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Assessing a Pilot Door-to-Door Municipal Collection Program in Greece: Implementation Insights and Evaluation Outcomes

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Door-to-door collection is the most effective method to meet the objectives of the EU's new circular action plan. In line with the Directives (EU) 2018/851 and 2018/852, several municipalities in Greece are transitioning from the conventional kerbside system to door-to-door collection. In the municipality of Rafina-Pikermi, a pilot scheme for the collection of Municipal Solid Waste (MSW) was implemented and operated for a nine-month period to separate waste into recyclables and biowaste. This study aimed to assess the effectiveness of door-to-door waste collection in terms of purity, contamination levels, and resident satisfaction, involving 154 households and 528 residents. The analysis is based on data collected during the pilot program and includes results from waste sampling and transport to two facilities: a Materials Recovery Facility and a Mechanical Biological Treatment plant. Collection occurred five days a week, excluding weekends, and waste was sorted using barcodes into two categories based on the color of the bag (brown for biowaste and blue for recyclables). Each bag was weighed at the transport vehicle and analyzed at the recovery and biological treatment facilities to determine the percentage of impurities in the total weight and to separate it into various waste fractions. The results show that the purity levels for recycling waste from source separation of biowaste and recyclables are approximately 98% and 93%, respectively. Finally, an analysis of questionnaire data collected from participating households indicated that they rated the overall experience as satisfactory and provided feedback on general operational issues that could be improved. In conclusion, the current study proves that the development of source separation schemes is essential to achieving the goals set by the EU.

Keywords: door-to-door collection, solid waste, biowaste, recyclables.

Introduction

The European Union (EU), under Directives 2018/851 and 2018/852, promotes separate waste collection using the door-to-door approach. Separate waste collection has proven to be the most efficient method for obtaining high-quality recyclable materials (Di Maria et al., 2020; Laurieri et al., 2020), as it enables the collection of certain types of waste without compromising the final product's quality. This is a critical success factor for the circular economy, sustainable development (Degli Esposti et al., 2021), and reducing landfill burden (Ramachandra et al., 2018). Additionally, EU legislation sets quantitative targets for packaging reuse and recycling. Specifically, under the European Commission's Packaging and Packaging Waste Directive, at least 65% of all packaging waste must be recycled by December 31, 2025, and at least 70% by December 31, 2030.

The MSW generation in Greece is 525 kg per capita, higher than the EU-28 average of 505 kg per capita (Eurostat, 2020). The average composition of MSW in Greece is 44.3% organics, 22.2% paper, 13.9% plastics, 4.3% glass, 3.9% metal, and 11.4% other materials (ESDA, 2020). For recyclable materials, the average composition is 23.13% paper/cardboard, 45.59% plastics, 12.25% glass, 11.36% metal, 6.77% wood, and 0.9% other materials. Additionally, in Greece, biowaste for door-to-door collection is around 5.7% (ESDA, 2020).

In Greece, waste collection across 332 municipalities has traditionally been achieved using 1,100 L bins over two decades. Typically, one green or gray bin is for mixed waste, and a blue bin is for recyclables. Mixed waste ends up in sanitary landfills, while recyclable materials are transported to Materials Recovery Facilities (MRFs) for sorting by material (e.g., glass, plastic). The impurities, or reject fractions, are then diverted to sanitary landfills. Under this system, Greece achieves a 21% recycling rate (Eurostat, 2019). Recently, 37 out of 66 municipalities in the region of Attica are attempting the transition to the kerbside method for biowaste collection (PESDA, 2022), by installing brown bins with a total capacity of either 1100 L or 240 L, where material is disposed of either in bulk or within plastic bags. These bins are placed at central locations where bins for mixed waste and recyclables already exist. However, residents often dispose of mixed MSW in the brown bins without sorting at home, leading to impurities in biodegradable waste and causing additional problems in waste management.

These issues include increased costs in the overall process (Ruggieri et al., 2008; Rossi et al., 2022). Moreover, the need for more expensive biowaste pretreatment, loss of processing capacity, and difficulty in selling treated biowaste as compost due to its low quality have been reported (Puig-Ventosa et al., 2013). Studies highlight the central importance of door-to-door biowaste collection as the most effective method for improving urban waste management (Abeshev and Koppenborg, 2023).

Regarding recyclable materials management, the blue bins network is part of a co-mingled packaging waste system, including other material fractions such as metals, paper, cardboard, plastics, aluminum, and glass. This system is supported by the Hellenic Recovery Recycling Corporation's waste recycling system, licensed by the Hellenic Recycling Agency, and began in 2003 (HERRCO, 2023). In 2019, the recovery rate for recyclable materials in the blue bins was 47.45% (PESDA, 2022). Currently, the percentage of recyclable materials in Greece remains approximately the same, falling short of meeting the EU targets set by Directive 2018/852, which mandates a 42.98% recycling rate by December 31, 2025. According to Chachami-Chalioti et al. (2024), Greece should re-evaluate its time-related goals of the MSW policies. Thus, adopting biowaste collection practices and expanding recycled content targets are among Greece's current waste management goals.

Regarding the literature review on the situation in other Greek municipalities, Karkanias et al. (2012) analyzed rational schemes concerning waste management in the context of best practice applications in the municipality of Preveza. Further Karkanias et al. (2014) evaluated recycling potential in the municipality of Neapoli-Sykies in central Macedonia, setting more strongly bases on the applicability of approaches on local scales, and, finally, Karkanias et al. (2016) assessed home composting programmes as an alternative for sustainable management of household biodegradable waste. Recently, Calabrò and Komilis (2019) evaluated waste collection systems in Reggio, Calabria,

finding that door-to-door collection enhances recycling awareness and citizen satisfaction, making it a superior alternative to kerbside collection. From the same group, Tsalis et al. (2018) presented the willingness of the residents of Xanthi in the region of Thrace to participate in a door-to-door recyclable waste collection, while Chachami-Chalioti et al. (2024) assessed public opinion regarding MSW management in 5 municipalities of Thessaloniki Regional Area in Northern Greece. All these studies widely look at waste management strategies and allow comparison of door-to-door programmes with other similar initiatives in Greece and highlight the potential of door-to-door collection as an effective strategy for improving waste management in Greece, provided that it is implemented with careful consideration of efficiency, community engagement, sustainability criteria, and local adaptability.

In the municipality of Rafina-Pikermi, which has a population of around 20,266 residents (EDSNA, 2018), the average impurity from blue bins between 2015 and 2019 was approximately 52.83% (corresponding to 512.27 t), while recyclable materials amounted to 452.06 t, corresponding to an annual quantity of 22.31 kg of recyclable materials (i.e., metal, paper, cardboard, plastic, aluminum, and glass) per capita and a recycling rate of 16.3%. Rafina-Pikermi ranks as one of the best performing municipalities in recycling rate in the Attica region, with Dionisos (24.7%) and Voula-Vari–Vouliagmeni (17.7%) leading (EDSNA, 2018).

Under this socio-economic perspective, in 2020, the Rafina-Pikermi municipality developed and implemented a pilot recycling program titled "Waste sorting at the source, a Sustainable Future.". The pilot program aimed at increasing the collection rates and purity level of recyclables and biowaste. The pilot program included an analysis of impurities and recyclable materials in blue and brown bins.

The underlying concept of the present study is that the targets of the local MSW management plan of Rafina-Pikermi (2021a) can be achieved through door-to-door collection. The door-to-door practice contributes to reducing waste management costs, improving service quality, raising citizen awareness on waste prevention and management, and increasing local job/business opportunities. This manuscript aims to present the implementation of the pilot study for door-to-door waste collection evaluated in two ways: (a) by showing the qualitative characteristics of biowaste and recyclable materials, and (b) by examining the program's implementation practices for delivering higher-quality waste collection services at the municipal level (Bel and Sebo, 2020). Assessing the effectiveness of MSW management programs is crucial for increasing general recycling efficiency (Stoeva and Alriksson, 2017) and obtaining important information about the efficiency of municipal services (Cervantes et al., 2018). The results are based on the pilot program conducted by the municipality of Rafina-Pikermi over a nine-month period from the beginning of November 2020 to the end of August 2021, with the evaluation performed directly by the participating volunteers.

This article contributes significant added value to the field of municipal waste management by presenting a comprehensive evaluation of a pilot door-to-door collection program. By detailing the implementation scheme and providing robust data on collection amounts and characteristics, this study offers valuable insights into the practical aspects of program execution. Furthermore, the focus on participant feedback enriches the understanding of community engagement and acceptance, highlighting the critical role of citizen involvement in the success of municipal initiatives. The novelty of the approach lies in the fact that it is a long-lasting door-to-door intervention that focuses on key waste streams (recyclables and biowaste) of European policy. The intervention was conducted with the full support of professional staff for the volunteers. At the end of the intervention, the volunteers assessed its efficiency and highlighted its strong and weak instances. The findings and methodologies outlined in this manuscript serve as a valuable resource for policymakers, urban planners, and environmental managers aiming to design, implement, and refine effective waste collection strategies in diverse urban settings.

Methods

The pilot scheme took place in the Nereus–Proteus sector of Rafina-Pikermi Municipality. It involved 154 households, corresponding to 528 residents, representing approximately 4.3% of the municipality's population. Participation was voluntary, with households living in single-family houses or small apartment buildings. The pilot lasted approximately nine months

(from 10/11/2020 to 31/08/2021). The methodology aimed to avoid disrupting residents' daily lives and is planned to be extended to cover the entire municipality.

The door-to-door collection process included: (i) weighing each material bag for each barcode (brown and blue) and transporting the blue bags to the MRF plant of Aspropyrgos; (ii) transporting the brown bags to the Mechanical Biological Treatment (MBT) plant (Prasino EMA) in the Ano Liosia area; (iii) conducting sampling by a research team before waste sorting; (iv) measuring resident volunteer satisfaction through questionnaires; and (v) performing statistical analysis and interpretation of data.

Two important waste fractions were included in the MSW collection pilot programme in Rafina-Pikermi: i) packaging recyclables (cardboard, paper, plastic, metals, glass, etc.) were collected in the blue bin, and ii) biowaste (primarily fruits, vegetables, leftover cooked food without bones, and used kitchen papers) was collected in the brown bin. Participating households received small bins of 10L and 50L capacity and bags for sorting household biowaste and recyclable materials and placing them inside the bins. The bins were placed in the residences of volunteers, and larger bins of 120L and 240L were installed in the open spaces of the houses. Some bins were locked because locked bins ensure secure closure and deter unauthorized access to the container (Zoumpoulis et al., 2024). Barcodes on each bag allowed tracking the exact origin of the material, matching the residence with the quantity of materials in each bag.

Materials were initially placed in small bins (10L and 50L) and then transferred to larger ones (120L and 240L), from where they were collected by a designated vehicle five days per week and transported to the MRF plant of Aspropyrgos for the recyclables and the MBT plant (Prasino EMA) for the biowaste. On weekends, bags were stored in large bins, as studies have shown that using bins of 120L and 240L improves the ergonomic level of waste collection (Degli Esposti et al., 2023). These were collected on the first working day of the week (Monday).

Every day, the content of each bag (initial samples) and the different fractions (sorted samples) were weighed. Moreover, the analyses conducted included measuring the percentage of impurities in the total weight of the bag load and separating materials into several waste fractions. The materials analyzed in the recyclable fraction included plastics (hard and films), paper/cardboard, metals (aluminum and tin), and glass, Similarly, the biowaste fraction was analysed for plastics, metals (aluminum and tin), and glass/inert materials.

Questionnaire design

This survey aimed to record volunteers' satisfaction with the pilot program of door-to-door waste collection. Voluntary households (154 households, corresponding to 528 residents) responded through questionnaires. The questionnaire is presented in *Tables A1-A2* in the appendix, and it is structured in three groups, as follows: (i) Group A: general questions about the implementation of the action; (ii) Group B: questions about separate collection and the equipment involved; and (iii) Group C: questions about communication satisfaction.

The survey questions were closed-ended, limiting respondents' answers to a fixed set of responses. Closed-ended questions are easier to answer and do not require a minimal level of education or language fluency (Ruane, 2015). The methods to reach the volunteers included face-to-face interviews and email questions. Face-to-face interviews were conducted with respondents over 60 years of age due to barriers to using technology, while those familiar with technology could participate using digital forms of the questionnaires.

Results and Discussion

Recovery rates per material

The waste composition analyses for the recyclable materials were conducted at the facilities of the MRF plant of Aspropyrgos. This plant focuses on materials with significant commercial value, such as plastics (divided into hard, and film-type plastics), paper/cardboard, metals, and glass.

The pilot program in Rafina-Pikermi for the recovery of recyclable materials using blue bags over a nine-month period resulted in a total recovery rate of 93.11%, amounting to 7834.10 kg from 528 residents (14.8 kg/capita, impurities not included). Notably, the recovery rates for plastics (28.34%), paper/cardboard (36.51%), metal (14.69%), and glass (13.57%) were significantly higher compared to the baseline data from the local

Table 1. *Average Recovery of recyclable materials among municipalities in the Attica region*

Municipalities of Attica with the best recycling rate[1]	Percentage (%) recycling rate[1]	Average recovery of recyclable (MRF) materials per resident[1] (kg/capita)	Average recovery (%) of all types of recyclable materials in the blue bag[2]
Dionysos	24.7	31.3	14.84
Voula-Vari-Vouliagmeni	17.7	33.02	
Filothei - Psychiko	17.6	37.32	
Rafina-Pikermi	16.3	20.97	
Penteli	14.5	26.48	
Papagos Cholargos	14.4	26.35	
Kropia	14.0	30.96	
Glyfada	13.6	30.76	
Pallini	12.6	26.22	
Chalandri	12.2	30.87	
Range of Attica with the best recycling	12.2–24.7	–	
Average production per resident	–	29.43	

[1] *EDSNA (2018);* [2] *Door-to-door pilot program, present research (2021b): 9 months, 528 Residents.*

MSW management plan of 2021, which included 20,266 residents (see *Table 2*). The baseline data indicated lower recovery rates for plastics (13%), metals (3.3%), and glass (3.4%), with paper/cardboard recovery being the highest at 28.1%. The total amount collected in the baseline period was 6,912,001.51 kg with an impurity rate of 58%, compared to the pilot program's 6.89% impurity rate (579.48 kg).

As shown in *Table 1*, there is a high variability in the average recovery of recyclable materials among municipalities. More particularly, the municipality of Dionysos presents the best recycling rate (24.7%), while Chalandri the least (12.2%). Finally, considering the available information (EDSNA, 2018) for the case of Rafina-Pikermi, recovery rates are above the average value provided as an indicator for the Attica Region.

Table 2. *Recovery of recyclable materials by type in the blue bag*

Recovery of recyclable materials by type in the blue bag[1]			Composition of recyclable materials by type MSW[2]		Recovery of recyclable materials by type blue bins[3]	
Material	Recovery rate	kg	Recovery rate	kg	Recovery rate	kg
Plastics (hard –and films)	28.34%	2384.78	13.0%	1,880,000.24	–	480,000.95
Paper / Cardboard	36.51%	3071.51	28.1%	4,064,000.22		
Metal	14.69%	1236.19	3.3%	477,000.29		
Glass	13.57%	1141.62	3.4%	491,000.76		
Total recovery	93.11%	7834.10	-	-	-	480,000.95
Impurities	6.89%	579.48	-	-	58%	664,000.20
Total amount collected	–	8413.85	-	6,912,001.51	-	1,145,000.15

[1]*Door-to-door pilot program, present research, 2021b): 9 months, 528 Residents;* [2]*Local MSW Management Plan of Municipality of Rafina-Pikermi, (2021a);* [3]*Local MSW Management Plan of Municipality of Rafina-Pikermi, (2021a), 20,266 residents.*

Because of its proximity to the Athens metropolitan area, the municipality of Rafina-Pikermi sees a surge in the number of seasonal residents and visitors from early May to late September. Therefore, the increased number of seasonal residents increases the total quantities of recyclables collected during the summer period. On the other hand, the pilot door-to-door program reported in the current manuscript is based on permanent residents. Therefore, the results of our sample do not show seasonal variation.

These results suggest that the door-to-door collection system is more effective in reducing impurities and increasing the recovery rates of recyclable materials, particularly plastics, metal, and glass. This comparison underscores the effectiveness of the pilot program and highlights the potential benefits of scaling this approach to improve overall waste management efficiency in the municipality. *Table 2* summarizes the recovery rate per material.

The local MSW management plan of the municipality of Rafina-Pikermi for the year 2021 involves systematic sampling of MSW. However, no standardized, universally accepted waste characterization protocol has been developed in Greece. According to FEK 4732/27-07-2023 (FEK, 2023), the government announced a waste characterization protocol for MBT/MRFs, which had not existed until now. Therefore, in this study, a generic and easy-to-apply MSW sampling and sorting protocol is developed and compared with the one used in the local waste management plan of the municipality of Rafina-Pikermi for the year 2021.

Regarding material composition, further comparison with other available quantities is of interest. Based on average values from three towns in Poland (specifically in the towns of Liszki, Skawina, and Zabierzów), there is an increased rate of metal and glass (56.8%), followed by plastics (19.63%), and paper/cardboard (13.2%). The average impurities in the door-to-door collection of these three towns are 10.37% (Łukasiewicz et al., 2018). Other available studies in Greece, specifically for the door-to-door collection in the municipality of Chalandri, show that apart from the quantity of biodegradables, the average values for recyclable materials are approximately: 12% plastics, 20% paper/cardboard, 3% metal, 7% glass, and 19% impurities (Mathioudakis et al., 2021).

In Mexico City, between September and October 2022, recyclable household waste generation was evaluated

by engaging waste collectors, including door-to-door individuals. The results of this study indicate that, in over seven weeks, household waste comprised up to 35% cardboard, 44% plastics, 17% glass, and 4% aluminum (Shruti et al., 2023). Additionally, a study on door-to-door collection in rural areas of Portugal showed that the average values for recyclable materials increased by around 30%. Specifically, there was a 35% increase in plastics/metal, 31% in paper/cardboard, 30% in glass, and a 21% decrease in residual waste (Vaz et al., 2019). A waste characterization was conducted at the University of Jordan during the academic year 2016/2017 which consisted of 60 buildings and over 40,000 students. The results of this case study show that at least 87% of selected waste can be recycled. Plastics make up the largest percentage (25.74%), followed by paper and cardboard (20.36%), while glass (5.77%) and metal (4.04%) make up the smallest percentages (Moqbel, 2018). Finally, data from door-to-door collection in Chile show an increased percentage for glass (51.7%), followed by paper/cardboard (21.7%), with much lower percentages for plastics (6.7%) and metal (1.5%) (Valenzuela-Levi, 2021).

The composition analyses for the biowaste collected in the brown bags were conducted at the facilities of the MBT plant of Ano Liosia (Prasino EMA). A total quantity of 12,360.34 kg of biowaste from 528 residents were collected (23.4 kg/capita) with 97.83% purity (see *Table 3*). As observed, in the composition analysis presented in *Table 3*, there were no significant quantities of recyclable materials in the biowaste, including the residue. The recovered quantity of biowaste was processed in the production line to produce high-quality soil conditioner. The results of the pilot program in Rafina-Pikermi for the recovery of recyclable materials using brown bags over a nine-month period show a recovery rate of 0.37%, totaling 45.51 kg of materials (plastics, metal, and glass/inert materials) from 528 residents. In comparison, the baseline data from the local MSW management plan of the municipality of Rafina-Pikermi for the year 2021, which involved 20,266 residents, did not provide specific recovery rates for these materials. However, the total amount collected for recyclables was 43.6%, equivalent to 6,306,000.04 kg, suggesting a substantial collection effort in a larger population. Despite the high impurity rate of 2.17% (268.02 kg) observed in the pilot program, the targeted recovery of specific materials like plastics, metal, and

Table 3. *Recovery of recyclable materials by type in the brown bag*

Recovery of recyclable materials by type in the brown bins[1]			Composition of recyclable materials by type MSW[2]		Recovery of recyclable materials by type brown bins[3]	
Material	Recovery rate	kg	Recovery rate	kg	Recovery rate	kg
Plastics	0.30%	36.67	-	-	-	-
Metal	0.05%	6.35	-	-	-	-
Glass - inert materials	0.02%	2.49	-	-	-	-
Total recovery	0.37%	45.51	-	-	-	-
Impurities	2.17%	268.02	-	-	-	-
Total amount collected	-	12,360.34	43.6%	6,306,000.04	-	2,208,000.86

[1] *Door-to-door pilot program, present research, 2021b): 9 months, 528 Residents;* [2] *Local MSW Management Plan of Municipality of Rafina-Pikermi (2021a);* [3] *Local MSW Management Plan of Municipality of Rafina-Pikermi (2021a), 20,266 residents.*

glass indicates potential areas for improvement and higher efficiency in future waste management practices. Comparing these figures highlights the need for continued optimization and scaling of the door-to-door collection system to achieve higher purity and recovery rates, aligning with the broader objectives of the EU's circular action plan.

The pilot program has shown significant results since its inception. The first and most important feature is the simplicity of its implementation. Additionally, the quality of the recyclable materials and the percentage without impurities are noteworthy. According to daily analyses of all bags from both fractions collected, they average 93% without impurities for recyclables and 98% for biowaste. For the impurities in the brown bin, we can compare it with the town of Milan, which shows a low level of impurities around 5% (Favoino et al., 2020). Another study in Greece, in the municipality of Chalandri, reports that brown bins have less than 1% impurities (Mathioudakis et al., 2021). Biodegradable bags are used in the separate collection method of municipal waste in Milan, Italy, and the Greek municipalities of Chalandri and Rafina-Pikermi in order to attain the lowest average levels of impurities (Puig-Ventosa et al., 2013). Another study found that door-to-door biowaste collection in the Barcelona Metropolitan Area reduced impurities from 11.3% to 2.9% (Meisterl et al., 2024). The actual percentage of 2.17% achieved for impurities (see *Table 3*) indicates that the biowaste collected in the pilot door-to-door program has excellent quality. Literature reports that when impurities exceed 10% in biowaste, valorization is hardly feasible, as impurities degrade the value of the produced soil improvers (Dubois et al., 2020; Huerta et al., 2008).

Pilot program evaluation by the participants

Questionnaires using both methods (face-to-face interviews and email questions) were conducted to reach the target respondents and subsequently analyzed, as detailed in this paragraph. *Table 4* presents the demographics of the sample volunteers. As shown, most participants are highly educated; women; more than

Table 4. *Demographics of the sample*

Gender			
Male	40.3%	Female	59.7%
Age			
18–30	2.6%	51–60	34.4%
31–40	17.5%	>61	26.6%
41–50	18.8%	-	-
Education			
None or primary school	0.0%	University (BSc)	48.1%
Secondary	6.5%	MSc/PhD	24.0%
High	21.4%	-	-
Number of household members			
0	9.1%	3	20.8%
1	22.1%	4	19.5%
2	22.7%	>4	5.8%
Residence status			
Rent	26.6%	Vacation rental	2.6%
Home owner-ship	70.8%	-	-
Number of apartments per building			
2	10.4%	>4	44.2%
3	21.4%	single-family	10.4%
4	13.6%	-	-

Fig. 1. *Results on Q7: Did the door-to-door waste collection method of the two streams (biowaste and recyclable materials) make it easier for you in the way you operate your daily life?*
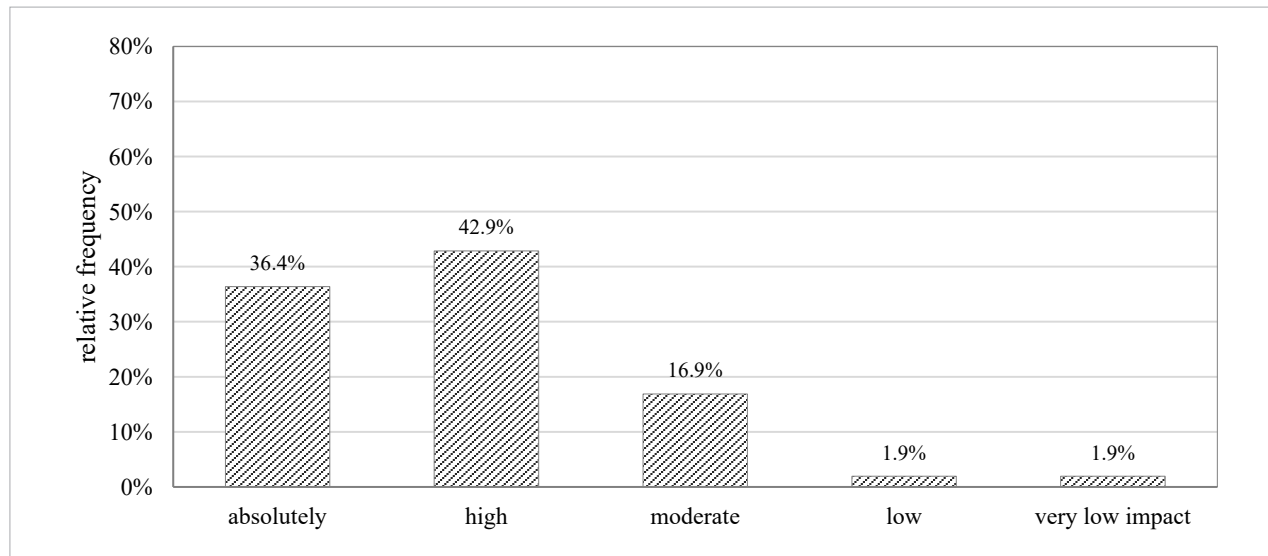
half of the participants are over 50 years old. Additional information recorded includes the number of household members, with the frequency of each class being around 20%. Finally, most respondents own their residences and live in apartment buildings.

The first group of questions examines the general framework for the implementation of the action per household. For instance, the first question (*Table A2*, Q7; *Fig. 1*) assesses the extent to which the program facilitated citizens' everyday lives (rated from 5 = absolutely to 1 = very low impact), where volunteers generally expressed satisfaction. It is evident from *Fig. 1* that over 80% of the participants are satisfied with the door-to-door collection scheme compared to the kerbside collection. This result agrees with the one reported for the city of Reggio in Italy by Calabro and Komilis (2019) and the city of Xanthi in Greece (Tsalis et al., 2018).

The following questions address difficulties encountered during program implementation. Regarding difficulties inside the residence, almost 57% of participating homes did not experience any problems. Among the issues mentioned, the small capacity of the bags provided was the main complaint (17.5%). Additional complaints included odors, spills, and disapproval of the bins being locked. Among the difficulties outside the residence, 76% of respondents reported no problems. Very few respondents cited issues such as neighbors'

refusal to install a bin in shared external spaces (13%) and lack of sufficient space for the bins (5.8%). Other issues reported by the participants include the arbitrary depositing of recyclable materials outside the bins and the non-cleaning of the collection site by the management operator.

In the next set of questions (*Table A2*, Group B; *Fig. 2*), respondents were asked about the provision of collection services and equipment, with around 95% of participants expressing satisfaction with the collection of biowaste during morning hours on working days. Regarding the use of bins and bags (Q13; *Fig. 2*), most participants (~65%) preferred either small or large bins, while small bags were the least preferred option. Finally, 77.3% of the participants preferred the bins to be locked (Q15), with some suggesting minor improvements in the locking mechanism. From this result, it is evident that citizens realize that locked bins ensure secure closure and offer better control of the collected materials, as reported in the literature (Zoumpoulis et al., 2024).

The last set of questions (*Fig. 3*) focused on the evaluation of communication with both the biowaste collection staff (Q16) and with the organization implementing the action, i.e., the administrative staff of the municipality (Q17). As shown, almost all citizens were satisfied with the collection staff, with around 86% rating the communication as excellent or very good. Regarding

Fig. 2. *(a) Q11: Would you prefer the waste collection to take place on weekends as well?, (b) Q12: How many days per week would you prefer the waste collection to take place?, (c) Q13: Concerning the equipment used for the collection, which one made it easier for you?, (d) Q14: Concerning the equipment used for the collection, is there any that did not facilitate you?*
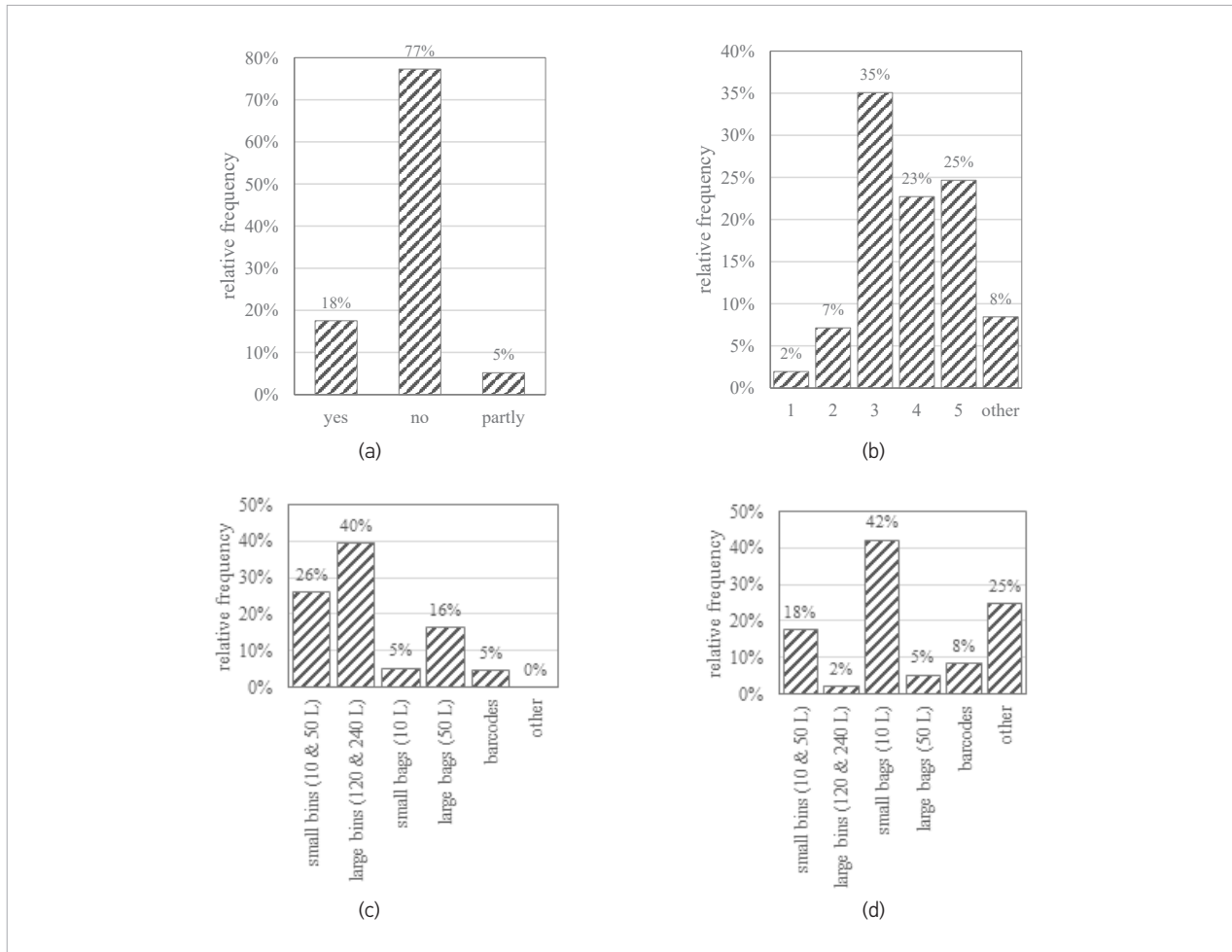

Fig. 3. *Findings from the assessment of communication with the municipality's administrative staff [Q17] and biowaste collection staff [Q16]*
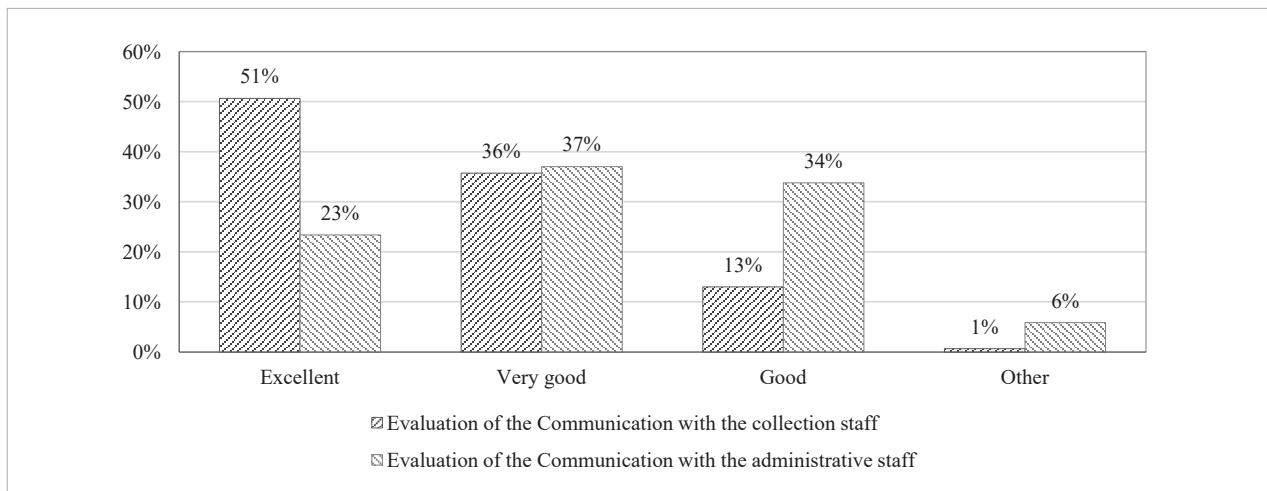
Fig. 4. *Results on Q19, Q21, Q22, and Q23 (Table A2; Group C)*
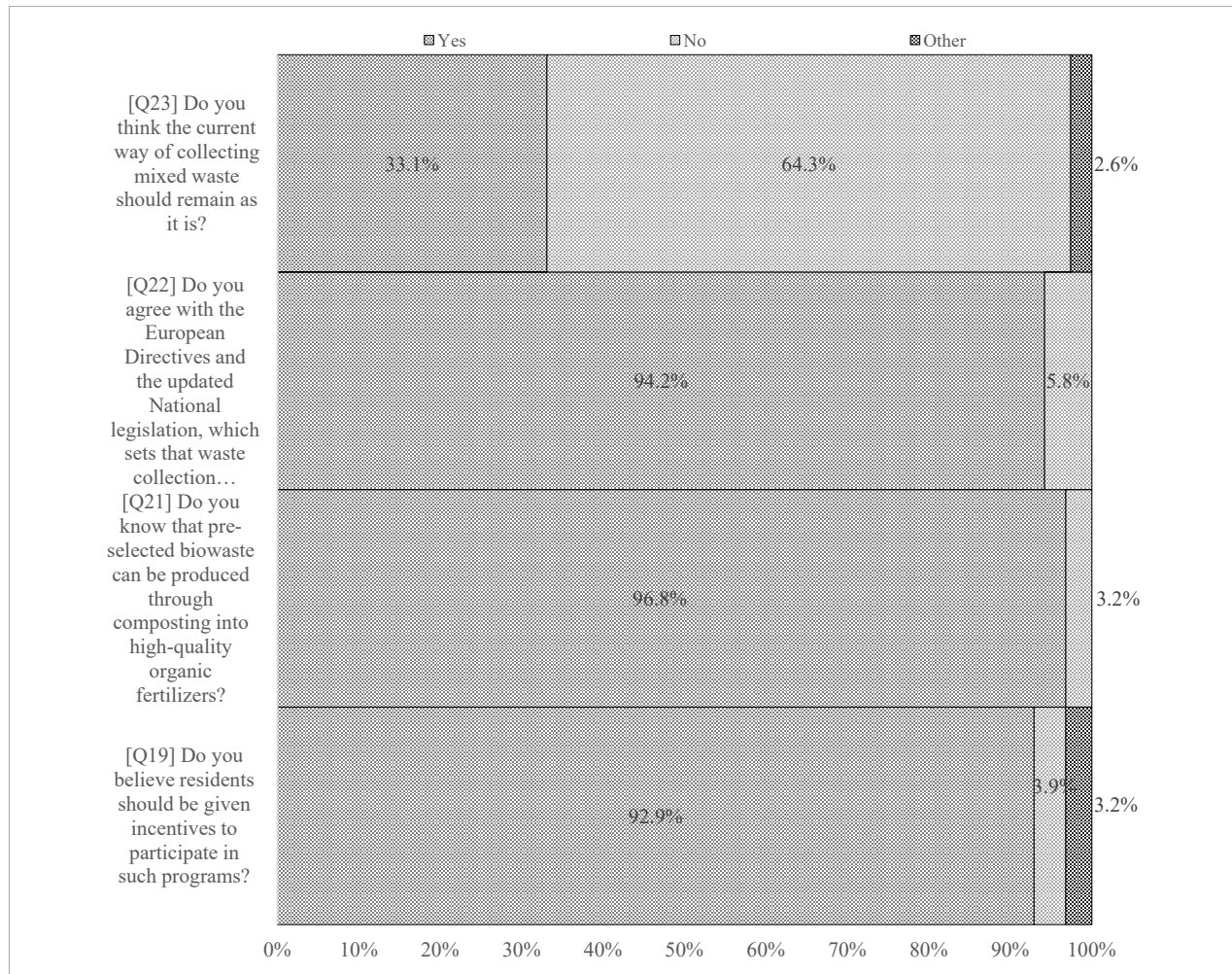
communication with the municipality, the level of satisfaction was lower (see *Fig. 3*) since several difficulties in communication with the organization were reported. These results indicate that proper communication with the citizens is crucial for the success of the door-to-door collection program.

68.8% of respondents cited recycling awareness as the most important factor when asked about their reasons for joining the program (see *Fig. 5*), followed by any incentives offered by the municipality. Only 4.5% cited the implementation of EU directives as a reason for participation (see *Fig. 5*), and the results were not generally related to the age of participants.

When asked if they consider it appropriate to incentivize residents to participate in such programs, almost 93% of respondents answered positively. This finding agrees with

a similar question originating from the city of Preveza in Greece (Karkanias, 2012). Additionally, they were invited to evaluate the information regarding EU Directives and updated national legislation on recycling and waste collection. Fifty percent reported "excellent" or "very good" on the information acquired about the relevant European Directives and the new national legislation, thirty-seven percent reported "good" information, and the remaining percentage reported "bad" or "absent" information (see *Fig. 6*). These findings suggest that the participants' level of knowledge has grown. Karkanias et al. (2016) have stressed the importance of building up knowledge and its significant contribution in promoting sustainable waste management schemes.

Two questions followed: (a) the participants' knowledge on the fact that pre-selected biowaste can be transformed

through composting into high-quality organic fertilizers (Q21), and (b) their opinion on EU Directives and the updated national legislation, which mandate that waste collection should be performed by source sorting in each residence (Q22), as applied in this pilot program. 97% of the citizens who participated in the questionnaires stated that pre-selected biowaste could be transformed into high-quality organic fertilizers through composting.

Additionally, around 94% agreed with the European Directives and national legislation recommending the source sorting method. Finally, only 33.1% of the participants (51 out of 154) believed that the current way of collecting mixed waste (in 1100L bins) was preferred (Q23), mainly to avoid odors inside the residence (43.8%) and the frequency of collection (29.2%), and other practical reasons as shown in *Fig. 7* (Q24).

Fig. 5. *Results on Q18: Which fact led you to participate in the program?*
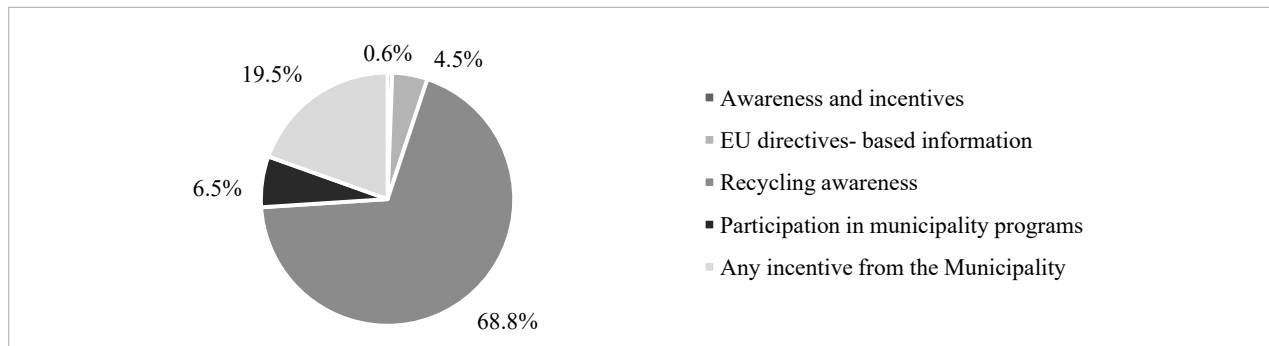

Fig. 6. *Results on Q20: How do you rate the information you acquired about the relevant European Directives and the new national legislation on recycling and waste collection?*
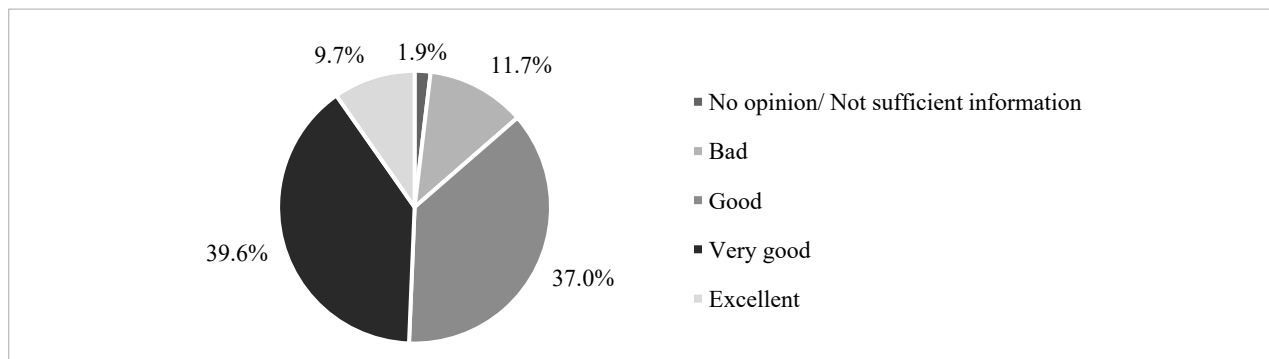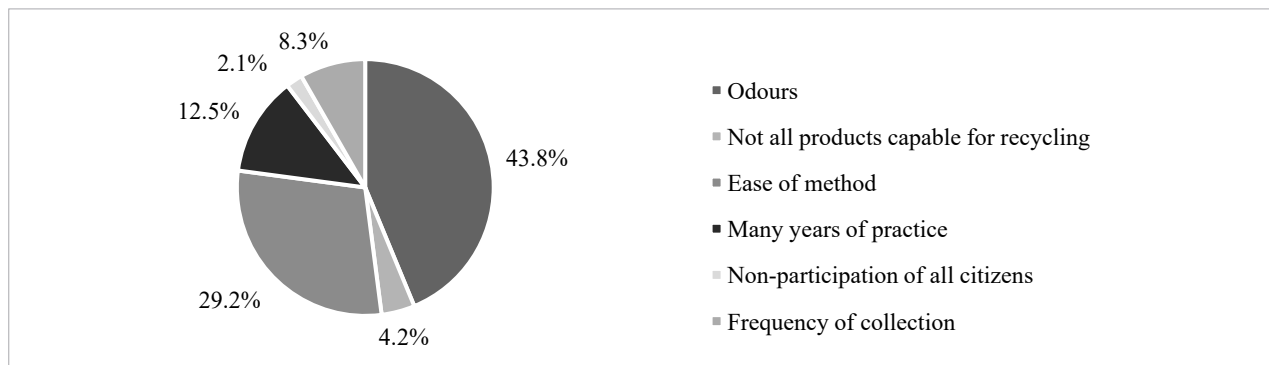

Fig. 7. *Results on Q24: Why do you prefer the existing waste collection method to remain?*

Conclusions

There is an urgent need for Greece to increase the diversion of recyclables and biowaste from the sanitary landfills to achieve the mandated EU targets. Towards this goal, the door-to-door collection scheme is examined as a promising alternative to the current kerbside collection. A simple pilot door-to-door program has been implemented for a period of nine months with the voluntary participation of 154 households for the collection of recyclables and biowaste in the municipality of Rafina-Pikermi in the Attica region of Greece.

The evaluation of the pilot program was performed in two axes. The first axis concerns the quality of the recovered materials. 23.4 kg of biowaste and 14.8 kg of recyclables per capita were collected. The analysis results indicate a very high purity level in the door-to-door collected biowaste and recyclables, corresponding to approximately 98% and 93%, respectively.

Regarding the second evaluation axis, that of public acceptance of the door-to-door collection, the majority of the participants agreed that the pilot program was introduced smoothly and didn't upset their daily routines, although they did identify a few operational problems that needed to be addressed. 60% of them did not face any problems. The participants were satisfied with the provision of the relevant infrastructure, i.e., bins and bags. Finally, proper and frequent communication with the collection staff was a positive aspect of the program that increased residents' knowledge and awareness regarding the management of biowaste and recyclables.

Overall, the study demonstrated that supporting the development of source separation schemes for the recyclables and biowaste streams is essential to achieving the goals set by the EU for all European countries. In addition to providing the necessary infrastructure, larger municipalities must engage the community and run awareness campaigns in order to scale up this strategy. It is advised that awareness campaigns be started prior to the start of door-to-door collection initiatives. In terms of management, our research demonstrated the fact that data reporting and a feedback mechanism can support the improved separation results of the waste streams in focus.

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Appendix

Table A1. *Basic information of the surveyed respondents*

General information
Q1: Gender [Male, Female]
Q2: Age [18–30, 31–40, 41–50, 51–60, >61]
Q3: Education [None or primary school, Secondary, High, University, MSc/PhD]
Q4: Number of household member [0, 1, 2, 3, 4, >4]
Q5: Residence status [Rent, Home ownership, Vacation rental]
Q6: If the residence is in an apartment building, how many apartments are there in total? [2, 3, 4, >4]

Table A2. *Respondents' personal behaviors and attitudes*

Group A: General questions for the implementation of the action per household
Q7: Did the door-to-door waste collection method of the two streams (biowaste and recyclable materials) make it easier for you in the way you operate your daily life?
Q8: What was the most significant difficulty you encountered in door-to-door collection within your residence that troubled you?
Q9: What was the most considerable difficulty faced in your participation in the implementation of the pilot program outside your residence?

Group B: Questions for the separate collection and for the equipment
Q10: Was the provision of waste collection services, which took place daily in morning hours except for weekends, convenient for you?
Q11: Would you prefer the waste collection to take place on weekends as well?
Q12: How many days per week would you prefer the waste collection to take place?
Q13: Concerning the equipment used for the collection, which one made it easier for you?
Q14: Concerning the equipment used for the collection, is there any that did not facilitate you?
Q15: Do you agree with large bins locking?

Group C: Questions regarding communication satisfaction
Q16: How do you rate your communication with the collection staff during the program's implementation period?
Q17: How do you rate your communication with the municipality's administrative staff during the program's implementation period?
Q18: Which fact led you to participate in the program?
Q19: Do you believe residents should be given incentives to participate in such programs?
Q20: How do you rate the information you acquired about the relevant European Directives and the new national legislation on recycling and waste collection?
Q21: Do you know that pre-selected biowaste can be produced through composting into high-quality organic fertilizers?
Q22: Do you agree with the European Directives and the updated national legislation, which sets that waste collection should be done by source sorting in each residence, as applied in this pilot program?
Q23: Do you think the current way of collecting mixed waste should remain as it is?
Q24: If Q23 answer is 'yes', why do you prefer the existing waste collection method to remain?