

Recommendations for improvement of Ukrainian Solid Waste Management System

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ABSTRACT

Municipal solid waste generation is growing constantly all over the world. Soil, air, and water are being contaminated as a result of irresponsible waste treatment. Therefore, the development of a decent waste management system is an important part of natural resources usage and transformation to a sustainable economy. Nowadays, Ukraine lacks basic features of a proper waste management system on every level – legislative, technical, economical. In the current master dissertation, the waste management system Strategic Plan was developed for Ukraine. Such Plan has its aim to provide practical guidance on how Ukraine might reach waste management goals adopted by EU until 2030. In order to start the development of such a plan, both legislative and practical levels of Ukrainian waste management were examined. Waste generation, existing waste treatment practices and facilities were assessed as well. Calculation rules for desired goals and mass balances for future waste treatment facilities were established in order to perform the calculation of future waste streams in Ukraine. Based on performed calculations, it was confirmed that Ukraine has theoretical chances to reach the main established goal – landfill less than 45% of waste in 2030. It is possible only through the introduction of major changes in the waste management system. For that reason, Strategic Plan provides technical guidance on waste collection, treatment and landfill systems, alongside economic and legislative improvement recommendations. Required installed capacities for waste treatment and their possible locations were addressed. Suggested legislative changes and economic instruments are described as well. Developed Strategic Plan was compared to existing Ukrainian waste management plan.

Keywords: European Union; Ukraine; Municipal Solid Waste; Waste hierarchy; Waste legislation; Waste management plan.

1. INTRODUCTION

Nowadays the world generates 2 billion tons of Municipal Solid Waste (MSW) annually, and such number expected to reach 3,4 billion tons to 2050[1]. Such growth is caused by the increase in living standards, consumption of goods and overall Earth population. Naturally, that increases the burden that humankind puts on the environment. Soil, air, and water are being contaminated as a result of irresponsible waste treatment. Even though, municipal solid waste represents only around 10% share among all waste generated in Europe[2], the benefits of its wise treatment are, indeed, diverse and valuable. Instead of choosing simple landfilling method, which was invented thousands years ago, nowadays it is possible to process waste in a relatively environmentally-friendly way in order to store it, collect valuable raw materials from it, extract energy from waste, use waste in production of completely new goods or even simply decrease waste generation to reduce its harmful impact. Mentioned options create so-called “waste hierarchy” – widely accepted approach in waste management, which values landfilling method the least, and considers prevention of waste generation as the best option[3].

There are 461 cities, 883 small-scale cities, and 28,376 villages in Ukraine[4]. Ukraine has landfill-oriented MSW management, practically implemented through waste disposal facilities, which are mostly do not meet modern environmental standards. Ukraine has signed the “Association Agreement” with the European Union, the European Atomic Energy Community, and their Member States[5]. In terms of waste management, such agreement dictates, that Ukraine

shall take immediate and decisive measures towards implementation of European standards and practices in the area.

Therefore, the main goal of the current dissertation is to create a Strategic Plan for MSW management in Ukraine. Such Plan will take into account current legislative and practical state of waste management system in Ukraine and will provide guidance on how to possibly achieve major EU goals in terms of waste management. Naturally, according to “Association agreement” mentioned plan have to be in line with EU practices in that regard. Such Plan will emphasize the practical side of MSW management, namely needed waste treatment facilities, waste collection schemes, economical tools to reach EU waste management goals. Strategic Plan is an important feature, as it will provide a rough waste management action plan for Ukraine on a National level and will be a foundation for further waste management plans on municipal levels. Currently, such a Strategic Plan is a kind of document that does not exist in Ukraine.

2. EUROPEAN LEGISLATION AND PLANNING IN TERMS OF WASTE MANAGEMENT

2.1. Waste management legislation

European waste policy is already developing for over than 40 years[6] through a series of environmental action plans and introducing an appropriate framework of legislation. The ultimate goal is to reduce a negative impact on the environment and public health[7]. The other task is to create an economy with effective use of resources and energy.

In December 2005 the European Commission has adopted the Thematic Strategy on the prevention and recycling of waste (Waste TS). It transferred to establishing a new Waste

Framework Directive 2008/98/EC, which includes many Waste TS from goals. Waste TS describes a set of crucial points adopted nowadays – waste prevention, promotion of reusing and recycling, establishing a recycling society. Mentioned objectives should have contributed to an overall decrease of harmful impacts of resource usage and improve overall environmental protection level. A vital requirement of Waste TS was a promotion of waste hierarchy, that was translated to a Waste Framework Directive 2008/98/EC.[8]

2.1.1. Major waste management directives

The main source of legislative guidance is the active Framework Directive 2008/98/EC on waste (WFD), established in 2008, which replaced previous Directive 2006/12/EC[3]. The purpose of the document was to establish basic concepts and definitions in terms of waste management. Such cornerstone principles of appropriate waste management as the “waste hierarchy”, the “polluter-pays principle” and “extended producer responsibility” were established by WFD. Important provision from the directive is the legal establishment of the waste hierarchy, to set priorities in waste prevention and management policies.

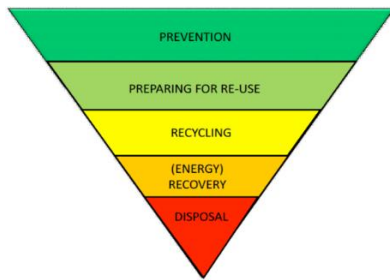


Figure 1: Waste hierarchy according to Waste framework directive[3]

In 1999 the EU established a Council Directive 1999/31/EC “on the landfill of waste” (LD). At that time WFD was not existing, therefore this document was established to meet the requirements of Directive 75/442/EEC from the year 1975[9]. The main objective was to unify and straighten technical and operational requirements on landfills and waste, reduce harmful effects on the environment from land-filling during the whole life-cycle of it. One of the most important features of such a directive was the introduction of quantitative goals for biodegradable waste disposal. In five, eight, fifteen years’ biodegradable municipal waste going to landfills must be reduced to 75 %,50%,35% of the total amount (by weight) of biodegradable municipal waste produced in 1995[9]. Named directive underwent a number of amendments. Decision 2003/33/EC was made in order to establish the criteria and procedures for the acceptance of waste at landfills[10]. The most recent amendment is of May 2018, where EU member states got an obligation of 10% or less of Landfilled MSW in the year 2035[11].

In 1994 EC issued a directive 94/62/EC “on packaging and packaging waste”. The main priority of such a document was the prevention of packaging waste production. The second priority was the recovery of produced packaging waste

through reuse, recycle and other treatment of it. In other words – the diversion of packaging waste from land-filling[12]. This directive promoted the prevention of packaging waste generation, set goals for plastic bags usage reduction. Common goals for recovery and recycling of packaging were introduced there. Another important feature was the establishment of requirements to return, collection and recovery systems alongside with marking and identification system for packaging waste. Named directive was amended with the directive (EU) 2018/852 in 2018[13]. Such amendment introduced new targets for packaging waste recycling for years 2025 and 2030[13].

2.1.2. Waste management planning

As legislation creates a framework for legal waste management actions, practical directions, and guidance are provided in Waste Management Plans (WMP). WMP is one of the main tools through which EU legislation is being implemented within the country or region. According to the WFD, all countries should establish at least one waste management plan, which will be covering all geographical territory of a given state, or the combination of such plans[3]. Other provisions given in the 28th article of the Directive includes requirements on information about:

- Type, source and amount of waste generated within the examined territory;
- Established waste collection schemes, existing waste treatment plants;
- Waste management policies, technologies, and methods used in particular member state.

Mentioned requirements are stated in the 3rd paragraph of the 28th article WFD[3], and represent the mandatory data to be included in waste management planning.

In order to improve the overall quality of crated WMPs and to unify them to a certain level, the European Commission has issued guidance on how to prepare a good WMP[14].

Mentioned requirements should be applied to a newly created or revised WMP. Structurally is advised to create a WMP which consist of the “status part” and” planning part”. Additional aspects like management policies, packaging waste management or any other important legislative provisions should be added.

A possible version of a WMP might include background part at first, with the assessment of overall waste problematic in a territory, EU legislation, national legislation, description of the national waste policy and prevailing principles to address overall waste problematic in line with the waste hierarchy, description of objectives set in specific areas. Next part is a mentioned Status part, with waste amounts, waste streams, waste sources, waste management options. There might be included also waste collection and treatment, waste shipment, organization, and financing. As a result – an Action Plan should be created containing measures for achieving objectives for: collection systems, waste management facilities, responsibilities, economy, and financing[14].

Such recommendations are the basis for the development of the Strategic Plan in terms of the current dissertation.

3. UKRAINIAN LEGISLATION AND PLANNING IN TERMS OF WASTE MANAGEMENT

3.1 Legislative background of waste management in Ukraine

The general scheme of Ukrainian waste management legislation provided in Figure 2. It is noticeable, that currently most legislative documents on waste management in Ukraine are relatively new, or even not properly approved yet. That creates an interesting legislative environment in Ukraine. New approaches and standards were established in “National Strategy on waste management” (NSWM) in 2017[15], but the rest of active waste legislation still is not in line with it. It created a three-year gap, were newly established waste management goals and practices should be implemented through existing outdated legislation, which does not contain necessary tools to perform that task. Fortunately, such a vital document as new Framework Law “About waste management” is already developed and should be signed in the current year[16]. Framework Law will conceptually substitute existing Law “About waste” to provide a legislative base for existing National Strategy and already developed “National Waste Management Plan” (NWMP)[17]. All mentioned legislative documents should be signed until the end of 2019.



Figure 2: Projected Ukrainian waste management legislation structure for the year 2019

3.2. Project for Ukrainian Framework Law “About waste management”

In November 2018, Ukrainian Ministry of Ecology issued for public discussion the project of a future Framework Law “About Waste Management” (FL)[18]. The legislative basis for such important move was mentioned ratification of the Association Agreement between Ukraine and the European Union, the European Atomic Energy Community, and their Member States in 2014. Legally, Ukraine has undertaken the responsibility to implement provisions of the Waste Framework Directive 2008/98 / EC in a timespan of three to five years from the date of the Agreement validity acquisition[5].

A number of main articles are almost directly transferred from EU legislation to Ukrainian. Waste Management Strategies and Plans are required to be developed by a new law and will be discussed further. Record keeping is also to be improved and unified with EU standards.

ISWA states[19], that the draft FL does not contain clear waste management quantitative goals. Generally, the establishment of quantitative targets in Law text is not typical of Ukrainian legislation. But the introduction of waste management goals into National legislation is one of the most important requirement according to Directive 2008/98/EC[3][19]. An incomplete transposition of the WFD into Ukrainian legislation will be considered as non-compliance with the requirements of the mentioned Association Agreement.

3.3. National Strategy and National Plan on Waste Management in Ukraine

It is to be said, that Ukrainian waste management planning currently is covered by two documents – “National Strategy on Waste management” and “National Plan on Waste management”.

In October 2017 Ukraine has adopted a “National Strategy on Waste Management to 2030”[15]. It claimed to be developed with regards to EU legislation as WFD and landfill, packaging, batteries, and WEEE directives. In November 2018, the Ukrainian ministry of Ecology issued a project of the “Waste Management Plan to 2030” for public discussion[17]. It was required by NSWM, that such a plan should have been developed until the year 2019. Such a Plan should be able to provide Ukraine with more precise and practical guidance on waste management, in contrast to NSWM.

The first document (NSWM) consists mostly of legislative measures and contains some waste management goals without precise means of its achievement. After it was issued, it was assumed that the next document will provide less legislative measures and evaluates more on the current Ukrainian situation on waste management and practical actions in its improvement.

Unfortunately, issued “National Plan on Waste Management” have broadened its ancestor mainly in terms of more detailed legislative regulation. It contains some practical recommendations on landfill system or waste recycling, but such guidance considered insufficient in terms of immediate practical actions, and Ukraine needs them. Therefore “National Plan on Waste management” seems to be a more detailed annexe to “National Strategy on Waste management”, rather than a document with practical plan on waste management system improvement. Such an approach is acceptable, as EU guidance on waste management planning[14] states that a number of complementary documents (from different administrative levels) could be used for WMP establishment. Which is alerting, is that Ukraine does not have an independent well-established administrative system on the municipal level, therefore it seems not wise to leave the most important practical decisions for such administrative level.

To be more detailed, there is a number of things lack in both documents. The current draft of NWMP lacks data on the morphology, amount and origin of waste generated within Ukrainian territory as well as evaluation on the future generation. There is no information on current waste collection schemes or future collection needs. Information on existing recycling, landfill, waste-to-energy facilities is not included.

Additionally, such document lacks data on capacity or localization criteria for future waste treatment facilities, which are planned to be built. Therefore, Ukraine is in need of better waste management planning to be developed.

4. ASSESSMENT OF CURRENT UKRAINIAN WASTE MANAGEMENT SYSTEM AND STATISTICS

4.1. Amount and structure of municipal solid waste in Ukraine

Since 2014 Ukraine started to collect statistic on MSW in a renovated form, called “TPV-1”, and it is assumed inappropriately to combine data collected before and after 2014 in one research. Therefore, Figure 3 provides data on collected MSW in the years 2014-2018.

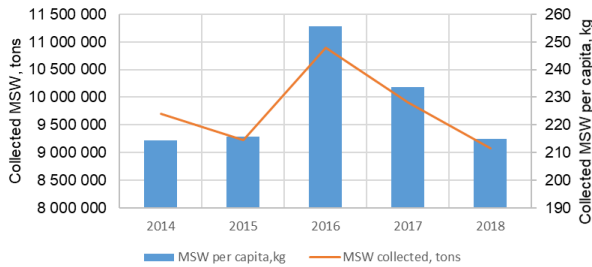


Figure 3: Amount of collected MSW in Ukraine 2014-2018[20], [21]

As for the separate collection territorial coverage, Ukraine has an overall score of around 3% in 2017 in that regard[22]. Figure 5 provides a dynamic of the introduction of the separate collection system in Ukrainian settlements.

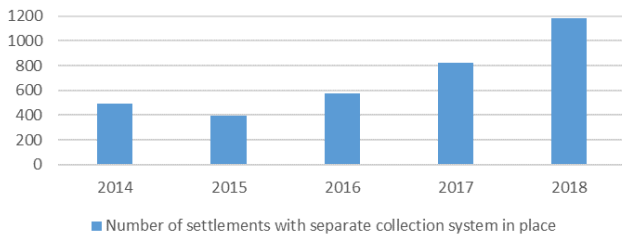


Figure 5: Separate waste collection by settlements, 2014-2018[22]

4.2 Current MSW treatment in Ukraine

The latest statistical document on MSW management in Ukraine was issued in March 2018. Such document confirms that there was little to no progress in terms of implementation of the waste management hierarchy in comparison to a previous year. However, such progress was required by the goals introduced in NSWM[17]. Indeed, Ukraine landfilled 93,21% of MSW in 2018, in contrast to 93,4% of MSW in 2017[21]. That means that recycling and other treatment options for waste were not developed as it was required in NSWM. However, it is possible to notice a slow positive trend in that regard over the last 5 years. The figure represents the MSW treatment hierarchy in Ukraine since 2014.[21]. It is noticeable that waste-to-energy treatment remains more or less stable, but the recycled waste share is

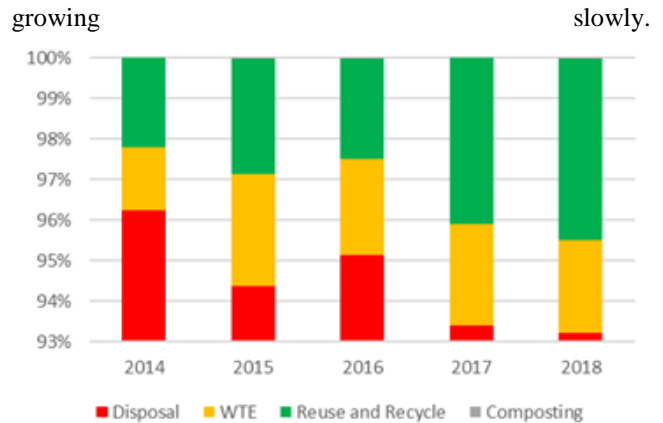


Figure 6: Waste treatment in Ukraine 2014-2018[21]

NSWM established an 80% landfill rate as the Ukrainian goal for 2018[15]. It is visible from Figure 6 that such goal was failed – instead of a 16% decrease in that regard, only 3% decrease was achieved. It gives some perspective on the overall quality of Ukrainian waste management planning and its practical implementation.

5. A STRATEGIC PLAN FOR UKRAINIAN MUNICIPAL SOLID WASTE MANAGEMENT

5.1 Timeframe for Strategical Plan

The observed time span of current planning is 2018-2030 years, as 2030 is a milestone year in terms of active Ukrainian NSWM, and current planning is considered as an alternative strategy in the same environment. Therefore, it would be appropriate to establish “milestone years” – time points at which appropriate calculations and evaluations will be made to ensure gradual progress, instead of having a 12-year “black box” with a certain goal in the end. In other words, it is proposed to divide planned timeframe into three parts: 2018-2023, 2023-2026, 2026-2030. Appropriate waste streams form, waste hierarchy, required practical actions, and construction plans are evaluated for all milestone years.

5.2. Geographical aspect

European directives in general, and provisions for waste management plans, in particular, provide proximity and self-sufficiency principles as ones, that should be followed during the development of waste management strategy[23]. In other words, waste should be processed and disposed near its origin, and such process should be self-sufficient in the boundaries of the chosen area. Therefore, for the sake of current waste management planning, Ukrainian territory is divided into five areas. Naturally, since municipalities are responsible for their own waste management, it is not viable to have any of them divided between mentioned areas.

Table 1: Waste generation and demographic data for established geographical Areas

	The total population in 2018	Waste accountable for in 2018	Waste collected in 2018, million tons	Urban population in 2018, %
Area 1 (4 municipalities+ Kyiv city)	8,160,486	25,14%	2,28	83,68%

Area 2 (3 municipalities)	9154,772	20,66%	1,87	55,70%
Area 3 (6 municipalities)	8,377,847	18,78%	1,70	55,61%
Area 4 (4 municipalities)	7,369,922	15,33%	1,39	59,70%
Area 5 (7 municipalities)	9,323,376	20,09%	1,82	73,85%



Figure 7: Proposed Strategic territorial division of Ukraine

5.3. Prediction of Ukrainian waste amount and morphology

In order to start Strategic planning for the waste management system, it is vital to understand the morphological composition of generated waste within the observed geographical territory. Such information creates a basis for future planning, as it defines which treatment operations is possible to perform.

Unfortunately, substantial and systematic research works on the morphology of MSW in Ukraine are absent. Most of the available articles consider a small area as its scope, – a particular village or city without a global context in terms of whole country[24], [25]. Some of the articles observe whole Ukrainian territory, but only in terms of the particular waste stream, like biodegradable waste[26]. Therefore, it is challenging to provide a precise assessment of waste composition.

In terms of current Strategic planning, morphological content of MSW is assumed to remain mostly similar over the next 12 years, as such time frame is insignificant to observe a drastic change in waste morphology. It is only assumed to sustain a 1% increase of plastics and paper fractions share, and a 2% decrease in biowaste fraction respectively, due to expected slow GDP growth trend which was observed in Ukraine in recent years[27]. Data on MSW morphology provided in Table 2.

Table 2: Prediction of Ukrainian MSW morphology for milestone years

MSW fractions		2018	2023	2026	2030
Bio waste		35%	34%	34%	33%
Packaging	Plastics	11%	12%	12%	12%
	Paper and cardboard	17%	17%	17%	18%

	Glass	6%	6%	6%	6%
	Metal	3%	3%	3%	3%
Other		28%	28%	28%	28%

It is important to predict a waste generation in milestone years to perform further calculations. An empirical formula from[28, p. 30] will be used to calculate a future waste generation. Minding provided assumptions it is calculated that:

$$G_{200i} = \left[(C_{200i-1} / \eta) \times 0,9\% + (C_{200i-1} / \eta) \right] \times \varepsilon \quad (1)$$

Where G_{200i} – The generated amount of MSW; C_{200i} – Collected amount of MSW; 200_i is a year in which MSW weight should be calculated; η – Collection coverage in 200_{i-1} year; ε – Collection coverage in the 200_i year; 0,9% is an empirical coefficient from [28, p. 30], related to GDP growth. As it was mentioned, the current coverage rate of Ukrainian MSW collection is 78% of the territory, but [28] suggests that achieved rate of extension of coverage rate for Ukraine is 1% per year. Such an assumption will be used for current strategic planning. Therefore, in 2023 it will be equal to 83%, in 2026 to 86% and 90% in 2030. Having this in mind and using a Formula 1 it is possible to calculate collected MSW in baseline years.

$$C_{2023} = 10,101,407 \text{ tons} \quad (2)$$

$$C_{2026} = 10,751,665 \text{ tons} \quad (3)$$

$$C_{2030} = 11,662,307 \text{ tons} \quad (4)$$

Current Ukrainian separate collection rate is 3%, but it is obvious that under such conditions it is impossible to achieve any waste management goals. So it is vital to bring a major change in a separate waste collection system and increase separate collection rates. Particular actions in that regard will be provided further, but in order to be able to calculate possible waste streams, a milestone separate collection numbers should be established for baseline years.

Targets provided by EC on separate waste collection is a natural choice for such case, but such targets are not numerical, but qualitative[3]. However, such a goal provided in NSW, – 50%[15] of separate collected MSW until 2030, it will be used in current planning. Having such a milestone for the year 2030, arithmetically it requires 3,62% annual growth from starting in 2018 and will secure a 24,5% of separate collection in the year 2023, and 35,48% in the year 2026.

$$R_{separ} = \frac{(50\% - 2,9\%)}{2030 - 2017} = 3,62\% \quad (5)$$

$$C_{separ2023*} = 2,9\% + 3,62\% \times (2023 - 2017) \approx 24,5\% \quad (6)$$

$$C_{separ2026*} = 2,9\% + 3,62\% \times (2026 - 2017) \approx 35,4\% \quad (7)$$

$$C_{separ2030*} = 2,9\% + 3,62\% \times (2030 - 2018) \approx 50\% \quad (8)$$

5.4 Summary of waste management goals

Diversion from landfill target should be measured in percentage by weight in relation to all collected MSW. It is the main target for current Strategic Plan. All EU member states should secure a 10% or less of landfilled MSW until 2035,

as it was stated in[11]. However, there is a possibility to postpone such goal by up 5 years, for those countries, who landfilled 60% or more of MSW in 2013. So for the sake of current management planning, it is assumed that Ukraine will use this option. At the same time, those states who are using postponing option are obligated to meet the different target – secure a 25% or less of landfilled MSW by weight in the year 2035. Minding that established time frame for current planning is until 2030, it is required to adjust the mentioned goal accordingly. Arithmetically, Ukraine has to decrease its landfill rate by 4% on average annually in order to meet EC legislative targets. Therefore, in the year 2030, the landfill rate should be around 45% – this will be a landfill diversion target for future calculations.

$$R_{landfill} = \frac{(93,4\% - 25\%)}{2035 - 2018} = 4,02\% \quad (9)$$

$$C_{landfil\ 2030}^* = 93,4\% - 4,02\% \times (2030 - 2018) \approx 45\% \quad (10)$$

Same as in the previous goal, WFD establishes a postpone option in terms of re-use and recycling rates. For the milestone year of 2030, proposed by EC goal states that a minimum of 55 % of MSW should be prepared for re-use and recycled[29]. As for the calculation rules, WFD provides the following requirements:

Another target related to exclusively packaging waste. No later than 31 December 2030 a minimum of 70 % by weight of all packaging waste will be recycled[13].

5.5 Numerical evaluation of Ukrainian future waste streams

Conceptually numerical evaluation is based on previously provided projected waste generation, separate collection rate and desired goals for three milestone years. The ultimate goal is to obtain a form of waste streams which will secure mentioned goals under projected conditions. In terms of calculation, 8 separate waste streams were defined, Figure 8.

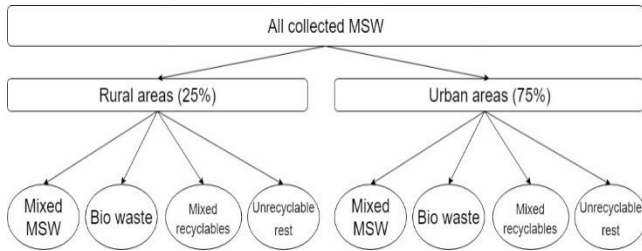


Figure 8: Waste streams used in calculations

By using provided assumptions for separate collection rate, projected MSW generation and waste morphological composition – it was possible to calculate each area contribution in terms of collected MSW. Projected amount in tons of the waste for each of 8 streams was evaluated.

A certain appropriate waste treatment technology was assigned to the respective waste stream through “usage coefficient” – the percentage of waste from a particular waste stream directed to particular waste treatment technology. Possible treatment technologies which were used for calcu-

lations are sorting, incineration, organic valorisation, mechanical-biological treatment, home composting, landfilling of MSW. Therefore,

$$S = W_{SORT} + W_{WTE} + W_{OV} + W_{MBT} + W_{COMP} + W_{LAND} \quad (11)$$

$$W_i = S \times x_i \quad (12)$$

Where S – the amount of waste in a stream; W_i – the amount of MSW directed to particular treatment technology; x_i – treatment technology “usage coefficient” individual for each waste stream.

Such “usage coefficients” introduce certain restrictions as well. It means that mentioned waste treatment technologies are available not for every waste stream discussed. Such rules reflect assumed principles of waste management in Ukraine adopted by the current Strategic Plan. The rules are the following:

- “Bio-waste” might only be composted at Organic Valorisation plant or at home;
- Home composting available only to “rural areas bio-waste” stream;
- Incineration available exclusively for “urban areas waste” stream;
- “Mixed recyclables” stream directed exclusively for sorting;

The further calculation process is rather trivial. Possible waste treatment technologies were assigned with appropriate mass balance coefficients. That in order to evaluate the mass of the output products from treatment plants under respective technology. Each treatment plant mass balance:

$$W_i = a_1 \times W_i + a_2 \times W_i + \dots + b_j \times W_i \quad (13),$$

Where W_i – a mass of processed MSW at the certain facility; $a_{1,2,3}$ – valuable output mass coefficient; b – rest fraction mass coefficient. Denotation “j” means particular waste treatment type. Therefore, the amount of waste (L_i) to landfill after each treatment operation (rest fraction) is:

$$L_i = b_j \times W_i \quad (14)$$

Table 3 provides the rest fractions for each mentioned waste treatment facility type.

Table 3: Rest fraction mass coefficient for waste treatment technologies[30]–[34]

Treatment technology	Rest fraction (b_i)
Sorting	10%
Incineration	20%
Mechanical-Biological treatment	50%
Organic Valorisation	35,7%
Home composting	13%

It is important to mention, that rest fraction of such treatment technologies as Organic Valorisation of Mechanical-Biological treatment is possible to send for further incineration. That case the rest fraction was assigned with additional usage coefficient.

$$W'_{WTE} = (b_{OV,MBT} \times W_{OV,MBT}) \times x'_{WTE} \quad (15)$$

$$L_{OV,MBT}' = b_{WTE} \times (b_{OV,MBT} \times W_{OV,MBT} \times x_{WTE}') \quad (16),$$

Where W_{WTE}' – the amount of rest fraction to undergo secondary incineration; x_{WTE}' – usage coefficient for rest fraction incineration; $L_{OV,MBT}'$ – the amount of waste to landfill after secondary incineration.

Provided formulas allow calculating the amount of waste underwent particular treatment and trace the outputs of such it. Summation of such numbers makes it possible to development waste stream schemes for milestone years. Figure 9 presents such a scheme for the year 2030. It is visible that some amount of MSW, particularly the rest fraction from Organic Valorisation and Mechanical-Biological treatment is directed to Incineration before landfilling.

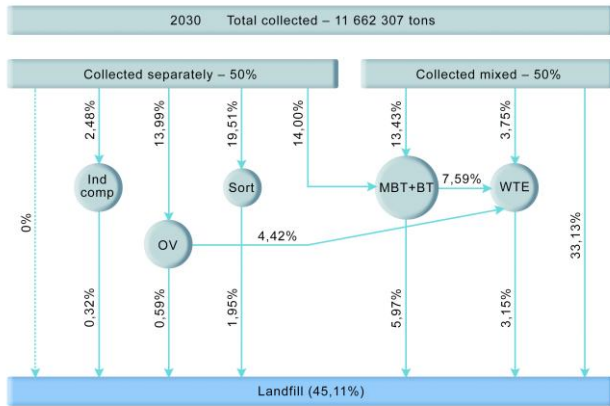


Figure 9: Projected Ukrainian waste streams in 2030

According to that, to calculate waste management target such as “diversion from landfill” it is required to calculate all disposed amount of waste from each waste stream. According to current calculation, such amount constitutes of three parts: directly landfilled waste, landfilled rest fraction from treatment, landfilled rest fraction from secondary incineration. All the mentioned components were calculated for all waste streams and summed up as follows:

$$L_{TOTAL} = \sum_1^8 (S_i \times x_{LAND}^i) + L_i + L_i' \quad (17)$$

All other waste management goals were calculated by the same approach, using EU calculation rules as guidance.

5.6 Evaluation of achieved waste management goals

First, and the most important value, is a diversion from a landfill or a landfill rate calculated by mass. In 5.4 it was stated that such a value should be 45% or less in 2030 by EC required. According to performed calculations, such parameter is equal to 45.11% in 2030, which is considered a satisfying result. As this number was obtained in line with provided legislative requirements in terms of calculation, it is to be concluded that it is possible for Ukraine to reach EC goals on diversion from landfill for the year 2030.

Another important goal was related to reuse and preparing for recycling rate. Preparing for reuse and recycle rate planned for 2030 in Ukraine is 36.76% according to calculations, but the aim established by EC is 55%. Obviously, such a result should not be considered as satisfying, but it is still great progress considering a starting point of 3%. Ukraine is the second-biggest country in the EU by area, and it makes it difficult to establish high recycle rates over a given time. It is dictated by the fact that the recycling rate does not strictly dependent on existing treatment capacities, but mainly on the development level of the separate collection system. Current strategic planning suggests ambitious progress in that regard, but still not sufficient to secure a 55% goal for recycling.

Another important goal which was established – is the recycling of, particularly packaging waste stream. In 2030 Ukraine, in terms of current strategic planning, will recycle around 52% of all collected packaging waste, in contrast to 70% goal established by EC. Similarly, as with total recycle rates, the obtained number is strongly underachieving in terms of EC aims but is good progress in comparison to 2018 level. Again, the problem lies not in recycling facilities, but in separate collection limitations. Indeed, there is a theoretical possibility to increase such numbers by introducing a “dirty” sorting facilities for a mixed collected fraction of MSW, but the cost-efficiency parameters of such options assumed to be inappropriate for the generally weak Ukrainian economy[28].

5.7 Evaluation of required waste treatment capacities according to provided calculations

In order to practically achieve the calculated result, Ukraine has to drastically increase waste treatment infrastructure. Figure 10 provides such data in terms of required installed capacities for three baseline years in comparison to existing capacities in Ukraine in 2018. It is visible, that over the years share of all waste treatment technologies is growing rapidly, so, of course, such progress will require big investments in the construction of facilities.

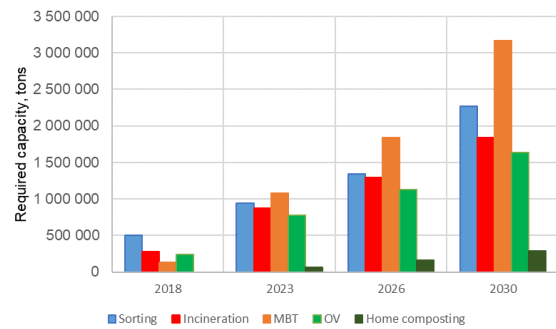


Figure 10: Predicted required waste treatment capacities

It is notable, that according to strategic planning, in 2030 the biggest share of MSW would be sent to MBT treatment. Even though MBT treatment is of least preferable options, according to the adopted waste hierarchy, the projected

amount of mixed-collected waste dictates the necessity to establish such treatment, as it is the most proven option to deal with it, avoiding low efficiency “dirty” sorting.

Required sorting capacity of separately collected MSW is also high, but such option is strictly limited by separate collection system, as it should be provided with appropriate feedstock. The same applies to organic valorisation plants, as their input is separately collected bio waste.

5.8 Brief description of proposed practical improvement recommendations

5.8.1 Improvement recommendations for waste collection system

Separate waste collection is a vital feature for current strategic planning, as on whether waste was separately collected depends on its possible treatment options and, therefore, rest fractions and valuable outputs. Separate waste fractions collection directly leads to an increase in recycling rates. Cornerstone decision to be made is the type of separate collection that should be introduced for MSW. That means particularly how many containers will be included in the collection scheme and what will be a pick-up policy. Tables below provide information on the type of separate collection and respective fees, as it is recommended by Strategic Plan.

Table 4: Proposed waste collection schemes

Housing type	Door-to-door collection system	Complimentary collection system
Individual houses in Rural areas	1 container	Civic Amenity sites in village administration
Individual houses in Urban areas	5 containers - Paper/cardboard - Metal/plastic - Biowaste - Glass - Residual waste	Bring points in the city Civic Amenity sites
Multi-store buildings in Urban areas	3 containers - Residual - Biowaste - Dry recyclables	Bring points in the city Civic Amenity sites
Multi-store buildings in Rural areas	3 containers - Residual - Biowaste - Dry recyclables	Bring points

5.8.2 Improvement recommendations for waste landfill system

As Ministry of regional development of Ukraine states, most of the illegal dump sites are created in rural areas where waste management system is not developed enough, or not working[35]. So, the measures proposed, in terms of current planning, are on the administrative part of things, not technical:

- To straighten penalties for illegal dumping which will be distributed among residents of a particular area to promote public awareness / To shift illegal dumping into the criminal code, not administrative with appropriate punishments;

- To introduce monetary reward for information about illegal dump sites;
- Possibly create a system for identification of dump sites using satellite images;
- Introduce regular inspection of closed dump sites in order to prevent its future usage.

The second part of the waste disposal problem is an outdated conception of landfills system. Therefore, current waste management planning suggests to start with a full and precise assessment of current landfills and simultaneously develop a new system of future “cluster” landfills. Such a system means the development of a map of “clusters” or areas with certain waste generation and population size. Based on that map, it is required to assign a landfill site with sufficient capacity to each cluster, and locate them appropriately to calculated capture radius.

- To develop and approve on a national level a new set of environmental, technical and exploitation requirements to landfills, based on respective European legislation;
- Each of 25 Ukrainian municipalities will evaluate respective capture radiuses and “cluster” landfill locations. It is important to note, that optimal clusters are not necessary will be located within the boundaries of one particular municipality, therefore such work will require inter-municipal coordination;
- Current landfills within each municipality should be inspected in order to define whether they are able to meet new environmental standards and, therefore, to be included in the new landfill system;
- To approve on a national level a set of legal financial guarantees. Such legislation will secure the fact that construction of new capacities, closure, renovation, and deactivation with further monitoring of existing landfill will be covered from the residential waste management fee;
- Until 2023 to start construction of new “cluster” landfills. It is advised in[28], that the minimal economically viable requirements for new landfills are to capture the area with at least 150,000 inhabitants and generation of at least 50,000 tons of MSW per year. The most optimal decision will be an area of capturing with 400,000 inhabitants. That will require a new system of around 100 landfills;
- When a new landfill will be ready to operate, the municipality should secure an environment-friendly closure of existing landfills, accordingly to developed “closure plan” for each facility;

5.8.3 Improvement recommendations for waste treatment facilities system

As it was shown in Figure 10, Ukraine needs to drastically increase the number of operating waste treatment facilities to secure EC waste management goals. Naturally, the main recommendation in that regards – actually constructs required plants. Therefore, in terms of main assessed waste treatment technologies, it was possible to develop suggestive construction order for Ukraine. Such data provided in Table 6. Such a table is based on projected MSW generation within

each particular Area for three milestone years. Already existing treatment plants, typical European size of respective facilities and their coverage area was also considered. In cases where it was possible, number and size of treatment plants were evaluated through simplified CAPEX and OPEX calculation for the 20-year lifetime of respective plants.

Table 6. Proposed construction order for waste treatment facilities

Capacities for Area 1	2023	2026	2030
Incineration, kilotons	200	-	-
Organic Valorisation, kilotons	200	100	110
MBT, kilotons	250	220	380
MRF, kilotons	150	200	200
Capacities for Area 2	2023	2026	2030
Incineration, kilotons	500	-	-
Organic Valorisation, kilotons	150	100	80
MBT, kilotons	200	185	325
MRF, kilotons	100	200	170
Capacities for Area 3	2023	2026	2030
Incineration, kilotons	-	500	-
Organic Valorisation, kilotons	150	50	100
MBT, kilotons	200	160	240
MRF, kilotons	100	150	180
Capacities for Area 4	2023	2026	2030
Incineration, kilotons	-	-	500
Organic Valorisation, kilotons	100	50	50
MBT, kilotons	-	-	265
MRF, kilotons	100	130	120
Capacities for Area 5	2023	2026	2030
Incineration, kilotons	-	-	-
Organic Valorisation, kilotons	150	50	130
MBT, kilotons	-	-	265
MRF, kilotons	100	180	180

It is visible from the table above, that required waste treatment capacity is rather high. That is dictated by the discussed low number of nowadays available treatment plants. Basically, Ukraine has not much-improved waste management infrastructure since gaining independence, and now has a lot of work to do in a narrow time frame. That will require sufficient financing from both the Ukrainian Government and private investors. But regardless, such a treatment system should be developed, as it is impossible to reduce the landfill rate without other waste treatment options in place.

6. CONCLUSIONS

In the current master dissertation, European and Ukrainian waste management legislation and planning were assessed. Present background on waste management environment and its problems were addressed for a whole territory of Ukraine, together with aims and goals in that regard. Based on that it was possible to develop a new waste management plan for Ukraine on the period of 2018-2030 with a purpose to secure appropriate European goals.

As it was shown in Chapter 5, Ukraine has theoretical chances to complete waste management goals provided by European legislation. Gradually, step by step Ukraine needs to simultaneously improve various waste management aspects – legislation and organization, economical encourage-

ing, technical and material base improvement, waste awareness campaigns. Indeed, such actions will require a lot of effort from key actors in the waste management field.

Technical actions to be done are mainly consist of a construction plan, which was provided above. Therefore, legislative, economic and social actions are represented further. Responsible Government and private bodies should perform the following actions according to secure Strategic Plan success.

All necessary measures of pure legislation or organizational nature shall be performed during the first time span, until 2023. It is uncertain how much time each improvement task will take, so the provided years are rather for comparison between targets order inside this strategy than actual solid deadlines. Year indicates the year where appropriate action should be implemented.

In terms of Government regulation:

- To sign a Framework Law “About waste management” and all required supporting directives (2019);
- To issue a set of guidance on waste management for lower municipal government bodies and waste management stakeholders, including assessment and renovation of existing all standards in the field (2020);
- Establish proper Government regulation in terms of licensing of waste operators and waste treatment facilities. Hold a regularly checks of their compliance with environmental standards (2020);
- Legally establish proposed separate waste collection scheme as an obligatory. Create an opportunity for local authorities and licensed businesses to sign contracts for waste collection on a transparent basis (2019);
- Establish a ban/ significant taxation on plastic bags and certain types of excessive plastic packaging (2021);
- Establish procedure of organised buying and distribution of individual composting units to the population alongside with discount system implementation. (2020);
- Develop a set of environmental, technical and exploitation requirements to landfills, based on respective European legislation (2019).

In terms of waste management planning:

- National plan on waste management should be reviewed and updated with lacking information according to Article 28, part 3 of WFD (2019);
- Regional plans should be developed in accordance with National Planning based on waste management background of each municipality (2019);
- On a regional level high attention level should be paid the following information:
 - Current waste management situation from technical, financial and legislative perspectives, including data on waste generation clusters, waste generation and morphology prediction;
 - Key actors responsible for different waste management operations;
 - Legislative, economic or social actions which planned to be implemented and their performance assessment;

- Existing waste treatment facility status and track of existing construction work and required capacities to be installed;
- Waste collection system performance, waste collection coverage, separate collection coverage;

In terms of awareness raising:

- Initiate a nationwide campaign on raising awareness about waste management topic generally, and about approved National Strategy on Waste and its goals in particular (2019);
- Establish a special awareness campaign on individual composting for the rural population (2019);
- To issue a set of guidance on waste management implementation and reporting for lower municipal government bodies and various waste management stakeholders (2019).

In terms of economic drivers, the following practices should be implemented:

- Establish a new system of charges for waste collection which will be able to cover expenses of appropriate collectors (2020);
- Establish a new system of charges/taxation for waste landfill, which will be able to cover operational and renovation expenses of appropriate facilities (2020);
- Pay-as-you-throw system in order to support changes in the waste collection from both waste producers and waste collectors (2020);
- Extended producer responsibility for packaging waste producers, probable implementation of deposit returning system for certain products (2022);

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