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## **DETERMINING THE COMPREHENSIVE TARIFF FOR HOUSEHOLD WASTE MANAGEMENT TAKING INTO ACCOUNT THE ENVIRONMENTAL COMPONENT AND THE VALUE OF SECONDARY RESOURCES**

One of the main reasons why the EU has achieved such impressive results in minimizing landfills and increasing the rate of recycling has been the “polluter pays” principle. The cost of waste management for the producer should be equal to all the costs of eliminating its adverse effects. The results of household waste management in Ukraine lag far behind those in Europe. Less than 1% of the total amount of household and similar waste is reused. Ukraine risks not achieving the waste management indicators specified in the national sustainable development strategy if the current organizational and economic models remain dominant. Low tariffs for waste management and the absence of a nationwide segregated collection program are believed to be the main factors behind the prevalence of unsanctioned dump sites. The backlog in the implementation of recycling centers, recycling mega-projects and, finally, separate collection programs are the result of insufficient funding. This study provides a full calculation of the inclusive household waste management tariff. The approach was to find the total financial costs, including design, land acquisition, landfill construction and operating cost then, estimate the environmental costs caused by the CO<sub>2</sub> emissions. The study estimates the real cost of collecting and transporting separately collected household waste and concludes the net cost after deducting the market value of recyclable materials. According to the results of the study, it turned out that the financial costs for the disposal of household waste in Ukraine reach up to UAH 355, and the cost of emissions may reach UAH 441/ton depending on the type of waste. The article reveals that the tariff for the collection and transportation of household waste must be adjusted depending on the density of the waste components and the market value of secondary raw materials. It has been also found that the costs of collecting and transporting some types of waste can be avoided if the recyclables are self-delivered to the recycling centers. The inclusive collection and transportation tariff, according

to this study, should fluctuate between UAH 453 and UAH 1628 per ton. Finally, the study has shown that waste generator can earn between UAH 1072 and UAH 2495 when his recyclables are collected separately.

**Keywords:** *household waste, tariff, landfill, Secondary raw material, environmental cost*  
**JEL:** *Q50, Q53, R22*

Однією з головних причин, з якої ЄС вдалося досягти вражаючих результатів у мінімізації сміттєзвалищ та збільшенні темпів переробки, був принцип «забруднювач платить». Вартість управління відходами для виробника повинна дорівнювати всім витратам на усунення їх несприятливих наслідків. Результати поводження з побутовими відходами в Україні значно відстають від європейських. Менше 1% від загальної кількості побутових і подібних відходів йде на повторне використання. Україна ризикує не досягти показників поводження з відходами, зазначених у національній стратегії сталого розвитку, якщо нинішні організаційно-економічні моделі й надалі діятимуть. Низькі тарифи на управління відходами та відсутність загальнонаціональної програми роздільного збору, як передбачається, є основними факторами поширення необладнаних звалищ. Відставання щодо впровадження центрів прийому вторинної сировини, мегапроектів з переробки та, нарешті, програм роздільного збору є результатом недостатнього фінансування. У цьому дослідженні наведено повний розрахунок інклюзивного тарифу на побутові відходи. Підхід полягав у тому, щоб виявити повні фінансові витрати, включаючи проектування, придбання ділянки, будівництво полігону та експлуатаційні витрати, а згодом оцінку екологічних витрат, викиданих викидами. Дослідження оцінює реальну вартість збору та транспортування окремо зібраних побутових відходів та робить висновок про чисту вартість після відрахування ринкової вартості вторинної сировини. За результатами дослідження з'ясувалося, що фінансові витрати на поховання однієї тони побутових відходів в Україні становили 355 грн., а вартість викидів може досягати 441 грн/тону залежно від виду відходів. У статті виявлено, що тариф на збирання та транспортування необхідно модифікувати залежно від щільності компонентів відходів та цінності вторинної сировини на ринку. Також виявилось, що витрати на збирання та транспортування деяких видів відходів можна уникнути шляхом самостійної доставки до пунктів прийому вторинної сировини. Інклюзивний тариф збору та транспортування, згідно з цим дослідженням, повинен коливатися між 453 грн. та 1628 грн. за тону. Дослідження також показало, що виробник відходів може заробити від 1072 до 2495 грн. при зборі своєї вторинної сировини.

**Ключові слова:** *побутові відходи, тариф на захоронення, вторинна сировина, екологічний тариф.*

**JEL:** *Q50, Q53, R22*

## 1. Introduction

In 2014, Ukraine signed the Association Agreement with the European Union (EU). In accordance with this agreement, Ukraine is committed to reflect the EU waste management directives in the national waste management system. The waste management in the EU is governed by several directives. Directive № 2008/98 / EC on waste, directive № 1999/31 / EC on waste disposal and directive № 2006/21 / EC on waste management in the extractive industries are the core waste management legislative acts. In order to comply with its obligations, the Cabinet of Ministers of Ukraine approved in 2017 the National Waste Management Strategy in Ukraine until 2030 (the strategy),

and in 2019, the National Waste Management Plan until 2030. In accordance with the Strategy, Ukraine undertakes the following obligations regarding the level of household waste recycling: to ensure the recycling of 15 percent of household waste by 2023 due to introducing incentive tools, increasing separate collection of household waste to reach 23% and commissioning of waste sorting lines and recycling plants; to process 50% of the generated household waste by enhancing separate collection of household waste to reach 48% and commissioning of additional waste sorting lines and waste processing plants; to construct a network of waste transfer stations (200 units) in order to reduce overall transport costs. In practice,

waste generation increased from 355 million tons in 2014 to 441 million tons in 2019 [1]. Recycling rates in Ukraine, according to official statistics, are below 1%, and incineration facilities cannot process more than 2.2% of all household waste generated in Ukraine [1]. On the flip side, EU countries in 2020 disposed only 1.5% of their household waste in landfills, recycling 95% of it before sending the resulting residue for disposal. 89.5% of the generated household waste was either recovered or converted to energy in the EU [2].

Obviously, it is not only integration of the directives and establishment of performance indicators needed to achieve the required targets, but also the maximization of the recovery of secondary raw material (SRM) and fully inclusive household waste tariffs that can be the main key factors to success.

In support of this hypothesis, Swiss official statistics state that the cost of waste disposal reaches 2.88 billion euros per year, where the “polluter pays” principle is applied [3]. Swiss municipalities are obliged to finance waste management costs with cost-covering and user-based fees [4]. The EU succeeded to export 36.8 million tons of recovered SRM in 2018 worth about €14.0 billion [5]. In 2020, the volume of SRM shipment from the EU reached 38.4 million tons [6].

## 2. Literature review and problem statement

The study of the composition of household waste in Ukraine gives a general understanding of the amount and share of SRM in the generated household waste. Comprehensive research conducted by Laznenko revealed decent quantities of polymers, paper and carton in the waste that varied depending on the urbanization type [7]. In 2019, Pavliuk’s research confirmed the high SRM potential in 8 Ukrainian cities [8]. Japan International Cooperation Agency issued a report in 2018 that led to the same conclusion regarding the SRM potential in the waste of Kyiv, Kharkiv and Dnipro cities [9]. On the other hand, Androshuk argued in his research that the lack of financing was

the main reason for missing the deadline to reform the waste management plan in Volyn region but, didn’t propose any specific mechanism to find any source for funding [10]. Samoilik concluded that building of 4 mixed waste sorting plants in the Poltava region would be the best environmental and cost-effective solution, but completely overlooked the SRM value generation from a potential source segregation practice [11].

There have been numerous studies to develop methods for uncovering the hidden costs of waste management. The research conducted by Korucu et al argues that the total cost of economic activity can be defined as the sum of the net operating costs (private costs) and the net external costs associated with the activity [12]. Some studies conducted in the first quarter of the 21<sup>st</sup> century started to include the cost of CO<sub>2</sub> emissions as an expense in the financial models [13]. Sweden, for example, imposed a Carbon tax of \$30 per ton back in 1991, which was increased to reach \$132 by 2019 and became the highest Carbon tax in the world [14]. The research conducted by Zhao in 2019 proposed a method to calculate these CO<sub>2</sub> emissions caused by the disposed household waste by quantifying the biodegradable fraction in each waste component ( $fb$ ), on dry base ( $QC$ ) after determining components moisture content ( $u_i$ ) [15].

## 3. The aim and objectives of the study

The aim of this article is to determine a inclusive household waste management tariff in Ukraine. The research identifies the full cost of waste disposal, including both financial and environmental parts and then, figures out the cost of the collection and transportation after subtracting the SRM market value. The total inclusive tariff is based on the best practices in the EU, thereby, assumes the implementation of household waste source segregation.

## 4. The study materials and methods

To achieve the objectives of this study, firstly, we sought to build a complete picture of the composition of household waste in Ukraine. The article compiled all available trustworthy research in this field

and unified them based on the economy of each Ukrainian region. Each study of waste composition used its own way to identify the components of household waste, thus, this research brought them together by common categorization method. All types of plastics, regardless their function, were combined in one category (polymers). Vessels, stones, leather, rubber, bones, fines, minerals, and other similar categories were grouped into a category called “others” because they will all be part of the “mixed waste” category in any waste collection program anyway. In the process of unification, the following data arrangements were made:

a) if the same category had different values in different composition analysis studies for the same city, their average was considered in the main table and the “others” category was adjusted accordingly;

b) wherever morphological analysis ignored textile and scrap wood as separate categories of household waste, they were added manually and their content was equal to their average content of all other studies. The reason for doing that was the fact, that such categories exist in the waste stream and not having them mentioned in the study as a separate category meant only that they were combined with “others”;

c) when the same component, in the waste stream of the same city was considered in one research and missed in another, the value from the first research was copied into the other and deducted from its “others” category;

d) multi-layer packaging was added to the “paper and carton” category because multi-layer packaging and carton are usually collected and recycled using similar method;

e) when hazard waste was separately categorized in the morphology analysis, it was added to “others” category, it’s extremely low content shouldn’t impose any adverse effect on the data accuracy.

At the next stage, the composition of household waste from other regions, which had never been included in any morphological analysis in the past, was taken based on the annual income of the population. The idea is to assume that people with the similar

income in the same country will basically have the same consumption habits, so they will produce the similar composition of household waste. Annual per capita income by regions of Ukraine was taken from official statistics [16]. Four groups by annual income were created (25,000–45,000 UAH/year, 45,001-60,000 UAH/year, 60,0001-65,000 UAH/year, and more than 65,001 UAH/year). Data on the annual generation of household waste by region were taken from the official data of the Ministry for the Development of Communities and Territories of Ukraine [17]. In addition, the full financial costs of household waste disposal were calculated based on the potential cost of land, landfill design and construction, CO<sub>2</sub> emissions, and operational costs.

The operational costs were calculated based on the current waste disposal tariffs as they all consider the total operational and administrative costs in the tariff calculations.

The other main part of the article is devoted to determining a sufficient tariff for the collection and transportation of household waste. The approach was to assume that separation of waste components by source was implemented and then calculate the costs of their collection and transportation based on their density.

Current tariffs were used as the reference cost, as they all take into account general the total operational and administrative costs when calculating tariffs. The market value of the segregated SRM was deducted from the proposed rate for their collection and transportation. A combination of waste collection and transportation, and disposal tariffs was proposed as an alternative household waste management fully inclusive tariff.

## 5. Results

### 5.1. Household waste composition in Ukraine

The unified composition of household waste in those cities where the study of the composition of waste was conducted is presented in the table below.

The data show that food waste makes the majority of household waste in the cities studied, but it is worth noting that its share in Lviv and Poltava remains low.

Table 1

The unified composition of household waste

Regional center	Annual income, thsd. UAH/ person annually	Food waste, %	Paper, cardboard, %	Metal, %	Polymers, %	Wood, %	Textile, %	Glass, %	Other, %
Kyiv	165.1	41	13.25	1.2	15.75	2.3	3.3	11.25	11.95
Odessa	72.8	67	5	1	8	1.04	2.82	4	11.14
Poltava	71.6	25.1	6.35	2	10.75	1.28	3.68	18.38	33.46
Dnipro	87.1	46.5	9	1.3	20.4	0.4	1.8	9.2	11.4
Kharkiv	65.5	41.9	17.65	1.95	11.3	1.3	3.3	9.75	12.85
Vinnitsa	64.7	40.4	6.8	1.90	10.2	0.4	2.82	10.2	27.28
Lviv	65.7	26	10	2	13	1.04	2.82	4	41.14
Kherson	57.1	40	12	4	20	1.04	2.82	3	17.14
Cherkasy	58.8	38	7	2	19	1.04	2.82	11	19.14
Donetsk	39.1	43.5	4.5	2.9	5	0.57	2	6.03	35.5

The higher the percentage of “others”, the less reliable the composite analysis (Poltava, Lvov, Donetsk, Dnipro). Such a high level indicates that the sorting activities during the study of the composition may not have been performed with a high level of attention. The low glass content in the vast majority of studies does not reflect the real picture. Only a small part of the glass bottles remains intact, while the rest are broken during handling and are mostly added to the “others”. In general, the data show a low content of metals, wood, and textiles in household waste. The calculated composition of household waste in other regions of Ukraine by groups of annual income is presented in Table 2 below.

It is estimated that about 40.9% of household waste in Ukraine is food waste. On the other hand, the popular types of SRM (paper, carton, plastics and glass) account for almost a third of the household waste stream (33.47%).

### 5.2. Total landfill Tariff in Ukraine

As a basis for further analysis, available data on disposal tariff in the official cities of Ukraine (Kharkiv, Nikopol, Zhytomyr, Chernihiv, Kropyvnytskyi, Ternopil and Kryvyi Rih) were used. It is noted that over the past 5 years, tariffs have been increased in

all cities. drivers of tariff changes, according to official statements, were increased operational and administrative expenses caused by inflation and consumables prices. Other expenses like social, environmental, landfill construction and land acquisition costs were completely ignored. To form a fully inclusive landfill cost, the financial and social costs were calculated separately, the calculation of financial costs was based on the following:

a) to determine the average cost of acquiring land for the construction of a potential landfill, a lot of Internet sources from different regions of Ukraine were analyzed. The search was limited to non-prestigious locations at a reasonable distance from the administrative centers. Based on the results of the search, it was decided to consider the price of UAH 3,000/m<sup>2</sup>;

b) the calculation of the landfill capacity was based on the density of compacted household waste of 900 Kg/m<sup>3</sup>. The reason for assuming such a high figure is the significant content of food waste and “other” components, that is, mainly minerals, stones and other relatively heavy materials;

c) the calculated life span of any newly constructed landfill was assumed to be 10 years;

Table 2

**The calculated composition of household waste in Ukrainian regions based on annual income groups**

Income group (UAH/year)	Region	Annual household generation (ton)	Food waste (%)	Paper, carton (%)	Metal (%)	Polymers (%)	Wood (%)	Textile (%)	Glass (%)	Other (%)
>65,000	Kyiv (region)	618,881	44.37	8.2	1.4	11.5	1.54	3.27	11.21	18.51
	Kyiv (city)	1,568,791	41	13.25	1.2	15.75	2.3	3.3	11.25	11.95
	Zaporizhia	427,379	44.37	8.2	1.4	11.5	1.54	3.27	11.21	18.51
	Odessa	520,653	67	5	1	8	1.04	2.82	4	11.14
	Poltava	290,405	25.1	6.35	2	10.75	1.28	3.68	18.38	33.46
	Dnipro	816,232	46.5	9	1.3	20.4	0.4	1.8	9.2	11.4
60,000-65,000	Kharkiv	779,690	41.9	17.65	1.95	11.3	1.3	3.3	9.75	12.85
	Zhytomyr	321,813	36.1	11.48	1.95	11.5	0.91	2.98	7.98	27.1
	Mykolaiv	286,426								
	Sumy	184,928								
	Kirovohrad	153,696	40.4	6.8	1.9	10.2	0.4	2.82	10.2	27.28
	Vinnitsia	269,268								
Lviv	618,881	26	10	2	13	1.04	2.82	4	41.14	
45,001-60,000	Kherson	196,437	40	12	4	20	1.04	2.82	3	17.4
	Khmelnyskyi	362,386	39	9.5	3	19.5	1.04	2.82	7	18.14
	Chernihiv	256,111								
	Cherkasy	210,323	38	7	2	19	1.04	2.82	11	19.4
25,000-45,000	Donetsk	702,479	43.5	4.5	2.9	5	0.57	2%	6.03	35.5
	Luhansk	154,359								
	Volyn	406,614								
	Zakarpattia	302,556								
	Ivano-Frankivsk	208,980								
	Rivne	222,648								
	Ternopil	677,440								
	Chernivtsi	214,056								

d) the cost of designing and building the landfill was assumed to be 69 UAH/t for 10 years. This figure was derived based on the author's practical experience and other life examples. This cost assumed the use of three layers of insulating lining (a two-millimeter-thick polymer and two layers of 400 gsm geotextile) and a sufficient leachate collection and treatment system. The calculations also assumed excavation 10 meters below ground level with a slope of 2 degrees and reaching a

maximum landfill height of 15 meters above ground level, then stopping the reception of waste and closing the landfill. A slope above zero is considered 1:3 (pyramid);

e) it was decided that the average operational cost of waste disposal should be equal to the average tariff for waste disposal among the cities of Ukraine;

f) the exchange rate was based on official data as of December 30, 2019 [18]. The reason for choosing this cut-off date was an

attempt to exclude the abnormal adverse effects of the pandemic and Russian aggression;

f) the current tariff for the placement of landfills in the Donetsk region is calculated based on the average tariffs of Marinka and Pokrovsk.

The total household waste disposal costs per region, excluding environmental and social costs, are shown in Table 3.

The table shows that UAH 207.77/t of household waste must be added to the current disposal tariff in order to compensate for those expenditure statements that are omitted from

the current tariff calculation methodology in Ukraine. On average, the disposal tariff, which could compensate for all financial costs, is UAH 355/t. This means that the total annual subsidy for waste disposal paid from the state budget would be about UAH 2.1 billion if tariffs remain unchanged.

The last type of cost of household waste disposal, which is not included in the current tariffs is related to the CO<sub>2</sub> emissions caused by the landfilled biodegradable waste and the generated leachate, based on the research that was conducted by Zhao [15]. Emissions per waste component are calculated as shown in Table 4.

Table 3

### The full financial cost of household waste disposal in Ukraine

Region	Annual compacted waste volume (thsd. ton)	10 years compacted waste volume (thsd. Ton)	The landfill area requirement(m <sup>2</sup> )	The land price (million UAH)	Landfill construction cost (Million UAH)	The costs (UAH/ton)			
						Land cost	Landfill construction cost	Current average financial cost	Full household waste disposal financial cost
Vinnitsia	299.19	2,992	119,674	359	187	133	69	181	384
Volyn	451.79	4,518	180,717	542	282			183	386
Dnipro	906.93	9,069	362,770	1,088	567			131	334
Donetsk	780.53	7,805	312,213	937	488			114	317
Zhytomyr	357.57	3,576	143,028	429	223			90	293
Zakarpattia	336.17	3,362	134,469	403	210			124	327
Zaporizhia	474.87	4,749	189,946	570	297			223	426
Ivano-Frankivsk	232.20	2,322	92,880	279	145			94	297
Kyiv	348.69	3,487	139,475	418	218			149	352
Kirovohrad	170.77	1,708	68,309	205	107			508	711
Luhansk	171.50	1,715	68,604	206	107			118	321
Lviv	687.65	6,877	275,058	825	430			NA	NA
Kyiv city	1,743	17,431	697,240	2,092	1,090			62	264
Mykolaiv	318	3,183	127,300	382	199			22	225
Odessa	579	5,785	231,401	694	362			135	338
Poltava	323	3,227	129,069	387	202			4	207
Rivne	247	2,474	98,955	297	155			158	361
Sumy	205	2,055	82,190	247	128			168	371
Ternopil	753	7,527	301,084	903	470			168	371
Kharkiv	866	8,663	346,529	1,040	541			34	236
Kherson	218	2,183	87,305	262	136			40	243
Khmelnyskyi	403	4,027	161,061	483	252			562	765
Cherkasy	234	2,337	93,477	280	146			39	242
Chernivtsi	238	2,378	95,136	285	149			104	306
Chernihiv	285	2,846	113,827	341	178			242	444

The calculations were conducted in accordance with the equation below:

$$(OCb)_i = OC_i \times (fb)_i \times (1 - u_i) \times P_i \quad (1)$$

Where:

$P_i$  - wet weight

The amount of CO<sub>2</sub> emissions resulted from one Kg of Carbon was calculated taking into consideration that 12 Kg of Carbon produce 44 Kg of CO<sub>2</sub> upon full decomposition and ideal oxidation [19]. The environmental cost of CO<sub>2</sub> emissions is calculated based on UAH 711/ton [20] (Table 5).

Table 4

**Total Carbon and biodegradable Carbon per component martial**

Component	$OC_i$ (KgC/Kg dry)	$(fb)_i$ (KgCO <sub>2</sub> /KgC)
Paper	44%	0.5
Cardboard	44%	0.5
Food waste	48%	0.8
Wood	49%	0.5
Textiles	55%	0.2

Table 5

**The total cost of CO<sub>2</sub> emissions in the household waste in Ukraine**

Region	Food waste		Paper, carton		Wood		Textile		Total		
	(thsd. ton)	CO <sub>2</sub> eq. (thsd. ton)	(thsd. ton)	CO <sub>2</sub> eq. (thsd. ton)	(thsd. ton)	CO <sub>2</sub> eq. (thsd. ton)	(thsd. ton)	CO <sub>2</sub> eq. (thsd. ton)	CO <sub>2</sub> eq. (thsd. ton)	Cost of CO <sub>2</sub> (million UAH)	Cost of CO <sub>2</sub> UAH /ton of waste)
Vinnitsia	109	92	18	13	1	1	8	3	109	77.5	287.8
Volyn	177	149	18	13	2	2	8	3	167	118.7	292
Dnipro	380	321	73	53	3	3	15	5	382	271.6	332.8
Donetsk	306	258	32	23	4	3	14	5	289	205.5	292.5
Zhytomyr	116	98	37	27	3	2	10	3	130	92.4	287.2
Zakarpattia	132	111	14	10	2	1	6	2	124	88.2	291.4
Zaporizhia	190	160	35	25	7	5	14	5	195	138.6	324.4
Ivano-Frankivsk	91	77	9	7	1	1	4	2	87	61.9	296
Kyiv	139	118	26	19	5	4	10	4	145	104	328.5
Kirovohrad	55	47	18	13	1	1	5	2	63	44.8	291.4
Luhansk	67	57	7	5	1	1	3	1	64	45.5	294.8
Lviv	161	136	62	45	6	5	17	6	192	136.5	220.6
Kyiv city	643	543	208	151	36	29	52	19	742	527.6	336.3
Mykolaev	103	87	33	24	3	2	9	3	116	82.5	287.9
Odessa	349	295	26	19	5	4	15	5	323	229.7	441.1
Poltava	73	62	18	13	4	3	11	4	82	58.3	200.8
Rivne	97	82	10	7	1	1	4	2	92	65.4	293.8
Sumy	67	56	21	15	2	1	6	2	74	52.6	284.5
Ternopil	295	249	30	22	4	3	14	5	279	198.4	292.8
Kharkiv	327	276	138	100	10	8	26	9	393	279.4	358.4
Kherson	79	66	24	17	2	2	6	2	87	61.9	314.9
Khmelnyskyi	141	119	34	25	4	3	10	4	151	107.4	296.3
Cherkasy	80	68	15	11	2	2	6	2	83	59	280.6
Chernivtsi	93	79	10	7	1	1	4	2	89	63.3	295.6
Chernihiv	100	84	24	18	3	2	7	3	107	76	297



On average, each region is required to add UAH 300.8/ton to the current waste disposal tariff to pay for pollution caused by emissions from biodegradable components. In total, this amount is estimated to be around UAH 130 million annually and is currently born by the Ukrainian budget. The inclusion of this portion in the current tariffs would compensate for the current unsanctioned landfills closure and cultivation, and the subsequent land remediation. From the other side, the efforts made by the municipalities and waste generators to reduce the mounts of the disposed biodegradable waste can be financially motivated in an amount that is equivalent to the eliminated CO<sub>2</sub> emissions.

### 5.3. Total collection and transportation costs in Ukraine

The final part in determining the tariff for the treatment of household waste is the cost of collecting and transporting waste. The final part in determining the tariff for the treatment of household waste is the cost of collecting and transporting waste. To reach the most accurate calculation, the following was considered:

a) the material density was considered to be the main factor to affect the current tariffs;

b) based on the strategy, it was assumed that the waste would be segregated from source. The clean sorted SRM would become a commodity that is sold to recyclers at market price. The SRM prices indicators, that were referenced to in this research, were in line with the public official EU reports of 2019 [21], and previous research [22] thus, the assumed sales prices were as follows:

€121/ton for ferrous steel, €850 Euro/ton for Aluminum, €118.7/ton for paper and cardboard, €290.6/ton polymers, and €56.3/ton for glass;

c) as the current tariffs for waste collection in Ukraine take into account the provision of waste containers and all operational and administrative expenses associated with mixed household waste(others), this provision was used in the calculations further;

d) the assumed density of mixed household waste in Ukraine was 216kg/m<sup>3</sup>, this figure was based on the research of Laznenko [7];

e) the current average tariff for collection and transportation of waste in each region was calculated on the basis of an advanced search for tariffs in the regions of Ukraine and taking into account the waste generation rate of 260.8 kg/year per capita;

f) as metals were not separated into ferrous and non-ferrous in the available literature, it was decided to assume that 90% of the metals reported in the waste composition studies were ferrous.

Previous research measured the density of different components of household waste in the UK [23] and the results were used to create a collection rate factor per component (Table 6). The factor represents the increase in volume compared to the reference mixed household waste.

Next, the tariff for the collection and transportation of components was calculated as the result of multiplying the current tariff by the collection coefficient (Table 7). The quantity of each component was calculated based on the results of waste compositions.

Table 6

Collection factors of household components depending on their density

Component	Density	Collection factor
Paper, carton	112	1.93
Glass bottles	323.3	0.67
Metals	53	4.08
Plastic containers	18.3	11.80
Plastics	29	7.44
Food waste (in 23-liters containers)	290	0.74
Mixed waste (no food waste)	427.5	0.51

Table 7

**Differentiated tariff for collection and transportation depending on the density of the components**

Region	Current collection and transportation tariff (UAH/ton)	New differentiated tariff (UAH/ton)							
		Food waste	Paper, carton	Metals	Polymers	Wood	Textile	Glass	Mixed waste "others"
Vinnitsia	547	405	1,055	2,231	4,068	787	787	366	405
Volyn	386	286	745.64	1,576	2,874	556	556	259	286
Dnipro	1,308	968	2,524	5,337	9,732	1,884	1,884	876	968
Donetsk	1,319	596	2,546	5,382	9,813	1,899	1,899	884	976
Zhytomyr	806	117	1,555	3,288	5,995	1,160	1,160	540	596
Zakarpattia	175	343	338	714	1,302	252	252	117	129
Zaporizhia	464	983	895	1,892	3,450	668	668	311	343
Ivano-Frankivsk	1,328	282	2,563	5,418	9,879	1,912	1,912	890	983
Kyiv	382	587	737	1,557	2,839	550	550	256	282
Kirovohrad	793	537	1,531	3,236	5,902	1,142	1,142	53	587
Luhansk	537	718	1,037	2,193	3,999	774	774	360	398
Lviv	970	482	1,872	3,958	7,217	1,397	1,397	650	718
Kyiv city	654	458	1,263	2,670	4,869	942	942	438	484
Mykolaev	619	812	1,194	2,524	4,602	891	891	414	458
Odessa	1,097	511	2,118	4,477	8,165	1,580	1,580	735	812
Poltava	690	203	1,332	2,817	5,136	994	994	463	511
Rivne	274	531	529	1,118	2,038	394	394	184	203
Sumy	924	346	1,783	3,769	6,873	1,330	1,330	619	684
Ternopil	468	80	904	1,910	3,482	674	674	314	346
Kharkiv	109	92	210	443	808	156	156	73	80
Kherson	124	416	239	506	923	179	179	83	92
Khmelnyskyi	408	532	787	1,664	3,035	587	587	273	302
Cherkasy	719	324	1,387	2,933	5,349	1,035	1,035	482	532
Chernivtsi	424	314	819	1,731	3,157	611	611	284	314
Chernihiv	437	405	844	1,784	3,253	630	629	293	324

The table shows that the average tariff for the collection and transportation of polymers, paper and carton will double with the introduction of separate waste collection in Ukraine with the introduction of separate waste collection in Ukraine. Minor changes will affect the tariffs for the collection and transportation of textile and mixed waste. The waste generator will pay less for the collection and transportation of food waste, glass and wood (30%, 55% and 80% respectively).

It is also possible to calculate a full differential tariff per waste component based on the environmental cost of CO<sub>2</sub> per component, the average financial cost for landfill establishment, and the expected revenue from SRM sales. The option for self-delivery of waste components was included to reflect the goal of the strategy to install recycling centers. This research assumed that 10% of the SRM sales value would be deducted to cover the cost of preparing it for sale when self-delivered to recycling centers (Table 8).

Net calculated household waste management tariff in Ukraine

Waste component	Average landfill financial cost (UAH/ton)	Environmental landfill cost (UAH/ton)	Sales value (UAH/ton)	Collection and transportation tariff (UAH/ton)	Net collection and transportation Tariff	Net income upon self-delivery to recycling centers (UAH/ton)	Total landfill tariff (UAH/ton)
Food waste	355	601	0	453	453	NA	956
Paper, carton		516	2,808	1,232	-1,576	2,527	871
Metals		0	5,100	2,605	-2,495	4,590	355
Polymers		0	3,122	4,750	1,628	2,810	355
Wood		575	0	919	919	NA	930
Textile		258	0	919	919	NA	613
Glass		0	1,481	409	-1,072	1,333	355
Mixed waste		0	0	473	473	NA	355

The table shows that any landfill tariff in Ukraine that falls below 355 UAH/t does not even cover financial costs. Such a low tariff simply implies the allocation of special subsidies from the state budget to compensate for depreciation of assets, operational and administrative costs. It also shows that in a fully transparent waste management system, the waste generator in Ukraine will be generously rewarded for separating paper, carton, metals and glass. Moreover, the extremely high tariff for the collection and transportation of polymers (UAH 1,628/t) can be turned into a revenue of UAH 2,810/t if the waste generator delivers them directly to the recycling center. The table also shows that landfilling food waste is a very costly practice due to high levels of emissions, which automatically justifies investment in alternative solutions such as composting and anaerobic digestion.

## 6. Discussion of the results

The current data on tariffs for household waste reviewed in this study are quite reliable in relation to information obtained from official sources. Assumptions regarding material density and per capita waste generation were also sourced from official databases and professional studies. Excluding economic and social anomalies by selecting data for 2019 was a carefully

considered precaution to eliminate situational inferences.

The analysis of waste composition could be more accurate if a national household waste characterization program were carried out to eliminate inaccuracies due to seasonal differences and social factors. Such measure is important in a country that is famous for its developed seasonal agrarian type of economy. It is important to emphasize, however, that every effort has been made in the current study to minimize error by linking household waste composition for missing regions to annual income.

The article provides scientifically justified tariffs that are understandable to the public and presents a potential reward system for those who choose to segregate the waste or reduce their consumption rate. However, a gradual implementation scenario that could have added more credibility to the results was not considered.

The results clearly show that the entire process of household waste management in Ukraine needs to be redesigned to introduce source segregation practices to achieve the objectives of the Strategy. That would lead to a significant increase in the prices of collection and disposal, but generously reward those who practice source segregation.

## 7. Conclusions

The current household disposal tariffs should be above 355 UAH/ton to sustain operations, cover the depreciation of assets, and purchase of land. The only way to be able to finance landfill remediation and emergency illegal dumping is to impose an additional tariff. The most logic justification for the extra tariff would be the cost of CO<sub>2</sub> emissions, which will range from UAH 200.8 to UAH 441 per ton, depending on the biodegradable content in each component. The fact that SRM is a commodity should be

fully exploited to enhance source segregation and minimize landfill, as the financial returns to waste generators become tangible. The segregation of SRM, combined with food waste reduction through home composting or any other means, may result in an increase in the total waste management bill but, this requires further detailed analysis. The results of this research are in line with the “polluters pay” principle applied in the EU and explain the reason behind the big gap between the household waste management tariffs in Europe and Ukraine.

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#### **DETERMINING THE COMPREHENSIVE TARIFF FOR HOUSEHOLD WASTE MANAGEMENT TAKING INTO ACCOUNT THE ENVIRONMENTAL COMPONENT AND THE VALUE OF SECONDARY RESOURCES**

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One of the main reasons why the EU has achieved such impressive results in minimizing landfills and increasing the rate of recycling has been the "polluter pays" principle. The cost of waste management for the producer should be equal to all the costs of eliminating its adverse effects. The results of household waste management in Ukraine lag far behind those in Europe. Less than 1% of the total amount of household and similar waste is reused. Ukraine risks not achieving the waste management

indicators specified in the national sustainable development strategy if the current organizational and economic models remain dominant. Low tariffs for waste management and the absence of a nationwide segregated collection program are believed to be the main factors behind the prevalence of unsanctioned dump sites. The backlog in the implementation of recycling centers, recycling mega-projects and, finally, separate collection programs are the result of insufficient funding. This study provides a full calculation of the inclusive household waste management tariff. The approach was to find the total financial costs, including design, land acquisition, landfill construction and operating cost then, estimate the environmental costs caused by the CO<sub>2</sub> emissions. The study estimates the real cost of collecting and transporting separately collected household waste and concludes the net cost after deducting the market value of recyclable materials. According to the results of the study, it turned out that the financial costs for the disposal of household waste in Ukraine reach up to UAH 355, and the cost of emissions may reach UAH 441/ton depending on the type of waste. The article reveals that the tariff for the collection and transportation of household waste must be adjusted depending on the density of the waste components and the market value of secondary raw materials. It has been also found that the costs of collecting and transporting some types of waste can be avoided if the recyclables are self-delivered to the recycling centers. The inclusive collection and transportation tariff, according to this study, should fluctuate between UAH 453 and UAH 1628 per ton. Finally, the study has shown that waste generator can earn between UAH 1072 and UAH 2495 when his recyclables are collected separately.

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