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CIRCULAR ECONOMY AND “POLLUTER PAYS” PRINCIPLE IN BULGARIAN MUNICIPALITIES *

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Abstract. The current method of defining waste fee (as a percentage of the property tax) does not stimulate citizens and economic entities to prevent waste generation and separate recyclable waste at source. Although Bulgaria amended its legislation to address the issue back in 2015, the application of the provisions has been postponed several times in the course of nearly ten years. The way to overcome this challenge is to optimise waste management and introduce municipal waste charges based on actual waste quantities produced by each household or economic entity generating municipal waste. In mid-2023, the European Commission services launched an infringement procedure against Bulgaria for failure to comply with the 'polluter pays' principle. In 2024, appropriate regulatory and guidance documents should be established to ensure full-fledged implementation of the principle. This article analyses the results of a demonstration project performed at a small scale on the territory of the municipality of Gabrovo inspired and supported by one of the authors. At ten waste collection points in the city, state-of-the-art equipment was installed to measure the quantity of waste disposed by individual households (more than 300 households agreed to participate). The data was stored in tailor-made software, providing feedback and motivation through a competition that awarded devoted participants. The obtained data from the two demonstration stages (without and with separate collection at source) were used for comparative analysis and forecasts on possible future implementation of pay-as-you-throw schemes. The rate of active participants (24%) and the potential to reduce residual waste generation in case of active participation (23%) are promising. The conclusion is that, based on the cost coverage principle, the expected average fee will not increase much with the new PAYT model. The most serious challenge appears to be the cross-subsidy between households and economic entities generating municipal waste, the latter being the prevailing source of waste fee revenues. The shift to fair calculation of waste fees requires difficult and unpopular decisions by all Bulgarian municipalities.

Keywords: circular economy; security; resilience; municipality; waste management; pay-as-you throw

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JEL Classifications: M12, M15, J24

1. Introduction

In the last couple of decades, Circular Economy emerged as a reliable alternative economic concept able to cope with the imminent global sustainability issues, created by the current unidirectional economic model, Linear Economy (Sillanpää & Ncibi, 2019; Rezk et al., 2023; Lyu & Liu, 2023; Rezk et al., 2025). Regulatory pressures (taxation solutions such as the polluter-pays principle (Ambec & Ehlers, 2011) started to be enforced nationally and internationally (Luppi, Parisi & Rajagopalan, 2012), what caused discussion how to make taxes as fair (Corvino, 2023; Priya, Varghese & Pivato, 2023; Aldeia, 2023; Mukherjee, 2023; Tao & Wu, 2025).

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The European Union has set ambitious waste management targets for member states. To achieve these targets, it encourages using economic and regulatory instruments such as fees according to the amount of waste generated, extended producer responsibility schemes and incineration and landfill fees.

Waste management in EU member states is carried out in accordance with national and/or regional policies and is most often carried out at the municipal and local level. The degree of reaching the set targets varies widely, and the comparison of data from different Member States and even from different settlements is difficult because of the variety of applied models, including data collection and processing methods. Over the past 20 years, significant progress has been made in developing effective schemes for charging households according to the amount of household waste generated. A number of viable fee models and technical solutions are in place that provide individual incentives to comply with the waste hierarchy.

2. Literature review

Pay-as-you-throw (PAYT) schemes are now widely recognised as an efficient tool for managing and financing waste-related activities. Studies have shown that they achieve significantly better results in terms of prevention and separate collection of waste than the flat fee model. Analyses at the EU level recommend a broad campaign to communicate the results and benefits of PAYT to overcome prejudice and encourage its implementation on a larger scale (Eunomia & COWI, 2019). Pay-as-you-throw schemes are quite widespread in Belgium, the Netherlands, Luxembourg, Germany, France and Italy. There have been positive experiences in Austria, Denmark, Finland, Spain, Portugal, and, recently, Greece. Information and data from PAYT implementation are also available for Slovenia, Poland, Hungary and more (Schweitzer & Card, 2016; Morlok et al., 2017; Rasera & Contarina, 2017; Emmanouil et al., 2022; Slučíaková, 2021; Ukkonen & Sahimaa, 2021; Di Foggia & Beccarello, 2023; Messina et al., 2023; Alves, Silva & Soares, 2020).

In general, pay-as-you-throw schemes should meet the following minimum requirements: quantifying at least residual municipal waste (based on volume or weight); unambiguous identification of the waste generator; association of the delivered amounts of waste with specific users (calculation of cost per unit of generated and disposed waste); tracking and encouraging good faith behavior (setting targets or other methods) (URBAN AGENDA FOR THE EU Programme, 2018).

Proper pricing of waste reflects its reduction and strengthens the circular economy. Many researchers correctly substantiate the connection between the circular economy and national security. And not only from the point of view of reducing environmental risks! In addition to ecology and economic effects, other areas of security and sustainability cannot be ignored, which are also significant. The main considerations are based on the fact that, due to sustainable use of resources, reuse and recycling reduce dependence on imports of raw materials and energy sources, strengthening the country's economic and energy independence.

On the other hand, the circular economy supports social stability and economic sustainability by promoting green innovations and creating jobs, and these are key factors for the internal and external security of a state. Gubanova et al provide an example of a circular economy achieving specific socio-economic benefits. Koval et al. (2023) point out the role of environmental investments in strengthening national economic security by mitigating biodiversity loss and managing ecological risks. Birgovan et al. (2024) present circular economy indicators at the organisational level, revealing a lack of standardised and socially inclusive measurement tools.

The main principle for calculating the amount of state and municipal fees is the principle of cost coverage. This also applies to municipal waste fees, which should cover the costs of providing services related to waste management. All the international documents generally suggest utilising almost identical approaches (Loktionov et al, 2023). When determining the fee amount, the annual revenues are expected to cover the waste management costs estimated in the relevant financial plan. Pay-as-you-throw schemes encourage households and economic entities that produce municipal waste to behave responsibly, i.e., prevent waste generation and separate recyclable fractions at source. Negotiations should not be neglected when implementing green policies to facilitate green business transitions (Sileniece, 2024).

A number of projects under the European Commission centrally financed programmes analyse case studies, implement pilots/demonstrations and elaborate methodologies and toolkits to launch economic instruments. They recommend a flexible approach to applying the polluter pays principle (baseline, advanced and supreme models to define the fixed and variable components of the fee) that allows comparison of the advantages and drawbacks of different alternatives and at the same time prevents from including in the fee costs that are obviously disproportionate to the amount and nature of waste generated. Last but not least, it is considered that fees should be socially affordable for the low-income population (URBAN AGENDA FOR THE EU Programme, 2018; LIFE Programme; Horizon Programme).

In July 2023, the European Commission announced its decision "to open an infringement procedure by sending a letter of formal notice to Bulgaria (INFR(2023)2064) for failing to apply the polluter-pays principle as laid down in the Waste Framework Directive (Directive 2008/98/EC) (European Commission, 2024).

According to the EC Press Release, in Bulgaria, the costs for waste management that citizens and businesses pay are based on the property's tax value and do not consider relevant parameters such as the quantity of household waste. Although Bulgaria amended its legislation to address the issue, applying the provisions has been postponed yearly since 2015. According to the latest information from the Bulgarian authorities, using the provisions could become effective in the following two years. The Commission is therefore sending a letter of formal notice to Bulgaria, which now has two months to respond and address the shortcomings raised by the Commission. Without a satisfactory response, the Commission may decide to issue a reasoned opinion". (European Commission, 2023).

The Bulgarian National Waste Management Plan 2021-2028 and the municipal waste management programmes state that the current method of defining waste fee (as a percentage of the tax on properties) is a serious obstacle to implementing the "polluter pays" principle. The cited documents acknowledge that the above method does not stimulate citizens and economic entities to prevent waste generation and separate recyclable waste at source. The programmes also identify measures to overcome this challenge by optimising the management model and, more specifically, designing municipal waste fees based on the "polluter pays" principle. In 2024, appropriate regulatory and planning documents are expected to be approved for the full-fledged implementation of this principle (Ministry of Environment, 2021; Municipality of Gabrovo, 2021).

As it is very well described in (Stoilov et al., 2022), the general weakness to overcome concerning our national strategic planning documents is the absence of a methodological basis for the elaboration of such documents. Similarly to the methodology for strategic energy planning, it is advisable to elaborate on one for strategic waste management planning. To this end, plenty of preliminary studies need to be performed, e.g., on appropriate research avenues (Wise & Stoilov, 2021), possible optimisation criteria (Hadzhiyska & Stoilov, 2023), significance and influence of public opinion (Nikolova & Stoilov, 2023), etc.

It is crucial to collect, maintain and protect waste management data, as security is a complex concept that covers many aspects, including environmental protection (Stoykov, 2018; Stoykov & Dimitrova 2018). The implemented ICT infrastructure should have sufficient capacity and cover all relevant processes and players, including the responsible municipal units, tax collection service, companies providing waste collection, recycling and landfill of waste, households and businesses that generate municipal waste.

3. Methodology of the study

3.1. Study area

The study is focused on implementing the "polluter pays" principle in municipal waste management systems in Bulgaria. Based on the results of the demonstration project BG16M1OP002-2.009-0078 "IoT Smart Waste Management" cofinanced by the operational programme Environment 2014-2020, as well as historical and forecast data, it analyses the efficiency of waste management processes and opportunities for full-fledged implementation of economic incentives towards reaching sectoral targets.

3.2. Data collection and analysis techniques

The demonstration took place over a one-year period. Participants were instructed to use the project waste containers in the first six months to dispose of all municipal waste. In the second half, municipal waste without the recyclable fractions was collected separately at source. All participants were households, and the project did not involve any business entities that generate waste similar to household waste.

Each household was granted personal access to the containers using plastic cards (covering 85% of all household members), which open a big compartment (20 l volume) or a small compartment (volume 5 l). The use of an appropriate compartment is guaranteed by providing households with plastic bags 20 l and 5 l and instructing them to dispose of only full bags. Therefore, it is assumed that each container opening and small/ big compartment use represents the disposal of the relevant waste quantity.

After an initial survey with the assistance of the municipality, 200 households agreed to participate, as planned. To ensure maximum success of the demonstration, additional 127 households have been invited. It is important to note that participation was completely voluntary and it was not possible to control whether each person from the 327 households involved strictly followed the instructions of the project team. In order to motivate the participants, a simulation game/competition was organised, and participants who strictly followed the instructions were awarded prizes.

Participation in the demonstration (including the simulation game/ competition) was monitored through the project-developed information system (software) (Information system developed and administered under the project), reporting and maintaining information and data on each household (owner, address, number of household members) and information on the date, time, and compartment used each time the container is opened through the provided personal access. The system can generate reports by aggregating information on the number of container (compartment) openings for a given time span for one or more households, as well as various ratios related to the age structure of the covered households. Information about the 10 containers covered (identifier, address, lat, lan coordinates, service dates of each container) is also supported.

The data collected as a result of the demonstration project were analysed using mathematical, statistical, and econometric methods, as well as expert assessment and qualitative information analysis.

Multi-criteria analysis (comparing possible options based on a set of criteria relevant to defined objectives) and efficiency analysis (comparing the costs of different actions that attain the same objectives) were used to define possible scenarios for the design of household waste fee based on the amount of waste generated by individual households, and propose the most effective calculation model.

4. Summarised survey results and comments

4.1. Analysis of the data obtained from the information system (SWAM IT system, 2023)

Household participation

The system shows that a total of 327 registered households participated in the demonstration, including 614 household members, to whom 548 access cards were distributed. It is interesting to analyse household activity by tracking the average number of openings of project containers per household (Figure 1).

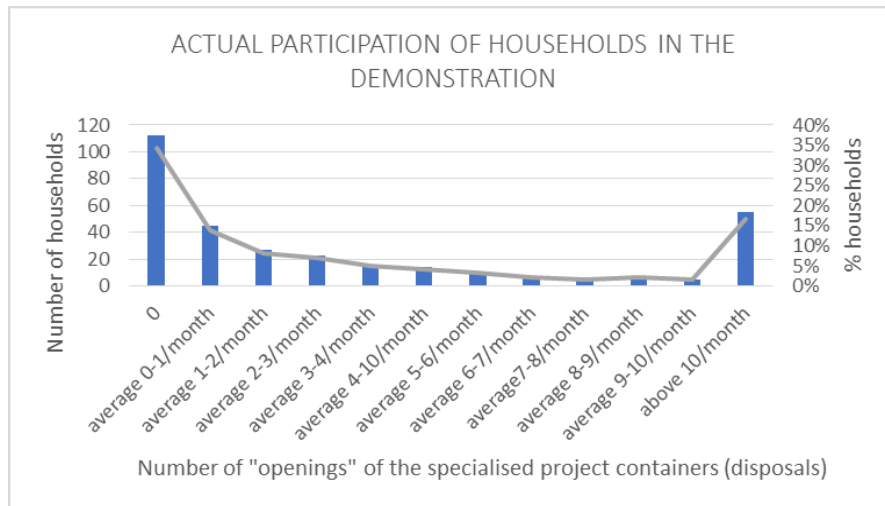


Figure 1. Actual participation of households in the demonstration

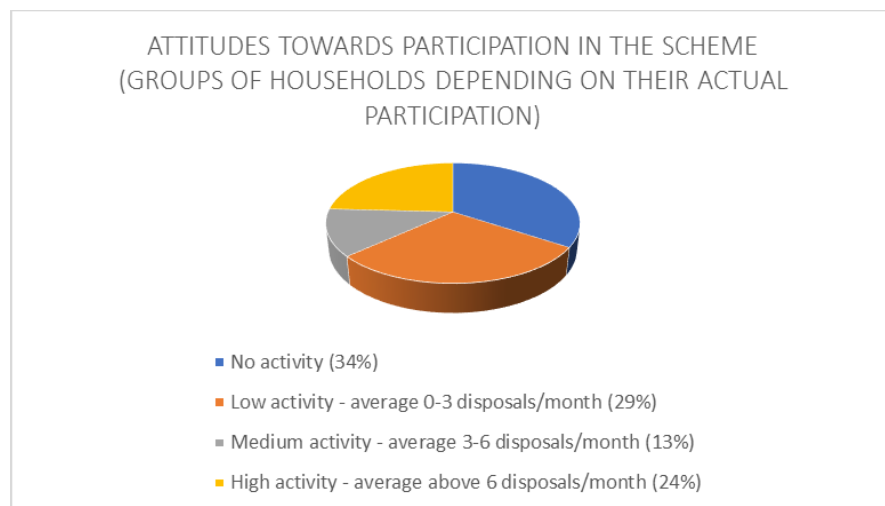


Figure 2. Attitudes towards participation in the scheme (groups of households depending on their actual participation)

As can be seen from Figure 2, 112 households (34% of those registered) have not used the access cards to the containers even once, 95 households (29% of those registered) used the containers on average up to three times per month, 41 households (13%) - on average between 3 and 6 times per month and 79 households (24%) - on average more than 6 times per month. This analysis is interesting as it provides insight into households' attitudes towards participating in such schemes.

Although 215 households (66% of those registered) used the containers with personal access at least once, i.e. formally took part in the demonstration, in order to ensure the reliability of the comparative analysis, it is important to examine the obtained data critically and determine a conservative criterion for forming a basis for the analysis. Based on expert assessment, we assume these are the "high activity" households that used the containers on average more than 6 times per month. 79 of those registered (24%) meet this criterion. The criterion is indeed conservative, and it is possible to exclude bona fide households, which have, however, been away from home for a long time or are regularly away from home. The opposite is also possible – dishonest behavior on the part of sampled households, e.g. more frequent disposal of smaller amounts of waste or simulated disposal (opening the container in vain) during the first six-month phase, as well as disposal of residual waste in other containers with free access located on the sites covered by the project - during the second phase. We assume that the opposite trends described compensate and do not define a % of error.

Of course, the included 327 households, as well as the “highly active” 24% thereof, are not representative samples. However, the obtained “field data” is a valuable source of information and for the purposes of the analysis of the demonstration (as well as comparison with the current situation), the data for the latter will be extrapolated to the entire municipality. Thus, the results show the possible effect of a well-planned, publicised and implemented scheme, in which households participate actively.

The average number of persons in a household is 1.88 for registered households and 2.13 for “active” households, which is close to the average for the municipality of 2.15 (National Statistical Institute, Demographic and social statistics). It is also interesting to analyse the age structure of the households covered by the demonstration, as well as the ones that showed “high activity” (Figure 3). The larger share of young people up to 18 years old, as well as persons 31-60 years old in the structure of “active” households, versus a decrease in the share of the age group 18-30 years old, is surprising.

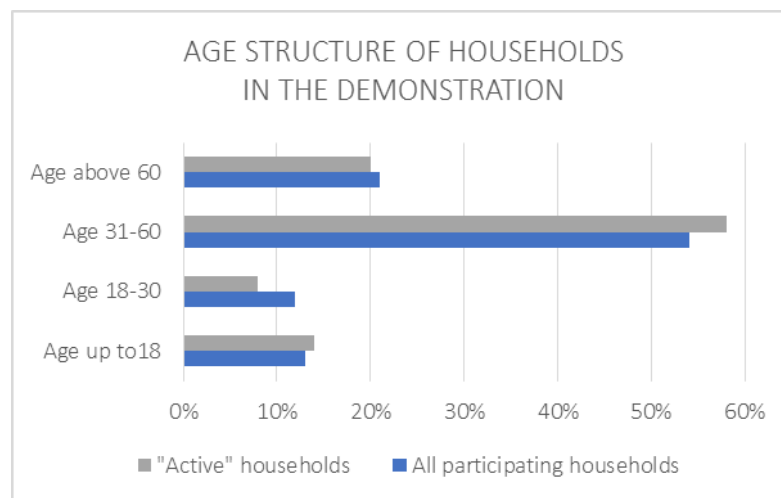


Figure 3. Age structure of households in the demonstration

If we consider the proportion of “active” households in each of the 13 building entrances covered, interesting results are also obtained (Figure 4). It turns out that in three building entrances, there is not a single active household, and in four “entrances”, the “active” households are between 30% and 40%. It is possible to explore the motivating factors further, e.g., the form of property management, etc.

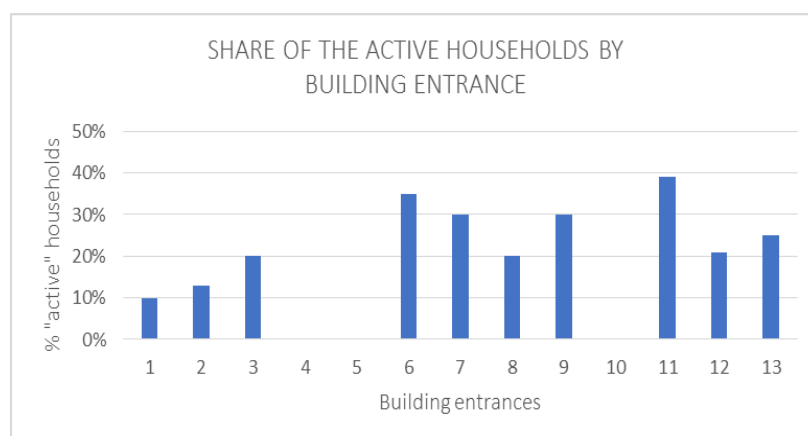


Figure 4. Share of the active households by building entrances

Quantities of waste disposed

The total amount of disposed waste for the entire duration of the demonstration from all households is 333730 l. The obtained waste volume values are converted into weight by applying the “weight volume” index (also known as “waste density”). Suppose we apply the index level recommended by the Ministry of Environment and Water document "Guide for determining the number and type of necessary containers and equipment for waste collection and transportation" of 2004 (Ministry of Environment and Water, 2004), i.e., (300-340 kg/m³ for settlements 25000-1000000). In that case, we obtain an accumulation rate (total household waste) that significantly exceeds the value for the municipality of Gabrovo according to the National Survey of the morphology of waste of 2019 (Ministry of Environment and Water, 2019). When applying a weight volume of 250 kg/m³ (although the cited old document recommends such levels for larger settlements), we obtain more realistic values of the rate, close to the results of the most recent morphology (see Table 1).

Table 1. Weight volume

Indicator		Number of inhabitants in the settlement			
		Up to 3000	3000 - 25000	25000 - 1000000	Above 1000000
Rate of accumulation	kg/person/day	0.40-0.50	0.90-1.00	1.05-1.15	1.15-1.25
	kg/person/year	150-180	330-365	380-420	420-455
	l/person/day	1.05-1.45	2.30-2.85	3.10-3.85	3.95-5.00
	m ³ /person/year	0.40-0.55	0.85-1.05	1.15-1.40	1.45-1.80
Weight volume	kg/m ³	340-380	350-390	300-340	250-290

Source: Guide for determining the number and type of necessary containers and equipment for waste collection and transportation of 2004 (Ministry of Environment and Water, 2004)

This approach enables the following comparisons. We compare the amounts of residual waste generated in the first and second six-month demonstration phases (for all registered households and separately only for the “active” households) (Figure 5).

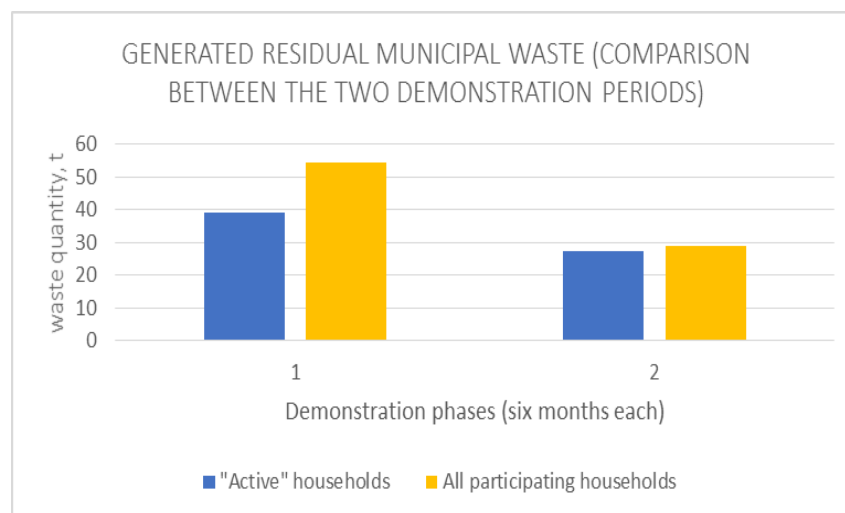


Figure 5. Generated residual municipal waste (comparison between the two demonstration phases)

In the first case, there is a decrease of 47% (from 216960 l. or 54.24 t. to 115235 l. or 28.81 t.) These data seem too inflated and confirm that, for further comparisons, it is appropriate to work only with the sample of “active” households (79 households that used project containers on average more than 6 times per month).

For this sample, the amounts generated during the first six-month phase (155765 l or 38.94 tons) decreased by 30% in the second six-month phase, reaching 108530 l or 27.24 tons. This more realistically shows the possibilities for separate waste collection at the source of their generation.

Next, we compare the accumulation rate (the amount of household waste generated per inhabitant per year) calculated for the first and second demonstration phases (only for the “active” households) (Fig. 6). The reduction in the amount of residual household waste per inhabitant in the second compared to the first phase of the demonstration is about 30%.

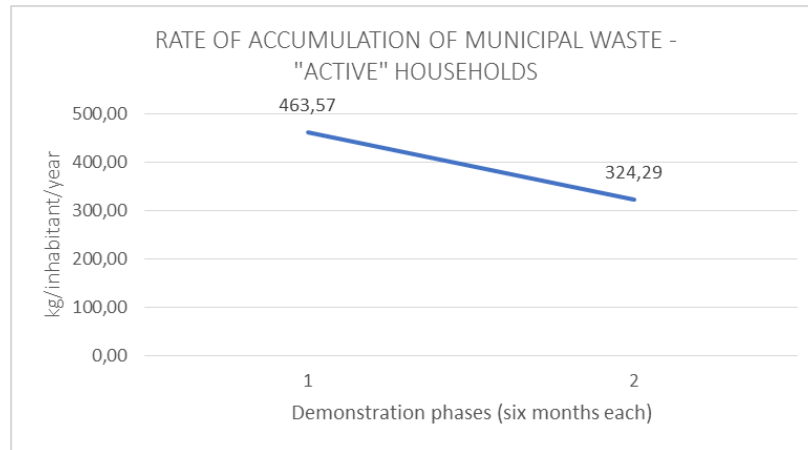


Figure 6. Rate of accumulation of municipal waste – “active” households

The comparison with the results of the National Morphology (the relevant section for Gabrovo municipality) (Ministry of Environment and Water, 2019) is interesting (Figures 7 and 8).

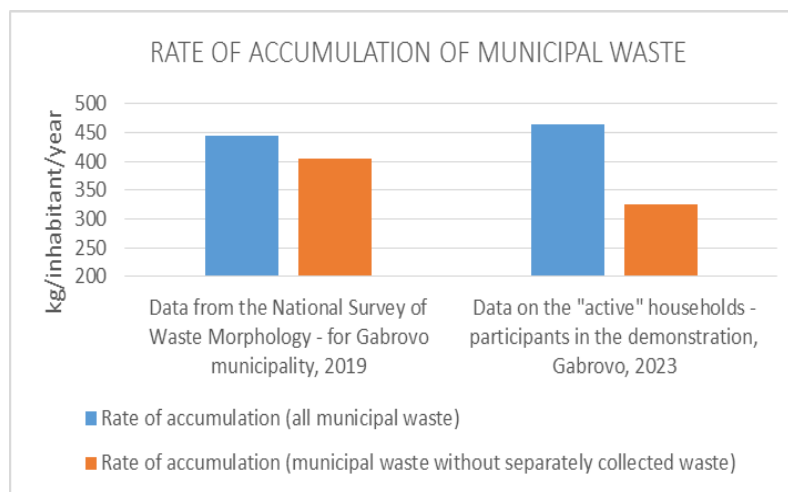


Figure 7. Rate of accumulation of municipal waste

Most interesting is the comparison of the rate of accumulation for the second phase with the rate of accumulation (household waste without separately collected waste) reported in the most recent morphology analysis (Ministry of Environment and Water, 2019) (Fig. 8). This gives us an idea of the expected efficiency of future schemes, or in other words, to what extent it is possible to reduce landfilling of household waste as a result of introducing a “pay-as-you-throw” scheme. From the reduction (24%), it is obvious that, with all stipulations and assumptions, introducing a pay-as-you-throw scheme has a real potential to reduce the amount of residual household waste generated significantly.

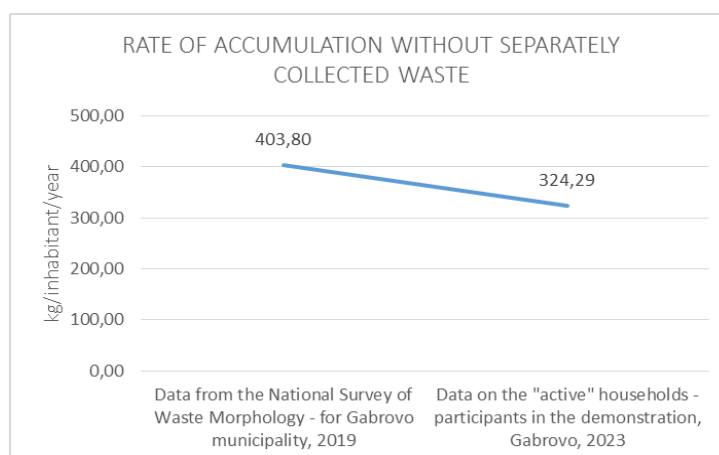


Figure 8. Rate of accumulation (municipal waste without separately collected waste)

The average value of the indicator “municipal waste accumulation rate” for Gabrovo municipality obtained by the National Survey of waste morphology of 2019 (Ministry of Environment and Water, 2019), was used as a reference value. For the purposes of comparison, it is considered more appropriate to use a value of the indicator specific to area “blocks of flats” (based on the categories recommended in the methodology for determining the morphological composition of municipal waste of 2012 (Ministry of Environment and Water, 2012)), however such information was not available in the latest morphology.

Regarding the expected increase in the share of separately collected recyclable waste, we unfortunately do not have “field” data, as the project demonstrates a base model of the “pay-as-you-throw” scheme, where only the amount of residual municipal waste is determined/ measured. It is assumed that the quantities reduced in the second six months correspond to prevented or separately disposed waste in the containers designated for this purpose.

When calculating the municipal waste accumulation rate for the demonstration, it is not possible to account for the seasonal nature of waste generation. The rate (kg/inhabitant/year) for each of the two phases was calculated by extrapolating the available six-month data. It was impossible to plan a two-year demonstration due to the limited maximum duration of the projects under the grant award procedure under the OPE 2014-2020.

4.2. Analysis of the feedback from the project team

The first prerequisite for the successful implementation of the demonstration was the established cooperation with the Gabrovo municipality. It started in 2019, at the stage of developing the project proposal, when a meeting was held with municipal experts to discuss the project purpose and scope, the technical means for determining the amount of waste generated and identifying the households that generated the waste. As a result, consent was issued by the mayor of the municipality for placing specialised equipment at 10 container sites in the city. A series of meetings with municipal experts followed in 2022, after the signature of the Grant Agreement under the OPE 2014-2020, to discuss the criteria for selecting the target group of households and opportunities for assistance. As a result, contacts, data and information were provided for demonstration and analysis purposes. An agreement has been reached on the participation of the municipal enterprise “Regional Development”, a specialised unit of the Municipality of Gabrovo, responsible for the collection and transportation of household waste. To guarantee the correct service of the specialised containers with limited access, technical training was conducted for the employees of the municipal enterprise, with the help of the company responsible for the production and delivery of the boxes, “Senstate Technologies” JSC. The demonstration was carried out in coordination and ongoing communication with this municipal enterprise.

Households were initially instructed at the project start. With the help of an employee of the Municipal Enterprise “Regional Landfill for Non-hazardous Waste” Gabrovo, initial contact with the target group and clarification of the purpose of the demonstration and participation in the scheme took place. At the beginning of the demonstration itself (after installing the specialised container equipment, participants were trained

technically, with the help of the company responsible for production and delivery of the specialised equipment, "Senstate Technologies" JSC, and the manufacturers of the hardware and software, "Tempus 2000". Constant contact was maintained with the target group of households, with the help of a key representative with good organisational skills who was recruited by the project (property manager of one of the selected buildings), who is responsible for distributing leaflets and access cards to the project boxes, distributing sealed envelopes with software access credentials, information about waste disposal with reference to the project website, discussing problems or questions, providing waste disposal plastic bags and gifts to the winners of organised competitions, posting contest announcements, etc.

While implementing the demonstration, the project team reported on several main groups of problems, mainly related to the attitudes of households. Initially, there was distrust of the demonstration and a negative attitude towards participation (more specifically, fears that participation in the scheme would increase household waste fee). In response, additional clarifications were provided, a house manager from the target group was recruited, and more households were included than originally planned (327 instead of 200). Another problem is the citizens' dissatisfaction with the volume of the waste disposal compartments, which, according to the project assignment, are 5 L and 20 L, respectively. According to the participants, these openings are insufficient and should be 20 l and 50 l. To avoid inconvenience, households were provided with waste bags volume 20 l and 5 l. The most serious challenge has been the illegal dumping on the sites, outside the containers (probably because of carelessness/ missing cards or unwillingness of certain household members to participate); therefore, complaints have been received in the municipality. Containers for residual household waste with free access had to be placed on the project sites. This contradicts the concept of conducting the demonstration, according to which all containers located at the project sites should be equipped with boxes with limited (individual) access, in order to motivate participation and ensure data reliability maximally. However, a deviation from the concept was necessary to solve the problem, given the voluntary nature of the demonstration.

4.3. Defining possible scenarios for the design of municipal waste fees based on the quantity of waste generated by individual households, including fixed and variable components. Coverage of waste management costs

Out of the possible main scenarios, the following scenario is examined in detail: The amount of municipal waste fee is to be determined based on the volume of the generated waste. The fee comprises a fixed part that covers 40%-60% of the waste management costs and a variable part that covers 40%-60% of the waste management costs, to be charged depending on the amount of waste generated.

Table 2. Description of the parameters of scenario 1

Area	Model	Customers	Data source
Area "Blocks of flats"	Replacement of all free-access waste containers with limited-access containers with RFID (based on waste volume)	Households and economic entities that generate waste similar to municipal waste	Project demonstration
Area "Single-family houses"	Model based on collection frequency (based on waste volume)	Households and economic entities that generate waste similar to municipal waste	Data from other projects, modelled data

Two versions of this most realistic scenario have been elaborated and compared. The reference period for the purposes of the analysis is the period 2016-2023, for part of which data and information are available from the municipal Waste Management Programme 2021-2028 (Municipality of Gabrovo, 2021). The missing data are modelled using appropriate methods. The year of the investment (or the year of the introduction of the PAYT scheme) was set to 2024, and the effect of the introduction of the scheme was analysed for a subsequent period of the same duration, 2024-2031.

As shown in Table 3 below, the model is based on the extrapolation of data from the demonstration. We can assume that in 2024, 24% of households in the municipality will be actively involved in the implementation of the scheme and therefore apply the rate of residual household waste generation obtained as a result of the analysis of project data (second phase). For the rest of the households, we assume that they will generate residual household waste equal to the waste accumulation rate, i.e., they will dispose of all their waste without any separate collection.

Data for past years and estimated population data are according to NSI (missing data are modelled linearly). The number of persons in a household for the reference period is also according to NSI data (average 2.15 for Gabrovo municipality) (National Statistical Institute, Demographic and social statistics). For the period 2024-2031, a reduction of this indicator (based on expert assessment) is allowed, given the population decreasing trend.

The share of “active households” (who will participate in good faith in the PAYT scheme) for 2024 is determined based on the results of the demonstration (24% of all registered participants). It is assumed that this share will increase by two points every year, considering there will be real motivation to reduce the household waste fee.

Table 3. Indicators - Demographics

3a. Traditional scheme

DEMOGRAPHICS	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Population of Gabrovo municipality, number	59663	58567	57625	56599	55768	53173	50578	53618
Average household members, number	2,15	2,15	2,15	2,15	2,15	2,15	2,15	2,15
Total households, number	27750	27240	26802	26325	25938	24731	23524	24938

3b. PAYT schemes

DEMOGRAPHICS	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Population of Gabrovo municipality, number	52769	51943	51117	50291	49465	48615	47765	46915
Average household members, number	2,15	2,13	2,11	2,09	2,07	2,05	2,03	2,01
Total households, number	24543	24386	24226	24062	23896	23714	23529	23341
Total of active households (24% to 38%) (PAYT), number	5890	6340	6783	7218	7646	8063	8470	8869
Total non-active households (76% to 62%) (PAYT), number	18653	18045	17442	16843	16249	15651	15059	14471
Total of active household members (PAYT), number	12664	13505	14312	15087	15828	16529	17195	17827
Total of non-active household members (PAYT), number	40104	38437	36804	35203	33636	32086	30569	29087

Table 4 below presents the comparison of the municipal waste costs of the traditional scheme and PAYT schemes. The total cost of waste management for 2016-2020 is according to the Waste Management Programme of Gabrovo Municipality 2021-2028 (Municipality of Gabrovo, 2021). Because of the lack of data on the distribution by groups of activities, the latter was modelled on the basis of practical experience and expert assessment (waste collection and transportation - 50%, disposal of household waste in landfills or other facilities - 30%, cleanliness of the territories for public use - 20% of the total costs). For the same reason, the costs for the period 2021-2023 are modelled using the linear interpolation method.

The costs until 2031 are estimated as follows: after introducing the PAYT scheme, the costs of waste collection and transportation and the costs of municipal waste disposal in landfills or other facilities are expected to decrease pro-rata with the reduced amount of residual municipal waste (it is assumed that the cost of collection and disposal per ton of waste is a constant value and the average value of these costs for the reference period is used for the forecast period). It is assumed that the introduction of the scheme will not affect the costs of

cleanliness of the areas for public use, and the values for 2024-2031 have been determined by applying the method of linear interpolation.

We should include ERP system development and maintenance costs and costs for specialised equipment in the municipal area "blocks of flats" for all containers (1306 containers, not including "the 12 underground containers). The costs for the ERP system are based on estimates for upgrading the system developed under the project. The costs for the specialised equipment of the containers are determined based on the project budget, considering the economies of scale when awarding major public procurement for the territory of the entire municipality. It is assumed that the price covers the costs of maintaining the equipment throughout the entire period of operation. The additional costs are spread over a period of 7 years, given the possibilities of using EU funding, including grants and financial instruments (Angelova, 2020; Anguelov and Angelova, 2019). Thus, we gain an idea of the potential for reducing the calculated fees after the initial investment is paid off. We tentatively assume that the amount of this cost category in the eighth year (2031) is 10% of the cost per year of the previous years, covering only maintenance costs.

It is assumed that the cost of introducing PAYT in the area "single-family houses" is negligible (set as 0,00 BGN).

Table 4. Indicators – Municipal waste costs

4a. Traditional scheme

MUNICIPAL WASTE COSTS	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Costs for waste collection and transportation, and costs for final disposal per ton of generated waste, thousand BGN	0,19	0,16	0,17	0,27	0,23	0,16	0,17	0,17
Costs for the activities on waste collection and transportation, thousand BGN	2267	1962	2097	2792	2427	2467	2507	2547
Costs for the activities on final disposal of waste in landfills and other facilities, thousand BGN	1360	1177	1258	1675	1456	1336	1504	1528
Costs for the activities on cleanliness of the territories for public use, thousand BGN	906	784	838	1117	970	987	1002	1019
Total costs, thousand BGN	4534	3924	4195	5585	4854	4791	5015	5095

4b. PAYT schemes

MUNICIPAL WASTE COSTS	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Costs for waste collection and transportation and costs for final disposal per ton of generated waste, thousand BGN	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19
Costs for the activities on waste collection and transportation, thousand BGN	2121	2050	1980	1911	1842	1812	1781	1748
Costs for the activities on final disposal of waste in landfills and other facilities, thousand BGN	1561	1538	1515	1491	1467	1465	1461	1456
Costs for the activities on cleanliness of the territories for public use, thousand BGN	1035	1051	1067	1083	1099	1115	1131	1147
Costs for development and maintenance of ERP system (PAYT), thousand BGN	26,00	26,00	26,00	26,00	26,00	26,00	26,00	2,60
Costs for specialised equipment in area "blocks of flats" (PAYT) for 1306 containers (N/A for 12 underground containers), thousand BGN	1632	1632	1632	1632	1632	1632	1632	163,25
Costs for waste containers in the area "single-family houses" (PAYT) - villages in the municipality, 750 containers x 1.1m ³ , thousand BGN	0	0	0	0	0	0	0	0
Total costs, thousand BGN	6376	6298	6221	6144	6067	6051	6032	4518

Table 5 presents the indicators related to generated municipal waste. For persons from “active” households, the rate of accumulation of residual household waste, achieved in the second demonstration phase (324 kg/inhabitant/year), was applied. On this basis, the amounts of residual household waste from active households were predicted (basis for calculating the relevant costs).

The generated residual household waste from non-active households was calculated at an accumulation rate according to the realistic forecast for the amount of generated waste in the municipal waste management programme (Municipality of Gabrovo, 2021) (basis for calculating the relevant costs). The total amount of residual household waste generated was also determined based on the above.

Table 5. Indicators – Municipal waste generated

5a. Traditional scheme

MUNICIPAL WASTE GENERATION	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Generated municipal waste (historical and forecast data WMP), tons	19298	19381	19960	16841	17173	24306	24131	23955

5b. PAYT schemes

MUNICIPAL WASTE GENERATION	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Generated municipal waste (historical and forecast data WMP), tons	23777	23606	23433	23259	23084	23399	23714	24030
Rate of accumulation of residual municipal waste for members of non-active households (PAYT) (based on forecast data WMP), tons/inhabitant/year	0,45	0,45	0,46	0,46	0,47	0,48	0,50	0,51
Generated residual municipal waste by non-active households (PAYT), tons	18070	17468	16871	16281	15697	15443	15177	14899
Rate of accumulation of residual municipal waste for members of active households (PAYT) (based on forecast data WMP), tons/inhabitant/year	0,32	0,32	0,32	0,32	0,32	0,32	0,32	0,32
Generated residual municipal waste by active households (PAYT), tons	4106	4379	4641	4892	5133	5360	5576	5781
Generated residual municipal waste by all households (PAYT), tons	22177	21848	21513	21173	20830	20803	20753	20680

Table 6 presents the municipal waste cost per household. When applying average values of the costs of waste collection and disposal and costs of disposal per ton of generated waste, the following are determined: average value of the total costs for one household; average aggregate costs per “active” household and average aggregate costs per “non-active” household. This allows the fee to be determined in compliance with the cost recovery principle.

Table 6. Indicators – Municipal waste costs by household

6a. Traditional scheme

MUNICIPAL WASTE COSTS BY HOUSEHOLD	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Average aggregate costs per household, BGN	163,40	144,08	156,52	212,17	187,17	193,71	213,18	204,31

6b. PAYT schemes

MUNICIPAL WASTE COSTS BY HOUSEHOLD	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Average aggregate costs per household, BGN	259,81	258,29	256,80	255,34	253,90	255,19	256,40	193,58
Average aggregate costs per active household (PAYT), BGN	105,16	105,16	105,16	105,16	105,16	105,16	105,16	105,16
Average aggregate costs per non-active household (PAYT), BGN	203,03	206,53	210,15	213,90	217,78	231,67	246,50	262,35

The indicators related to municipal waste fees and revenues from fees are shown in Table 7 below. The two PAYT scenarios are as follows:

- Pay-as-you-throw scheme with fixed component 60%, presented in Table 7 (7b);
- Pay-as-you-throw scheme with fixed component 40%, presented in Table 7 (7c).

Notably, in 2024-2031, no significant increase in fees is needed to cover all costs. Estimated revenues from the fixed and variable components of the fee to cover 60% to 40% of total costs, respectively (for the scheme to meet the minimum PAYT criteria), have been calculated. To compare the two phases, an average household fee was calculated. The initial increase in 2024 is from BGN 223.31 to BGN 259.81.

It should also be noted that the average value of a household fee fixed component, or in other words the limit to which the fee can be reduced in the case of zero residual municipal waste generation immediately after the introduction of the model (2024), is 30% lower than the average value of fees paid in 2023 (BGN 155.89 compared to BGN 223.31).

An important aspect of the scheme is the fair definition of the fee, so the following indicators have been calculated:

- average value of variable component per household;
- average value of the variable component per active household;
- average value of the variable component per non-active household.

It is assumed that in case of obtaining negative average values of the variable component, the active households should pay 0,00 BGN variable component, as shown in Table 7 (7b). This means that the waste management system would collect more revenues than the incurred costs. Moreover, the surplus would be paid by the active households who follow the rules of the PAYT scheme, which is not fair.

The obtained negative values show the potential to increase the share of the variable component to 60%. Finally, we arrive at the main indicators, namely:

- average value of the fee per active household;
- average value of the fee per non-active household.

After paying off the investments, the listed indicators reach BGN 116.15 and BGN 262.35, respectively, as shown in Table 7 (7c).

Tables 7. Indicators – Municipal waste fees and revenues from fees**7a. Traditional scheme**

MUNICIPAL WASTE FEES & REVENUES	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Total revenues from waste fees, thousand BGN	2926	3970	4210	4328	4854	4604	5086	5568
Revenues from fees minus waste management costs, thousand BGN	-1607	45	15	-1257	-0,23	-185	71	473
Average amount of the fee per household, BGN	105,47	145,75	157,10	164,41	187,16	186,20	216,24	223,31

7b. PAYT scheme with fixed component 60%

MUNICIPAL WASTE FEES & REVENUES	PAYT SCHEME WITH FIXED COMPONENT 60%							
	2024	2025	2026	2027	2028	2029	2030	2031
Expected total revenues from waste fees, thousand BGN	6377	6299	6221	6144	6067	6051	6032	4518
Expected revenues from fees minus waste management costs, thousand BGN	50,72	49,81	48,92	48,04	47,18	47,95	48,67	10,99
Average amount of the fee per household, BGN	259,81	258,29	256,80	255,34	253,90	255,19	256,40	193,58
Revenues from fees (fixed component = 60% of total costs) (PAYT), thousand BGN	3826	3779	3732	3686	3640	3631	3619	2711
Revenues from fees (variable component = 40% of total costs) (PAYT), thousand BGN	2550	2519	2488	2457	2426	2420	2413	1807
Average amount of the fixed component per household (PAYT), BGN	155,89	154,98	154,08	153,20	152,34	153,11	153,84	116,15
Average amount of the variable component per household (PAYT), BGN	103,92	103,32	102,72	102,13	101,56	102,08	102,56	77,43
Potential to decrease the fixed component per household (PAYT), BGN	-50,72	-49,81	-48,92	-48,04	-47,18	-47,95	-48,67	-10,99
Average amount of the variable component per active household (PAYT), BGN	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average amount of the variable component per non-active household (PAYT), BGN	47,14	51,56	56,07	60,69	65,44	78,56	92,66	146,20
Average amount of the fee per active household (PAYT), BGN	155,89	154,98	154,08	153,20	152,34	153,11	153,84	116,15
Average amount of the fee per non-active household (PAYT), BGN	203,03	206,53	210,15	213,90	217,78	231,67	246,50	262,35

7c. PAYT scheme with fixed component 40%

MUNICIPAL WASTE FEES & REVENUES	PAYT SCHEME WITH FIXED COMPONENT 40%							
	2024	2025	2026	2027	2028	2029	2030	2031
Expected total revenues from waste fees, thousand BGN	6377	6299	6221	6144	6067	6051	6032	4518
Expected revenues from fees minus waste management costs, thousand BGN	50,72	49,81	48,92	48,04	47,18	47,95	48,67	10,99
Average amount of the fee per household, BGN	259,81	258,29	256,80	255,34	253,90	255,19	256,40	193,58
Revenues from fees (fixed component = 40% of total costs) (PAYT), thousand BGN	2550	2519	2488	2457	2426	2420	2413	1807
Revenues from fees (variable component = 60% of total costs) (PAYT), thousand BGN	3826	3779	3732	3686	3640	3631	3619	2711
Average amount of the fixed component per household (PAYT), BGN	103,92	103,32	102,72	102,13	101,56	102,08	102,56	77,43
Average amount of the variable component per household (PAYT), BGN	155,89	154,98	154,08	153,20	152,34	153,11	153,84	116,15
Average amount of the variable component per active household (PAYT), BGN	1,24	1,85	2,44	3,03	3,60	3,09	2,60	27,73
Average amount of the variable component per non-active household (PAYT), BGN	99,10	103,22	107,43	111,76	116,22	129,59	143,94	184,92
Average amount of the fee per active household (PAYT), BGN	155,89	154,98	154,08	153,20	152,34	153,11	153,84	116,15
Average amount of the fee per non-active household (PAYT), BGN	203,03	206,53	210,15	213,90	217,78	231,67	246,50	262,35

The average value of a household fee, as well as the levels of fees that active and non-active households are expected to pay, are below the threshold of social affordability, regardless of how it is calculated (1% of annual household income or 1.5% of annual income of the third decile group).

Tables 8. Indicators – Income and social affordability

8a. Traditional scheme

INCOME & SOCIAL AFFORDABILITY	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Average amount of total income per household in Gabrovo municipality, BGN	13306	14887	14091	16885	17210	19534	23216	24867
Social affordability threshold (1% of the income), BGN	133,06	148,87	140,91	168,85	172,10	195,34	232,16	248,68

8b. PAYT schemes

INCOME & SOCIAL AFFORDABILITY	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Average amount of total income per household in Gabrovo municipality, BGN	26519	28171	29822	31474	33126	34777	36429	38081
Social affordability threshold (1% of the income), BGN	265,19	281,71	298,23	314,74	331,26	347,78	364,29	380,81

It is possible to consider further whether it is appropriate to introduce lower fees for vulnerable social groups, given the expected educational effect of higher fees. The income and social affordability are shown in Table 8 above.

Results

This article analyses the results of a demonstration project performed at a small scale on the territory of the municipality of Gabrovo inspired and supported by one of the authors. At ten waste collection points in the city, state-of-the-art equipment was installed to measure the quantity of waste disposed of by individual households (more than 300 households agreed to participate). The data was stored in tailor-made software, providing feedback and motivation through a competition that awarded devoted participants. The obtained data from the two demonstration stages (without and with separate collection at source) were used for comparative analysis and forecasts on possible future implementation of pay-as-you-throw schemes.

As a result of the analysis of the *data received by the project IT system (SWAM IT system, 2023)*, conclusions can be drawn in two main directions:

Attitude to participate in pay-as-you-throw schemes: 34% of registered households did not participate in the demonstration (did not use the specialised containers even once), 42% of registered households showed low/medium activity (used the containers on average up to 6 times per month) and only 24% participated actively (used the containers on average more than 6 times per month). It is assumed that in the presence of a strong communication campaign and real opportunities to reduce the household waste fee, this percentage will increase significantly;

Potential to reduce the amount of generated residual municipal waste: If we compare the amounts of residual municipal waste generated by all registered households in the first and second phases of the demonstration, we get a reduction of 47%, which is rather unrealistic. Therefore, we compare the accumulation rate for the two phases, based on data from only the "active" households (expert assessment of the most reliable data for the purposes of the analysis), and obtain a more realistic reduction of 30%. It is interesting to compare the accumulation rate from the second phase (again based on data on "active" households) with the accumulation rate (without separately collected waste) from the most recent morphology of 2019 (Ministry of Environment and Water, 2019). The resulting reduction of 23% gives an idea of the potential to reduce the generation of residual household waste per capita, with active participation in a future scheme organised by the municipality. This is possible through a strong communication campaign and real opportunities to reduce the household waste fee.

The feedback received from the project team does not contain specific data, but it also provides important information and a basis for qualitative analysis of the demonstration. In practice, it is confirmed that the introduction of the "pay-as-you-throw" scheme should start with a large-scale and long-term explanatory campaign for households, test introduction and phased coverage of the territory of each municipality. Another key lesson learnt is the need for good cooperation of all stakeholders. Of course, introducing such schemes will also require strengthening control and sanctions for non-compliance with the rules of the introduced scheme, strengthening control and sanctions for illegal disposal, and positive measures such as incentives for conscientious users.

It is recommended that Bulgarian municipalities start a phased introduction of a basic model of the "pay-as-you-throw" scheme, which provides for the measurement of only residual household waste according to the volume of waste generated.

It is proposed to introduce a different model for the collection of household waste in the different municipal areas, defined in the Ministry of Environment and Water document "Methodology for determining the morphological composition of household waste" of 2012 (Ministry of Environment and Water, 2012), for the area "single-family houses" and the area "blocks of flats". Unfortunately, the lack of field data does not allow differentiated consideration of the two types of areas, but it is generally known that for areas with prevailing single-family houses, it is more appropriate to introduce a model based on the frequency of waste collection. Finding an appropriate way to collect field data from such municipal areas is advisable.

Last but not least, it is important to carefully analyse the propensity to generate waste of households and economic entities that generate municipal waste and to decide on how to fairly define the fixed and variable parts of the fee for both groups of users. Based on available data and information, the model only calculates average values of the two components for active and inactive players.

The analysis uses averaged indicators, but in reality, the share of households in the revenues from the household waste fee for cities of the size of Gabrovo is below 10% (according to data from the National Waste Management Plan 2021-2028 (Ministry of Environment and Water, 2021)). The main revenue from waste fees comes from economic entities. It is time to put an end to this cross-subsidy practice and finally start to apply economic instruments to meet the waste targets. This requires difficult and unpopular decisions at the municipal level, but the process must be launched. A possible solution is to provide a phased coverage of all waste management costs through municipal waste fees.

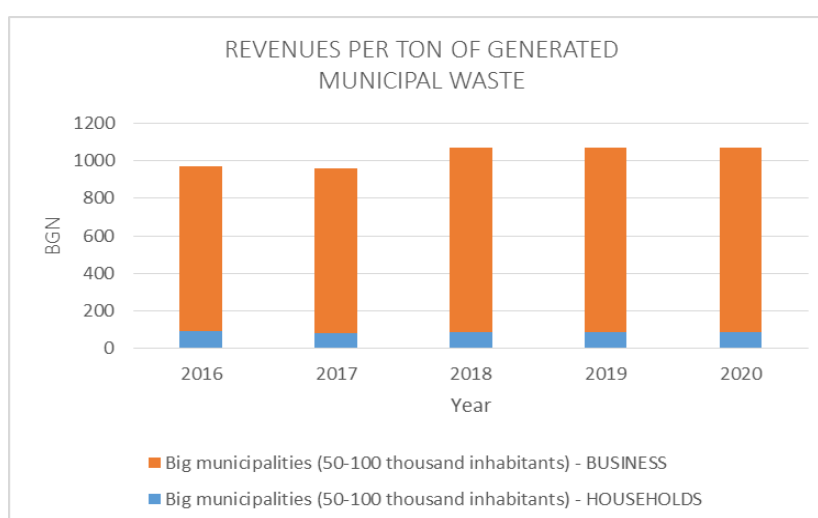


Figure 9. Revenues per ton of generated municipal waste in big municipalities
Source: National Waste Management Plan 2021-2028.

At first glance, the results of the model outline a more pessimistic scenario regarding the achievement of landfill and recycling targets compared to forecasts in the municipal waste management programme. However, the analysis steps on “field” data and, based on the modest experience and scale of the demonstration, reaches some interesting conclusions and may support Bulgarian municipalities in the process of introducing economic incentives to apply the waste hierarchy and “polluter pays” principle.

Conclusions

The article examines the possibilities for reducing waste through the application of the polluter pays principle. Not only the environmental consequences of the application of this model — especially in relation to strengthening the circular economy — but also its social dimensions are analysed. The authors emphasise the need for a preliminary assessment of the social sustainability of the model before it is implemented in real conditions. In this context, the study demonstrates the possibilities for applying the model in a medium-sized Bulgarian city's specific social and institutional environment. The results obtained have both theoretical value and practical applicability for decision-makers in sustainable waste management.

The study contributes to expanding knowledge in the field by empirically confirming the model's applicability based on the polluter pays principle in the context of municipal waste management. In addition, the article proposes an analytical framework that should be used to assess the conditions for its implementation. This framework includes an analysis of the socio-economic characteristics, institutional capacity and public perception of the model. Thus, the study provides a practically applicable methodological tool for municipalities planning to introduce such an approach.

The analysis in the article is based on the results of a demonstration project implemented on a limited scale in the municipality of Gabrovo, Bulgaria. Therefore, the data obtained are most applicable to cities of similar size and characteristics within the country. The application of the same model in significantly larger or smaller settlements and regions with different institutional and social contexts requires further adaptation and validation of the approach according to local conditions.

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