24.2	26.9	29.9
4th decile	7.3	8.3	8.6	9.0	8.0	9.3	10.3	11.5	13.1	15.1	17.4	19.8	22.4	25.0	27.8
5th decile	8.8	9.2	10.3	10.8	9.7	11.2	12.4	13.9	15.8	18.2	21.1	23.9	27.1	30.1	33.5
6h decile	8.1	9.7	11.0	9.9	8.9	10.3	11.4	12.8	14.5	16.8	19.4	22.0	24.9	27.7	30.8
7th decile	8.3	11.3	10.4	14.3	12.8	14.8	16.3	18.4	20.8	24.0	27.8	31.5	35.7	39.8	44.2
8th decile	9.2	14.1	11.8	14.0	12.6	14.6	16.1	18.1	20.5	23.7	27.3	31.0	35.2	39.1	43.6
9th decile	13.0	14.1	17.5	15.6	14.0	16.3	17.9	20.1	22.8	26.4	30.5	34.5	39.2	43.6	48.5
10th decile	15.9	17.5	15.5	21.6	19.4	22.4	24.7	27.8	31.5	36.4	42.0	47.6	54.0	60.1	66.9

Source: developed by financial experts of COWI

Average household size

The average size of a household is assumed to be 2.53 for all years in the analyses. This was the average household size in 2022.

4.2 Data and assumptions

The main data used in the affordability analysis for waste is:

- Ukrainian tariffs MW waste service in UAH/m³ for 2018-2023
- Waste generation in Mykolaiv in kg per capita per day (calculated based on developed forecast for MW generation till 2032)
- Ukrainian VAT rates for MW service tariffs.

The VAT rates are provided by Ministry of Regional Development, Construction, Housing and Communal Services of Ukraine. The MW management service tariffs data are provided by the municipality of Mykolaiv.

4.3 Analysis of current tariffs for MW management service

Baseline analysis of the tariff data includes data for 2018-2023. In Mykolaiv city, there was a gradual increase in the tariff for solid waste management service (Table 4-3). However, this increase was more related to the necessity of covering basic costs for service provision with the impact of inflation. Significant increasing of the tariff has been noted in 2020. Such increase of the landfill tariff appeared after a long period when the tariff has not been adjusted. Also, such increase related to the changes in the system when only one tariff rate could be established for all types of consumers.

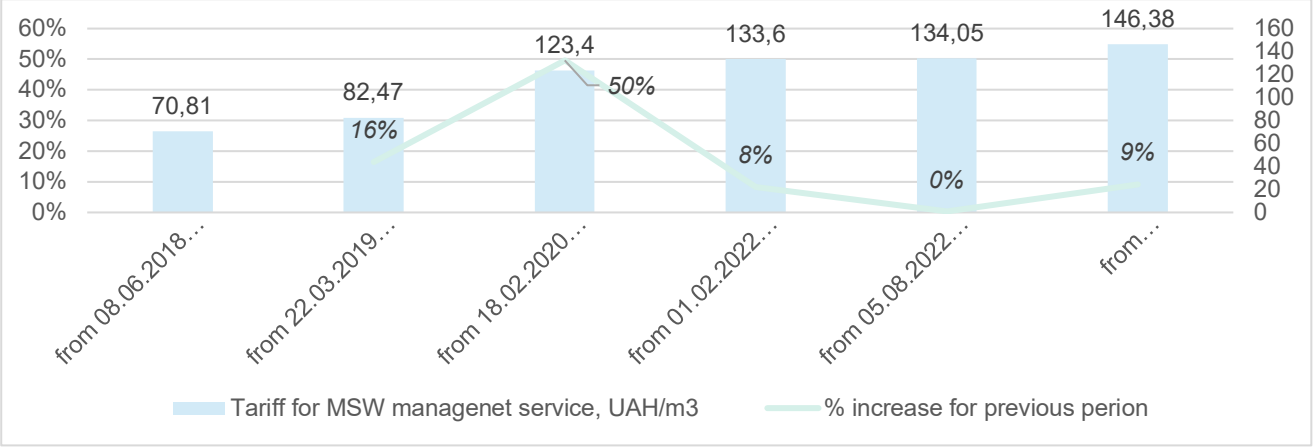

Figure 4-1 Changes of MSW management service tariff during 2018 - 2023

Based on the average MW generation rate for 2023, the payment for the population was about 25 UAH per person per month (for MW only) or 29–31 UAH per person per month (for MW, bulky, repair waste management), equivalent to 0.3% of the average income per person per year.

Table 4-3 Tariffs for MW management services in Mykolaiv city, UAH / m3

The name of tariff category	UC "Mykolaivkomuntrans"		UC "Obriy-DKP"	
	With container system	Without container system	With container system	Without container system
from 08.06.2018 till 22.03.2019[6]				
For population	70.81	100.38	67.33	99.15 (29.75)
For budgetary institutions	78.48	110.86	74.67	109.52
For other organizations	106.65	148.88	101.67	147.13
from 22.03.2019 till 18.02.2020[7]				
For population	82.47	112.83	86.39	117.81
For budgetary institutions	91.25	124.50	95.55	136.41
For other organizations	123.31	166.68	128.91	182.21
from 18.02.2020 till 01.02.2022[8]				
For population	123.4		129	
For budgetary institutions	**		**	
For other organizations	**		**	
from 01.02.2022 till 05.08.2022[9]				
Municipal solid waste	133.6		131.28	
Bulky waste	158.99		271.57	
Repair waste	158.99		242.17	
Liquid waste	308.8		233.52	
from 05.08.2022[10]				
Municipal solid waste	134.05		135.24	
Bulky waste	179.46		276.79	
Repair waste	179.46		254.43	
Liquid waste	347.58		234.36	
from 01.09.2023 [11]				
Municipal solid waste	146.38		151.93	
Bulky waste	256.28		313.6	
Repair waste	256.28		284.51	
Liquid waste	416.45		278.97	

* Management service includes the next operations according to the new legislation: collection and transportation; recovery and disposal. The names of the operation in this table are in compliance with legislation which has been in force till July, 2023

** From 2020 according to the legislation amendments only one tariff for all categories of consumers is established
Source: data provided by MCA

MW collection and transportation tariff is revised every year for while the tariff for landfilling of MW waste is revised once every two years. Before 2020 landfill tariff was about 8,53 UAH/m3 which is

[6] https://mkrada.gov.ua/documents/28712.html
[7] https://mkrada.gov.ua/documents/31201.html
[8] https://mkrada.gov.ua/documents/33414.html
[9] https://mkrada.gov.ua/documents/38623.html
[10] https://mkrada.gov.ua/documents/39414.html
[11] https://mkrada.gov.ua/content/utilizaciya-vidhodiv.html

about 40 UAH/t or 1.35 EUR/t (Figure 4-2). After the last revision of the landfill tariff in 2022 it was about 3.6 EUR/t.

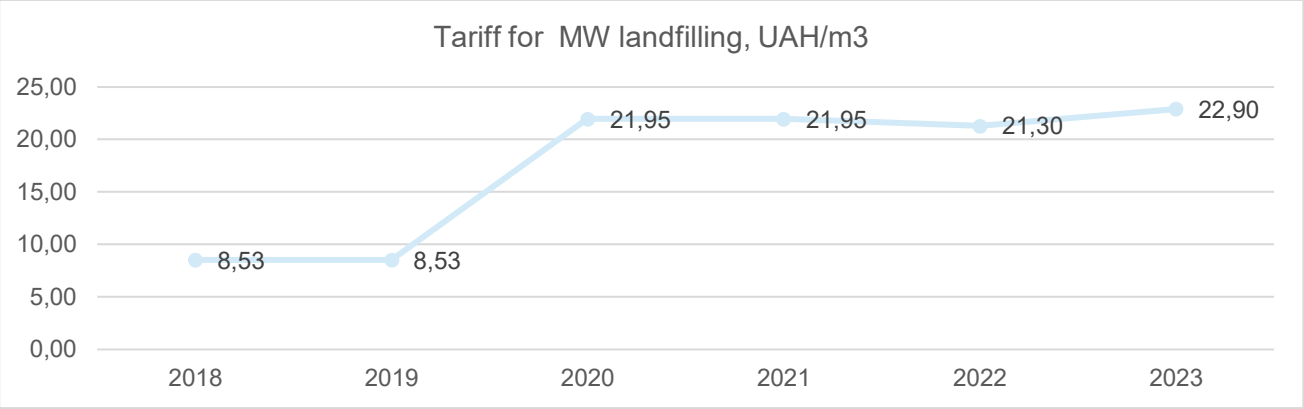

Figure 4-2 Dynamics of the tariff for MW landfilling, 2018 – 2023, UAH/m3

Source: https://mkrada.gov.ua/documents

*For 2022 tariff for the landfilling has been established in UAH /m3 and in UAH/t (140.92 UAH/t)

4.4 Results

The MW service average weighted tariff has been calculated for the period 2030 – 2032. The latest year of the forecasted tariff growth has been limited by the data on the revenue forecast (based on EBRD forecast of macroeconomic indicators). The first year of tariff that has been taken into consideration is 2030 when all planned infrastructure on MW management will be in operation. Tariffs include VAT

Tariffs have been calculated for two scenarios:

- Scenario 1: Sorting + composting + MBT for mixed waste + landfilling
- Scenario 2: Sorting + composting + WtE for mixed waste +landfilling

For the tariff growth calculation:

- Recovery of required CAPEX and OPEX has been included;
- The compounding tare was established as 14%;
- Within the CAPEX the different terms of CAPEX recovery have been considered (MBT – 20 years, WtE plant – 20 years, composting plant – 10 years, new landfill – 20 years, sorting line – 10 years, CAPEX for new vehicles have been included too). Ther terms of CAPEX recovery could be clarified during the FS.

For the MW generation rates assumptions described in Chapter 2 have been used. The basic for MW generation per capita per 2024 has been considered as 0,309 t/person/year. Calculated MW generation per capita for 2030 – 2032 is described in Table 4-4

Summary of results presented in Table 4-4 below. With defined level of income increase affordability will become lower over the years as income growth rate is lower that inflation rate and

increasing of costs for the MW service. The Scenario 1 (average affordability rate is 1.6 – 1.7%) is more affordable for population than Scenario 2 (average affordability rate is 2.2 – 2.4%). But considering this within 10 deciles for population this % is more differentiated.

The level of affordability for MW management service is recommended to be 1.0 – 1.5% (% of payment for the service from Average income).

For Scenario 1 the 7th - 10th income decile will not have any waste affordability problems towards 2032 assuming an affordability threshold of 1.0 – 1.5%. The 1st – 6 th income decile will have an affordability problem from 2030 to 2032 as the affordability ratio exceed the threshold of 1.0 – 1.5%.

For Scenario 2 the 10th income decile will not have any waste affordability problems towards 2032 assuming an affordability threshold of 1.0 – 1.5%. The 1st – 9 th income decile will have an affordability problem from 2030 to 2032 as the affordability ratio exceed the threshold of 1.0 – 1.5%.

To be as close as possible to the affordable level the CAPEX and infrastructure creation should be spread out in time. Construction of all necessary infrastructure within the short timescale will have negative impact of the system of payments. Also attracting grants could cover part of costs to reduce impact of the tariff.

Table 4-4 Average weighted tariffs on MW management service and affordability 2030 - 2032

	2030	2031	2032
Generation of MW, t/person/year	0.313	0.314	0.315
Generation of MW, t/household/year*	0.793	0.794	0.796
Average revenue per household, UAH/ household/ month	29,877.0	33,253.0	37,010.0
Scenario 1			
Scenario #1 Sorting + composting + MBT for mixed waste (RDF/SRF production + biostabilisation) + landfilling **			
Average weighted MW management service tariff (Excluding VAT), UAH/t	6,195.62	7,063.00	8,051.82
Average weighted MW management service tariff (Including VAT), UAH/t	7,434.74	8,475.60	9,662.19
Payment for MW management service (Including VAT), UAH/household/ month	491	561	641
% form average income	1.6%	1.7%	1.7%
Scenario #2 Sorting + composting + WtE for mixed waste + landfilling **			
Average weighted MW management service tariff (Excluding VAT), UAH/t	8,477.69	9,664.56	11,017.60
Average weighted MW management service tariff (Including VAT), UAH/t	13,221.12	13,221.12	13,221.12
Payment for MW management service (Including VAT), UAH/household/ month	672	768	877
% form average income	2.2%	2.3%	2.4%

* There is 2.53 persons per 1 household

** MW collection service and CAPEX recovery for new vehicles is included

Table 4-5 Waste services affordability in Mykolaiv (pct.)

Affordability	2030	2031	2032	2030	2031	2032
	Scenario 1			Scenario 2		
average household	1.6%	1.7%	1.7%	2.2%	2.3%	2.4%
1st decile (lowest)	2.9%	3.0%	3.1%	4.0%	4.1%	4.2%
2nd decile	2.5%	2.5%	2.6%	3.4%	3.5%	3.6%
3rd decile	2.1%	2.1%	2.1%	2.9%	2.9%	2.9%
4th decile	2.3%	2.2%	2.3%	3.1%	3.1%	3.2%
5th decile	1.9%	1.9%	1.9%	2.6%	2.5%	2.6%
6th decile	2.1%	2.0%	2.1%	2.8%	2.8%	2.8%
7th decile	1.4%	1.4%	1.4%	1.9%	1.9%	2.0%
8th decile	1.5%	1.4%	1.5%	2.0%	2.0%	2.0%
9th decile	1.3%	1.3%	1.3%	1.8%	1.8%	1.8%
10th decile	1.0%	0.9%	1.0%	1.3%	1.3%	1.3%