

Untapped potential in unsorted waste:

technical and scientific investigation of recyclable
materials found in unsorted municipal waste



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1. Introduction

1.1 The widespread nature of recycling and collection rates in Europe

This report presents the findings of the sampling of unsorted municipal waste carried out by Erion, with operational support from the Institute for the Protection of Wood Plants and the Environment (IPLA), and with methodological guidance from the Milan Polytechnic. The sampling was carried out between July 2024 and July 2025 with the aim of estimating the residual presence of waste streams of particular interest to the Erion System.

The poor interception of different types of waste is a growing, multifactorial critical issue in Europe's waste management system. Although European directives aim to transform waste into a resource, the reality is more complicated. According to 2022 Eurostat data, only around 50% of waste is sent for recycling or energy recovery (Eurostat, 2024). In particular, high-value waste streams such as Waste Electrical and Electronic Equipment (WEEE), portable Waste Batteries (WB) and textile waste perform particularly poorly: WEEE collection covers just 40% of the total placed on the market, while the figures are even lower at 25%¹ and 13%² respectively for batteries and textiles. Therefore, the presence of this waste in the unsorted waste stream indicates ineffective awareness-raising, infrastructure and collection strategies, and represents significant environmental and economic losses. These deficits have significant environmental and social impacts. These include the loss of essential raw materials, contamination by toxic substances, the additional cost of treating unsorted waste, and widespread reliance on landfills and incinerators (European Environment Agency, 2025).

The reasons for low interception rates are complex and interconnected. Inadequate collection infrastructure, inefficient management systems, low public awareness and regional disparities all exacerbate the issue. As the European Environment Agency has noted, progress on many circular economy initiatives is slow. Progress towards EU targets requires stronger efforts in terms of waste prevention, separate collection and product design, the latter of which remains not very recycling-oriented. Therefore, accurately monitoring the presence of high-value waste in residual waste is essential for defining action priorities and calibrating prevention and recovery policies.

1. Calculated according to the methodology set out in Regulation 1542/2023, using data from the National Clearing House for Batteries and Accumulators (CDCNPA).

2. Based on collection data from the ISPRA Registry (ISPRA, 2024) and JRC estimates (Köhler, 2021).

1.2 Unsorted waste in Italy

In 2023, the production of municipal waste at a national level reached approximately 29.3 million tonnes, marking a 0.7% increase on 2022 (ISPRA, 2024). Of this waste, 66.6% originated from separate collection, representing a 1.4 percentage point increase compared to 2022 (ISPRA, 2024).

While this result is positive, it implies that approximately 9.7 million tonnes of waste are managed as unsorted.

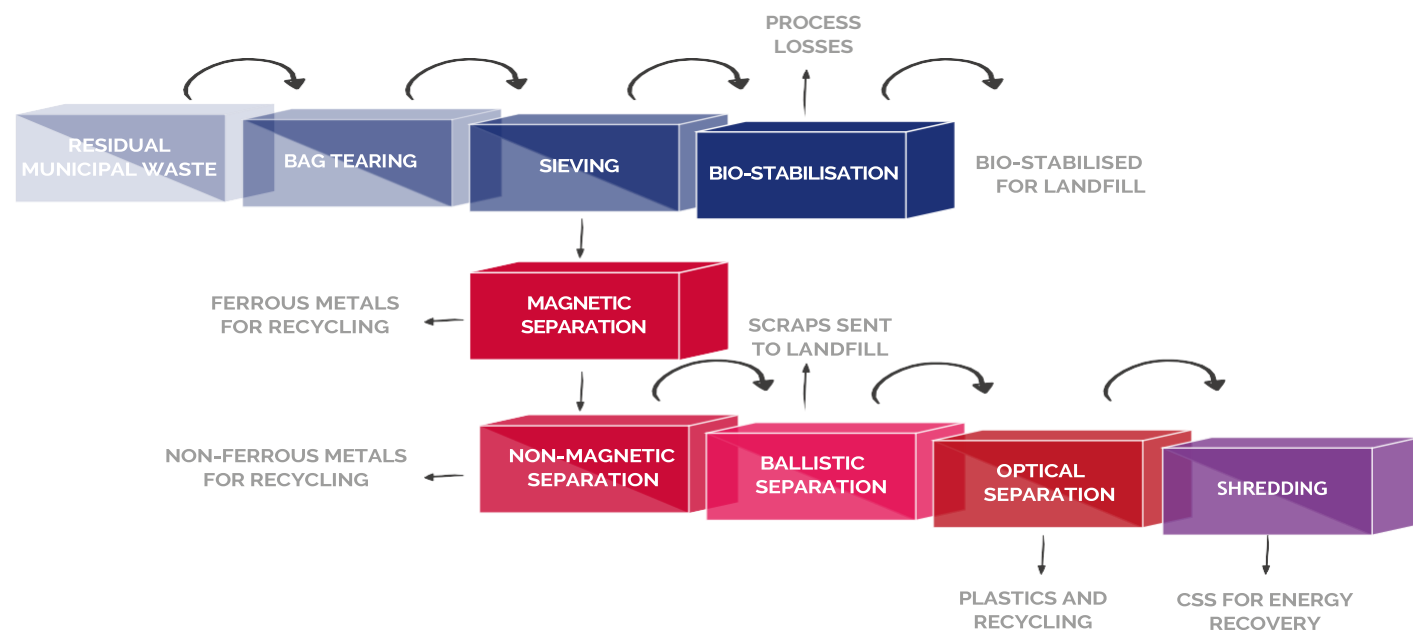
Once collected, unsorted waste has three possible destinations:

(i) Incineration with energy recovery: this is one of the most common methods for managing non-recyclable unsorted waste. This process involves burning waste at high temperatures and under controlled conditions. This reduces the volume of

materials while generating heat, which can be converted into electrical or thermal energy. Although incineration reduces waste volume, the obvious disadvantage is that it fails to recover any recyclable materials present in unsorted waste. It is only recently that the study of heavy ash treatment has become widespread, enabling the recovery of metals and inert materials.

(ii) Landfill: although landfill use has decreased in recent years, unsorted waste is sometimes sent to them after pre-treatment when there is insufficient incineration capacity. Landfilling is a last resort in waste management. It involves burying waste in specially prepared sites that are managed to minimise environmental impact. However, once material has been sent to a landfill, it cannot be recovered.

Figure 1. Stream of unsorted waste destined for mechanical-biological treatment



(iii) Mechanical-biological treatment (MBT): as an alternative, unsorted waste can be sent to MBT plants for processing first. There, the waste is separated and processed in order to recover recyclable materials and minimise the amount sent to landfills or incinerators. According to ISPRA (Higher Institute for Environmental Protection and Research), in 2023, 29.5% of municipal waste underwent intermediate mechanical/biological treatment prior to final recovery or disposal in 2023, compared to 30.1% in 2022. Article 7 of Legislative Decree 36/2003, which implements Directive 99/31/EC, states that waste must undergo treatment before it can be disposed of in landfills. In line with these provisions, 93.5% of waste disposed of in landfills, as well as around 51% of waste incinerated, underwent preliminary treatment in 2023. That year, almost 9 million tonnes of waste underwent mechanical-biological or purely mechanical treatment, around 78% of which originated from unsorted waste collection. In 2023, mechanical-biological and mechanical treatment plants produced over 8.1 million tonnes of waste³. Of this total, only 106,000 tonnes (1.3%) consisted of recoverable or recyclable materials, such as paper, plastic, wood, glass, textiles and metals, obtained through mechanical treatment (ISPRA, 2024). The other fractions are destined for composting, energy recovery or landfill, depending on the quality and nature of the waste. The efficiency of this process hinges on various factors, such as the type of plant, the technology employed, and the composition of the waste. In fact, the amount of metal obtained can vary greatly depending on the type of metal present. Ferrous metals, such as iron and steel, are relatively easy to recover due to their magnetic properties. MBT plants use magnetic separators to extract these metals, achieving recovery efficiencies of over 90% (Gadaleta, De Gisi, Todaro, & Notarnicola, 2022).

Separating non-ferrous metals, such as aluminium, copper and zinc, is more complex and requires technologies such as eddy current (Foucault) separation or optical separation. These technologies use an induced magnetic field to separate non-ferrous metals from non-metallic materials. Although the recovery of non-ferrous metals is less efficient than that of ferrous metals, recovery rates can still reach between 50% and 80%, depending on the technology employed and the quality of the waste processed (Gadaleta, De Gisi, Todaro, & Notarnicola, 2022).

Although some recyclable materials can be recovered from unsorted waste through mechanical-biological treatment, the most efficient circular economy solution is to send separate collection fractions for recycling.

3. Composed of: dry fraction: over 3.8 million tonnes (47.1% of the total waste produced); secondary solid fuel (SSF): over 1.6 million tonnes (20.5%); non-composted organic fraction: over 1.1 million tonnes (14.1%); bio-stabilised: just over 740,000 tonnes (9.1%); wet fraction: over 474,000 tonnes (5.8%); leachate: over 148,000 tonnes (1.8%) recoverable/recyclable fractions sent for recovery operations, including recycling (paper, plastic, metals, wood, glass, textiles): approximately 106,000 tonnes (1.3%); bio-dried: 27 thousand tonnes (0.3%).

2. Scope of the study

As previously mentioned, this report presents the results of the characterisation of unsorted municipal waste carried out by Erion.

The campaign focused on WEEE, WB, textile waste, and EEE packaging due to their recycling potential. For various reasons, the focus was also extended to include cigarette butts to ensure they were managed correctly. This study aims to estimate the presence of these fractions in unsorted municipal waste in several Italian municipalities. This information will help identify areas where awareness can be raised and new activities can be developed.

The decision to involve IPLA was made due to the institute's recognised technical expertise, as evidenced by historical data and analyses covering the entire country. This establishes IPLA as a leading authority on this type of study.

The study began with the acquisition and analysis of IPLA historical data series relating to the Lombardy-Piedmont macro-area, as this area was considered to be representative and characterised by a high degree of granularity. This series of data covers a vast and diverse geographical area, including urban centres of various sizes and levels of urbanisation, and allows for the identification of any significant differences in disposal and collection behaviours. It should be noted, however, that while these results represent an excellent starting point, they cannot automatically be extended to the national level. This is because waste collection systems in different territories are significantly influenced by socio-economic, morphological and urban conditions. For this reason, a two-phase campaign was launched. The first phase, which involved sampling unsorted municipal waste, was carried out by Erion in 2024. Five cities across the Lombardy, Piedmont and Veneto macro-areas were covered, with ten product analyses carried out in total. The second phase of the campaign, conducted in 2025, involved an additional geographical area comprising ten locations in the Campania and Lazio regions. Due to the characteristics of its settlements and the

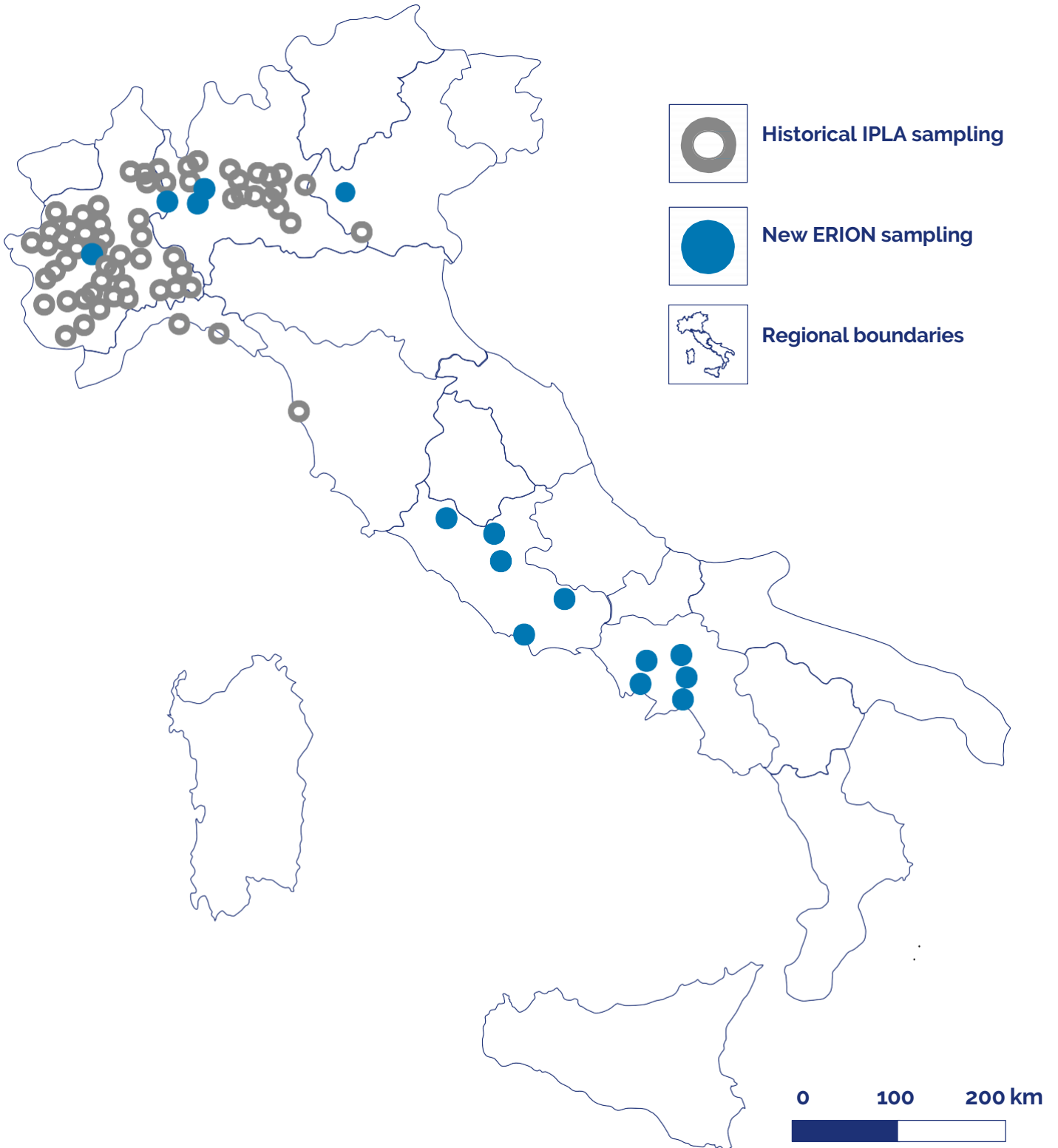
distribution of its urban centres, it was possible to create a sample structure similar to that in the north of the country. This makes it possible to compare areas with a similar level of urban variety. However, the thirty eight sampling conducted by Erion with operational support from IPLA covered larger population centres than those included in the historical database.

The sampling was specifically conducted in the following cities:

- Avellino
- Benevento
- Caserta
- Desio
- Frosinone
- Latina
- Milan
- Naples
- Novara
- Rieti
- Rome
- Salerno
- Turin
- Verona
- Viterbo

Figure 2 illustrates the distribution of the samples within the IPLA historical database and the new campaign. Although the results are informative, they cannot be considered statistically representative.

Figure 2. Historical distribution of IPLA samples (empty circles) and the new sampling campaign (blue circles).



2.1. Methodology

As mentioned earlier, Erion's campaign was developed in two phases:

- The first phase of activities involved investigating the presence of WB and WEEE in unsorted municipal waste;

- the second phase saw the investigation expanded to include textile waste, cigarette butts and EEE packaging.
-

2.1.1. Desk activities

In the first phase, a specific analytical procedure for WB and WEEE in unsorted municipal waste was defined in collaboration with IPLA, in line with the methodological guidelines already established at a national level, in order to quantify their presence in a specific and representative manner. In particular, the sample identification and preparation phase refers to the IPLA-CNR methodology described in Volume VI of the Environment Series, Compost Analysis Methods, published by the Environment Department of the Piedmont Region, and subsequently incorporated and expanded in the ANPA guidelines (RTI CTN_RIF 1/2000).

This methodology was then extended to cover the additional fractions considered in the second phase.

A typological classification was decided upon for WEEE, WB and textile waste, divided into the following groups:

- single-cell batteries,
- button cell batteries,
- battery packs,
- WEEE with integrated batteries,
- WEEE without batteries,
- WEEE without batteries belonging to Group R5,
- synthetic textiles,
- natural textiles,
- shoes,
- accessories (bags, belts).

No further classification was defined for cigarette butts or EEE packaging as they were only included in the pilot study involving 14 products. However,

due to their unique characteristics, cigarette butts are dealt with separately in an appendix to this report.

As the percentage of WB and WEEE in total waste is low, it was deemed appropriate to increase the sample size compared to that normally expected for traditional product analyses. It was therefore decided that a waste stream of approximately 300 kg should be analysed for each product, with the sorting activity focusing exclusively on the fractions under study. This choice was motivated by the desire to increase the volume of waste analysed in a given time period, thereby improving the statistical robustness of the results without increasing the time or cost of the analysis.

Some additional preparatory steps were also taken before the fieldwork began. Firstly, a number of unsorted waste disposal facilities were identified. Then, the collection operators and facility representatives were preliminarily contacted to agree on the availability of covered spaces suitable for carrying out the activities, and to define the arrival times of the streams to be monitored. At the same time, the geographical origin of the waste was identified and specified, including the municipality and any additional user characteristics (e.g. households, commercial or mixed).

2.1.2. Fieldwork

As defined by the IPLA-CNR methodology mentioned above, the fieldwork was divided into several phases. The material to be analysed was unloaded in accordance with the plant's logistical conditions. Where there was adequate space, the load was divided into quarters using a mechanical shovel. Otherwise, the waste was unloaded into separate piles spaced 1–2 metres apart, to ensure that the entire stream was sampled uniformly and representatively. Before the sorting process began, the driver was asked to verify that the load did not contain waste from places such as hospitals, supermarkets, or prisons, as such waste could have compromised the significance of the results.

Product analysis was carried out using a sieve with a surface area of at least one square metre and a 2 cm mesh grid. The sieve was also fitted with a scale with a maximum capacity of 100 kg and an accuracy of five grams or less. This level of precision was necessary in order to detect even the smallest quantities of WB present in the sample.

Manual sorting was subsequently carried out. After

the material selected for analysis had been weighed, it was placed on the sieve for manual analysis. In the first phase, only WB and WEEE were selected; in the second phase, the additional fractions provided for were also selected. All other product fractions were discarded. At the end of the sorting process, the undersize fraction (less than 20 mm) was checked for items of interest, particularly button cell batteries. In cities where cigarette butts were analysed, this control was also extended to them. If these fractions were too light to be detected by the scale in use, they were transferred to the laboratory for weighing with the correct equipment.

As defined in the methodology phase, analysis activities were conducted on a target sample size of 300 kg to ensure adequate representation of the fractions. Organising field operations to achieve this quantity impacted the timing and logistics. For instance, extending the analytical procedure to encompass textile waste, EEE packaging, and cigarette butts necessitated more meticulous manual sorting of each 300 kg sample. This process also involved classifying and quantifying these additional categories.

2.1.3. Qualitative insights

To gain a fuller picture of the factors affecting the performance of waste collection systems and waste disposal, interviews were conducted with technical representatives and local operators. These interviews enabled qualitative and quantitative data

to be collected, which could then be used to correlate the results of the analyses with contextual elements such as local collection procedures, service infrastructure levels, and public awareness.

3 Results

3.1. WEEE, WB and textile waste

The campaign provided detailed data on the presence of different fractions in the unsorted waste stream. The results for WEEE, WB and textile waste are presented in aggregate form in Table 1. As these three waste streams have an official separate collection system, the data obtained from sampling unsorted waste can be compared with IPLA's historical data. Sampling was conducted for WEEE packaging and cigarette butts in a pilot phase to verify operational feasibility, and the results are

presented separately in Section 3.2 and Appendix I. Table 1 summarises the average data for the sampled cities in terms of the percentage of waste (WEEE, WB and textile waste) found in unsorted waste, as well as the corresponding annual per capita kilograms for each type of waste. For comparison, it also shows the annual per capita kilograms collected through official channels in the cities concerned.

Table 1. Results of the product category analysis, compared with the official channel collection

	WEEE (R4 and R5)	WB	Textile waste
Percentage by weight in unsorted waste	1.04%	0.06%	8.65%
Equivalent to kg/capita/year in unsorted waste	198	0.12	17.67
kg/capita/year collected by official channels	134	0.06	2.74

As most of the WEEE found in unsorted waste consists of small electrical appliances and light bulbs (Figure 3), the kgs per capita for this waste stream were calculated using only the data from

Groups R4 (IT and consumer electronics, lighting equipment, small electrical appliances, and other items) and R5 (light sources). This approach was maintained for the remainder of the analysis.

3.2. EEE packaging

The survey on EEE packaging was conducted using pilot samples from four cities, in order to verify the feasibility of identifying this packaging category.

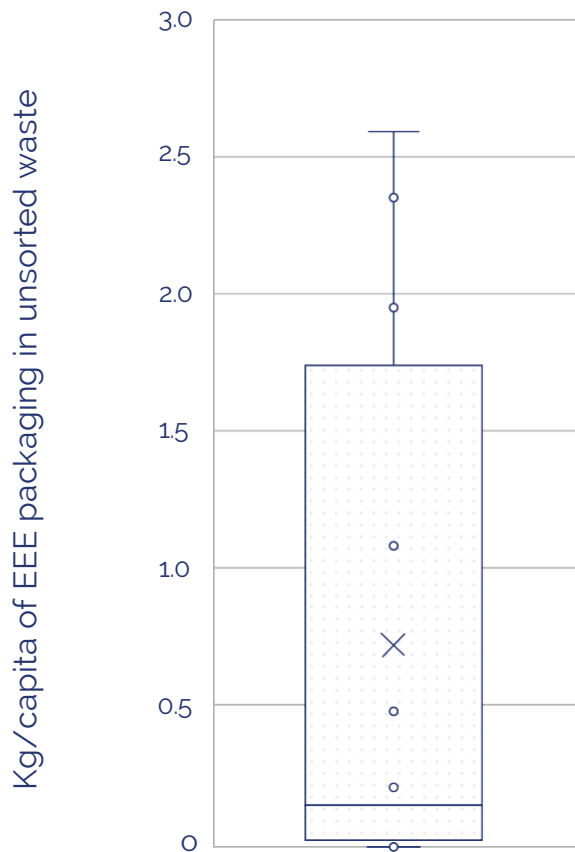
The amount of EEE packaging sampled certainly underestimates the actual presence of this waste stream in unsorted waste, since only a proportion

can be directly traced back to electronic products. Furthermore, according to historical IPLA sampling data, the packaging category accounts for around 50% of items found in unsorted bin bags. As can be seen in Figure 7, the collected data is highly variable and requires further analysis to enable statistically valid extrapolation.

Figure 6. Packaging directly attributable to EEE found in samples of unsorted waste



Figure 7. Range of EEE packaging values (kg/capita/year) for the various samples taken

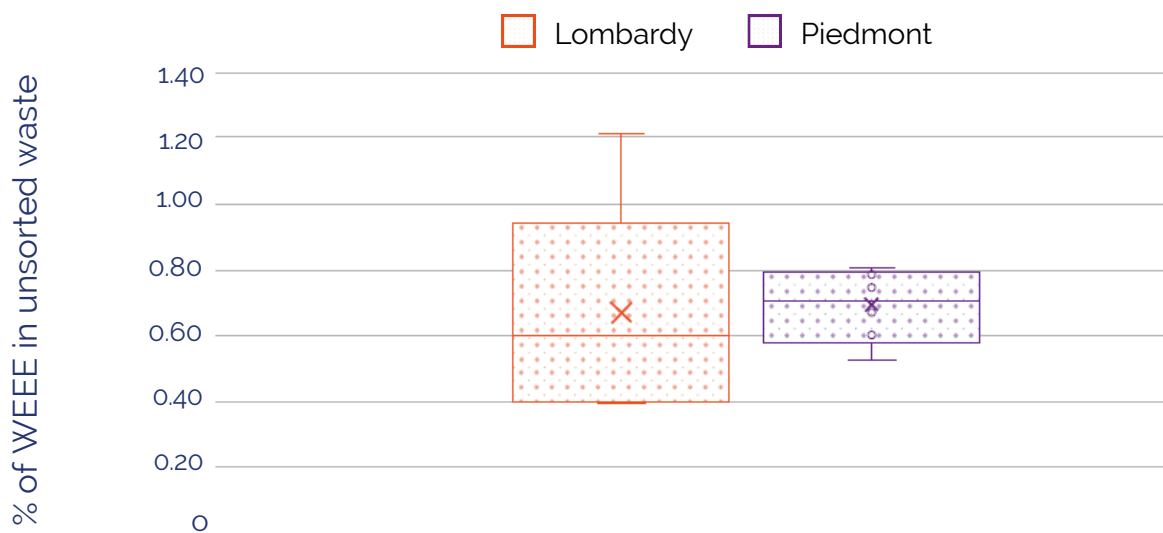


3.3 Historical data series analysis: WEEE, WB and textile waste

Examining the historical data collected from IPLA campaigns reveals a fluctuating trend that remains within a relatively stable range. This suggests a certain consistency in volumes, with variations that, while not particularly significant, may nevertheless

reflect seasonal trends or changes in collection policies. While waste streams are relatively predictable, some fluctuations require further analysis to identify any external factors influencing these changes.

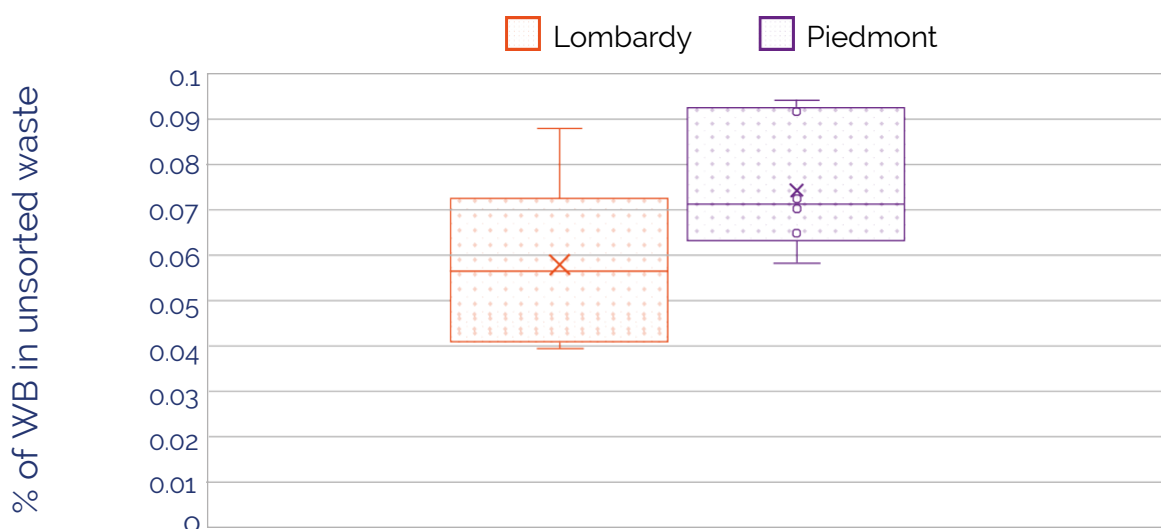
Figure 8. WEEE in unsorted waste, as analysed by the IPLA database



In the case of WEEE sampling (see Figure 8), the geographical area covered by the activities includes the regions of Piedmont and Lombardy. Although an

average lower percentage of WEEE is found in unsorted waste, Lombardy exhibits greater variability in its data than Piedmont.

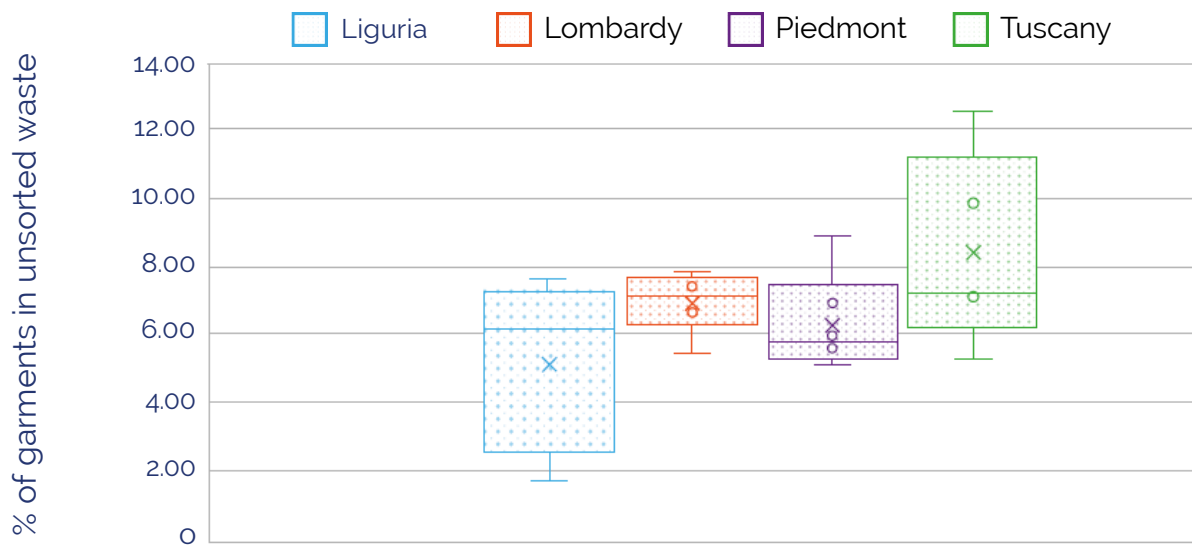
Figure 9. WB in unsorted waste, as analysed by the IPLA database



Also with regard to WB, Piedmont shows a higher proportion of batteries in the unsorted waste stream

than the Lombardy samples (Figure 9).

Figure 10. Textile waste (excluding accessories and footwear) in unsorted waste, as analysed by the IPLA database



Finally, historical data on textile waste is available for four regions. This indicates a broader spectrum than in previous cases. Conversely, textile waste

constitutes a higher proportion of unsorted waste in Lombardy than in Piedmont (Figure 10).

3.4. Sample analysis and correlations: WEEE, WB, textile waste

The data obtained from the sampling of unsorted municipal waste conducted by Erion provides a fundamental basis for analysing citizens' behaviour with regard to waste management. It was therefore compared with a set of variables, including:

- the population residing in the municipality on 31 December 2024, as reported by the National Institute of Statistics (ISTAT, 2025);
- the volumes of unsorted waste produced by the municipality, as reported by the Higher Institute for Environmental Protection and Research (ISPRA, 2024);
- in the case of WEEE and WB, the official collection of various waste streams was reported by the

respective Clearing Houses (CDC RAEE, 2024; CDCNPA, 2024). For textile waste, the official collection data was provided by the Higher Institute for Environmental Protection and Research (ISPRA, 2024);

- where possible, the number of disposal options per unit of surface area is provided. Due to the limited availability of information affecting all waste streams to varying degrees, this figure is the most accurate estimate available, but it is in fact an underestimate.

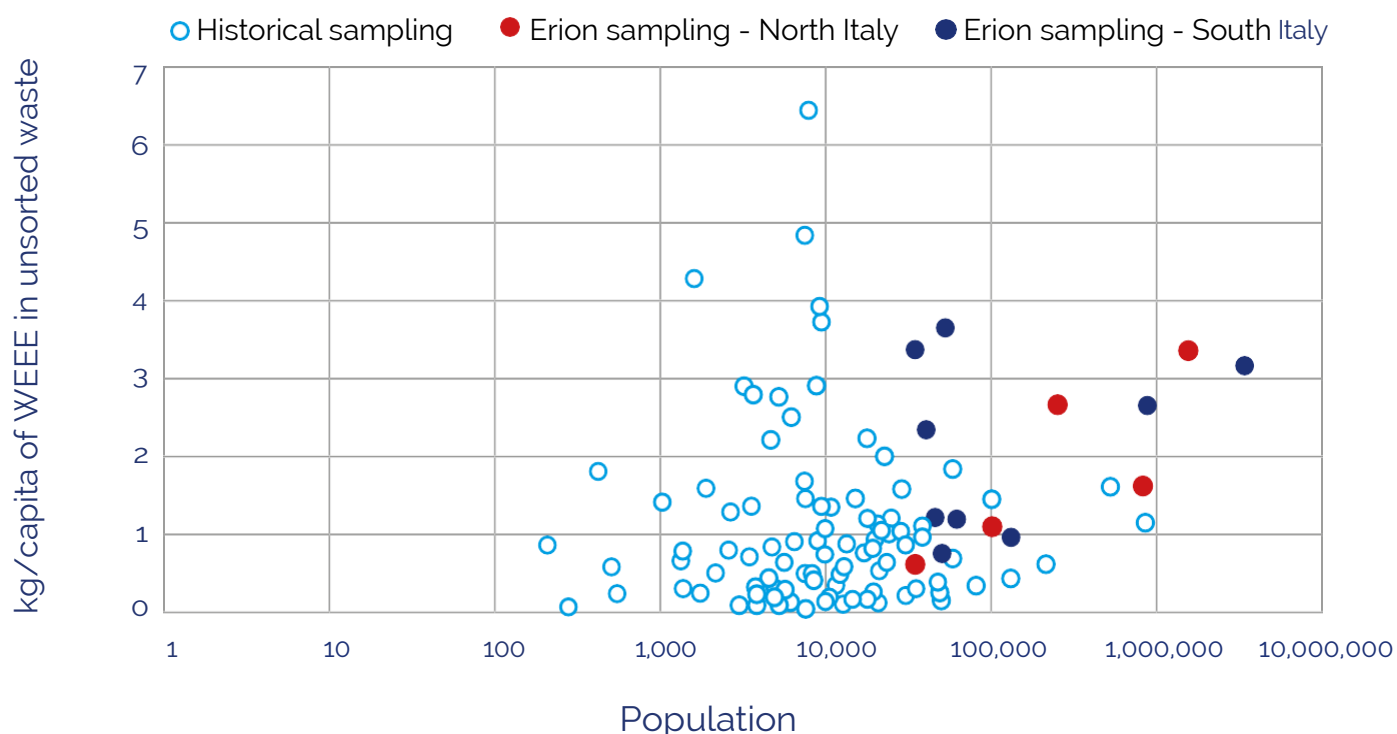
The disposal options for WEEE and WB have been quantified using data from the relevant national clearing houses, which map the locations of the disposal points from which collections are made.

Disposal options for WEEE and WB have been quantified using data from the relevant national clearing houses, which map the locations of the disposal points from which collections are made. Some collecting points, such as waste battery stations located in commercial premises and stores that take back WEEE on a one-for-zero basis, may not be mapped because they are managed directly by municipal companies. For this reason, the analysis incorporates qualitative information provided by the municipal companies, as well as publicly accessible information from sources such

as the *junker* app and the municipal companies' websites. This was also done to confirm that the information was available. Finally, the sampling data were compared with the estimated waste generation figures from the following sources: the Global E-waste Monitor (Baldé et al., 2024) for WEEE; the most recent study by the Joint Research Centre for the European Commission (Bobba, Manni, Orefice & Mathieu, 2024) for batteries; and the European Environment Agency (EEA, 2025) for textile waste.

3.4.1. WEEE

Figure 11. Comparison of kg/capita/year of WEEE found in unsorted waste streams with population size



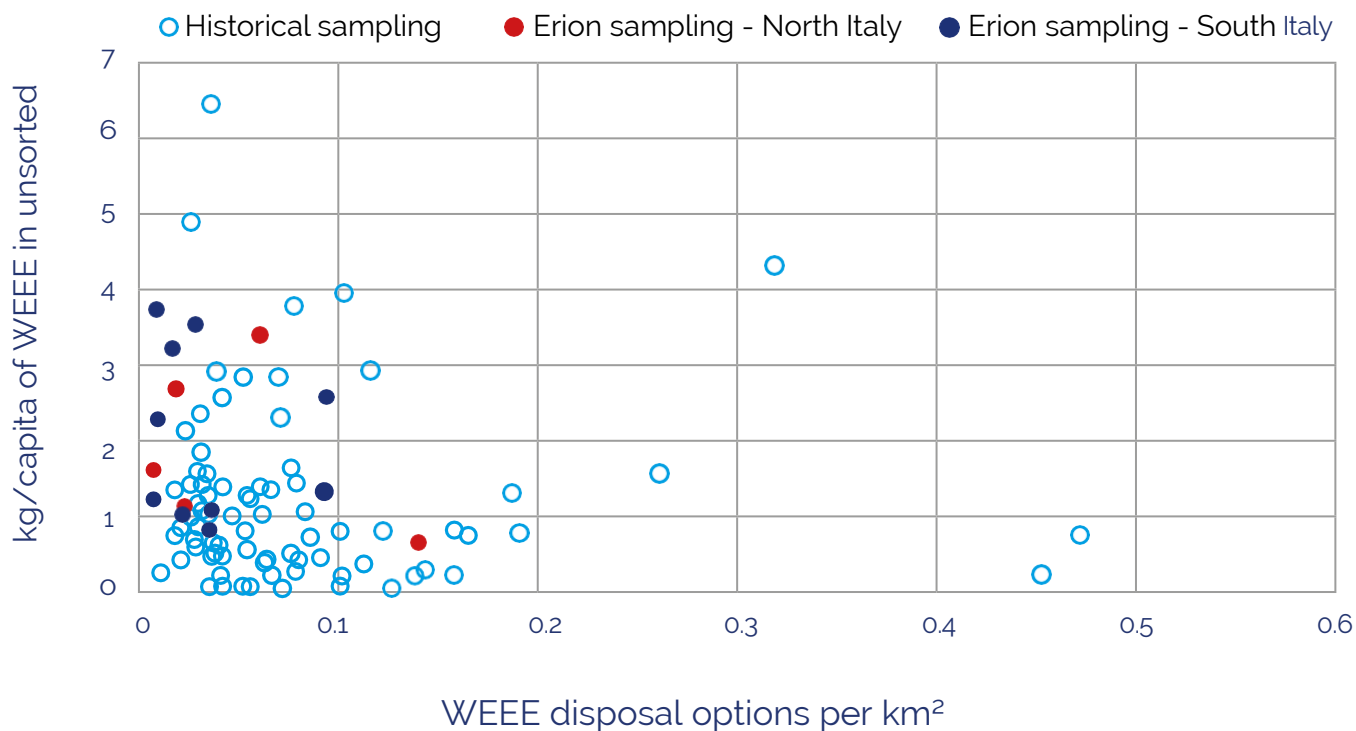
The larger size of the urban centres involved in the study enabled us to identify a new pattern in the data. In municipalities with a population of over 50,000, the amount of WEEE detected in the unsorted waste stream per capita tends to increase,

suggesting a loss of efficiency in the collection system. An in-depth analysis of the outliers showed that abnormal concentrations of WEEE in unsorted waste were due to collecting points with opening hours that did not align with the normal working day.

Cross-referencing data on the presence of WEEE in unsorted waste streams with the number of disposal solutions per km², it is evident that the highest concentrations of waste are found in municipalities

with a low density of solutions. Conversely, an increase in the number of disposal solutions tends to result in less WEEE being found in unsorted waste (Figure 12).

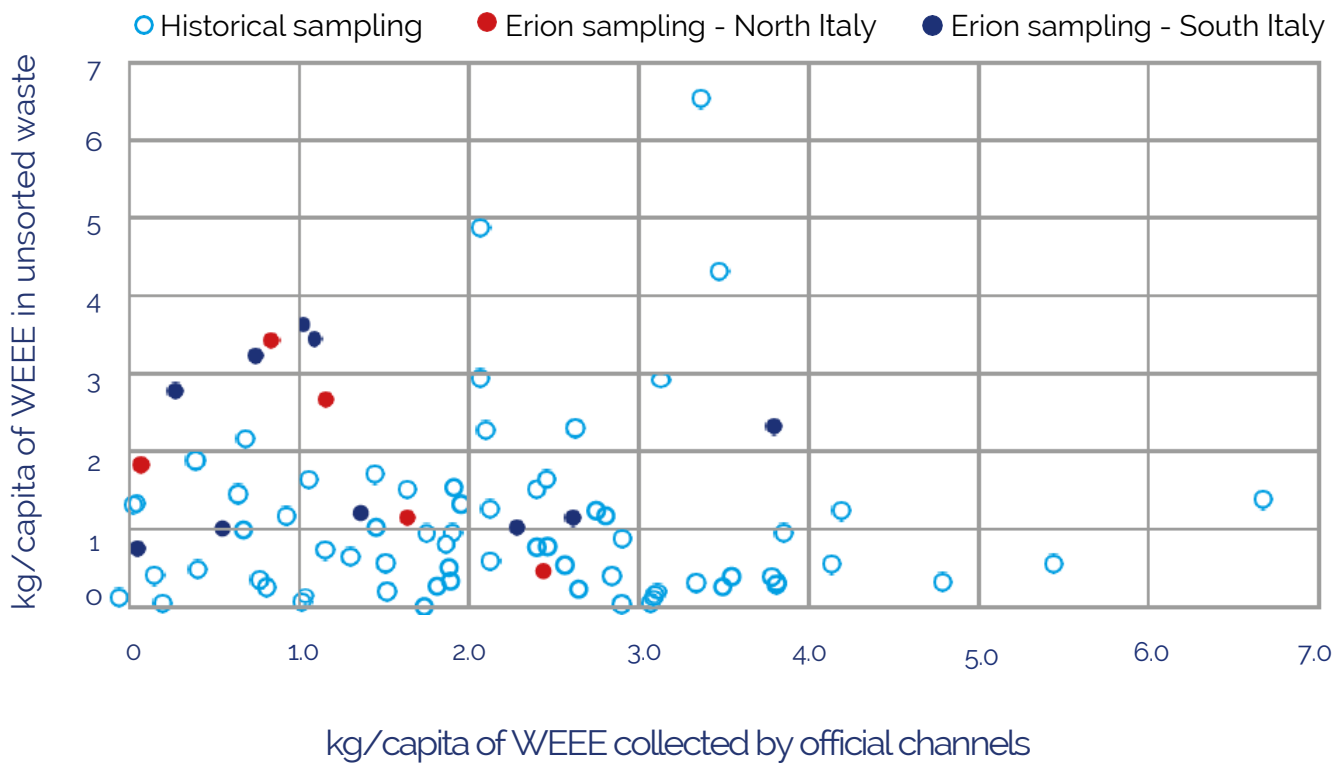
Figure 12. Comparison of the volumes of WEEE found in the unsorted waste stream with the number of disposal options per km²



Examining the link between the kg per capita collected by official systems and the kg of unsorted waste (Figure 13) reveals two interesting findings. Firstly, unsorted waste typically contains a higher proportion of WEEE than that intercepted through official channels. Secondly, the low levels of WEEE interception by official channels are often reflected in the low levels of WEEE found in unsorted waste.

Due to the small size of the WEEE items, and because many people are unaware of the disposal options available, the items often remain in people's homes even after they have reached the end of their useful life. This results in substantial economic value being immobilised, which can only be recovered through recycling. In effect, cities become veritable 'urban mines'.

Figure 13. Comparison of the official collection with the volume of WEEE found in the unsorted waste stream (kg/capita/year).



Finally, it is useful to compare the obtained data with the most reliable waste generation estimates, which suggest a rate of 8 kg per capita per year (Baldé et al., 2024). These estimates distinguish between small cities (with fewer than 100,000 inhabitants)

and large cities (with more than 100,000 inhabitants). The cities in the following figures have been anonymised and are arranged in ascending order by population size.

Figure 14. Comparison of the quantities of WEEE found in unsorted waste collected through official channels with the estimated annual waste generation, for cities with fewer than 100,000 inhabitants

Cities with fewer than 100,000 inhabitants

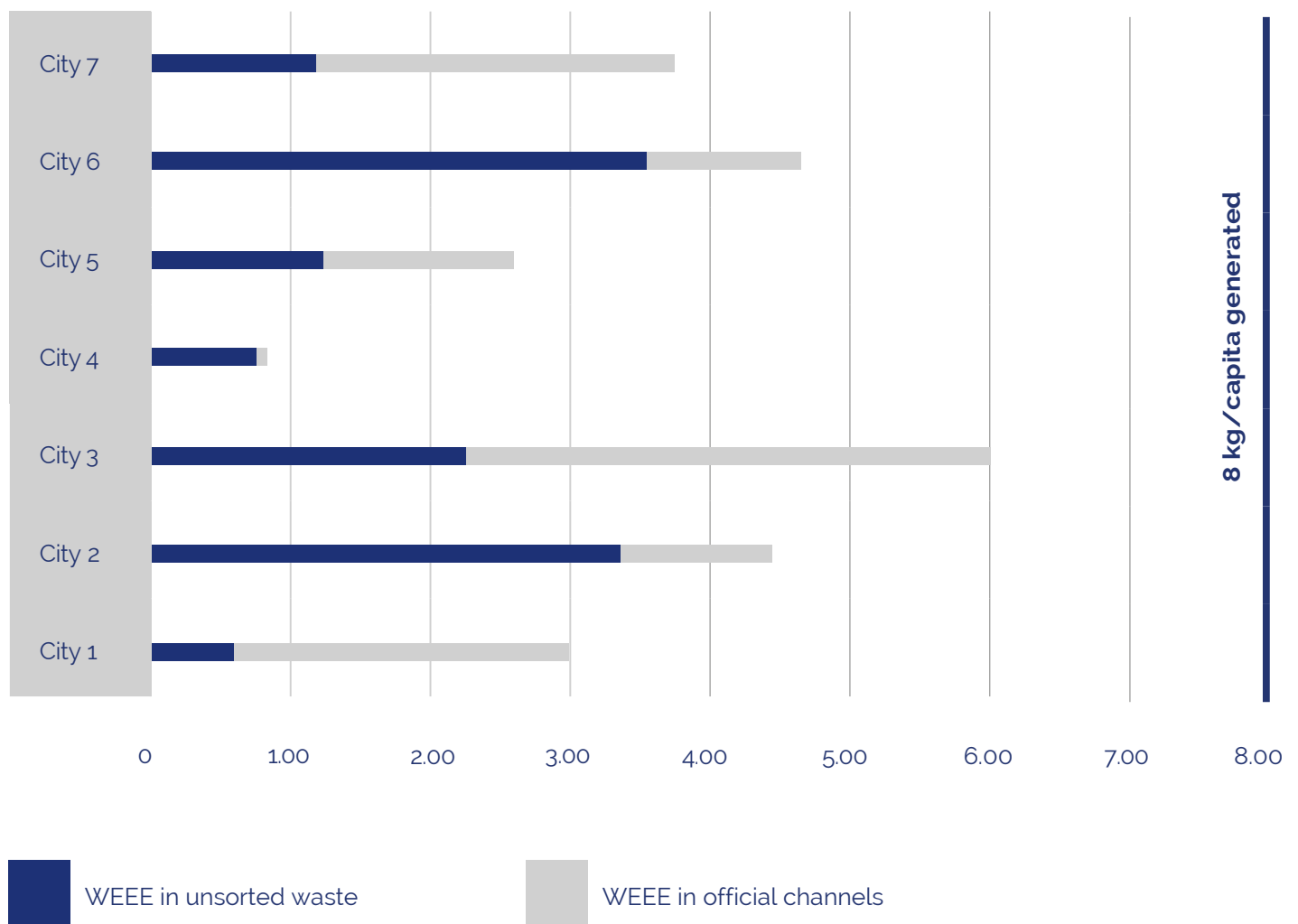
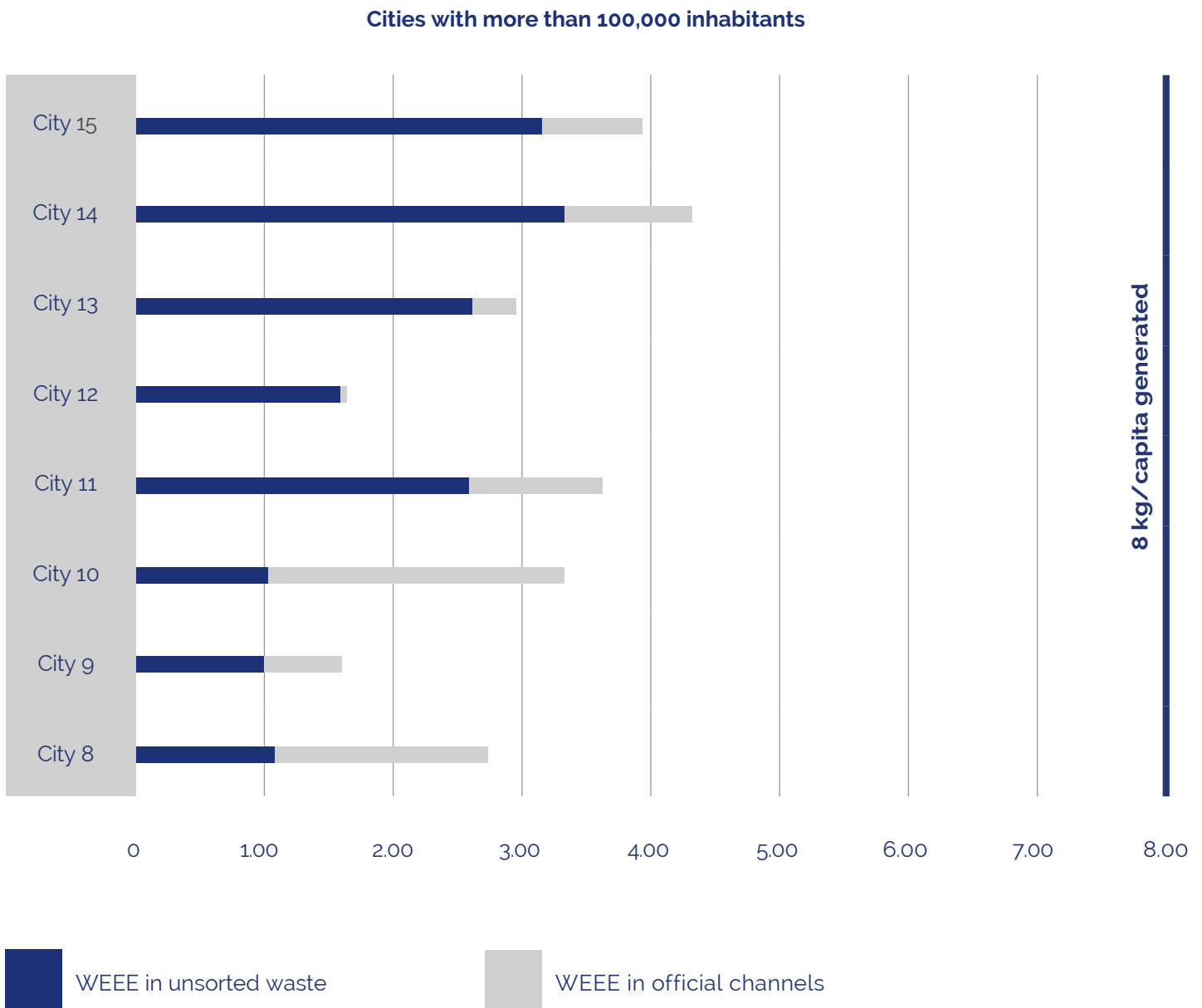


Figure 15. Comparison of the quantities of WEEE found in unsorted waste collected through official channels with the estimated annual waste generated by cities with more than 100,000 inhabitants



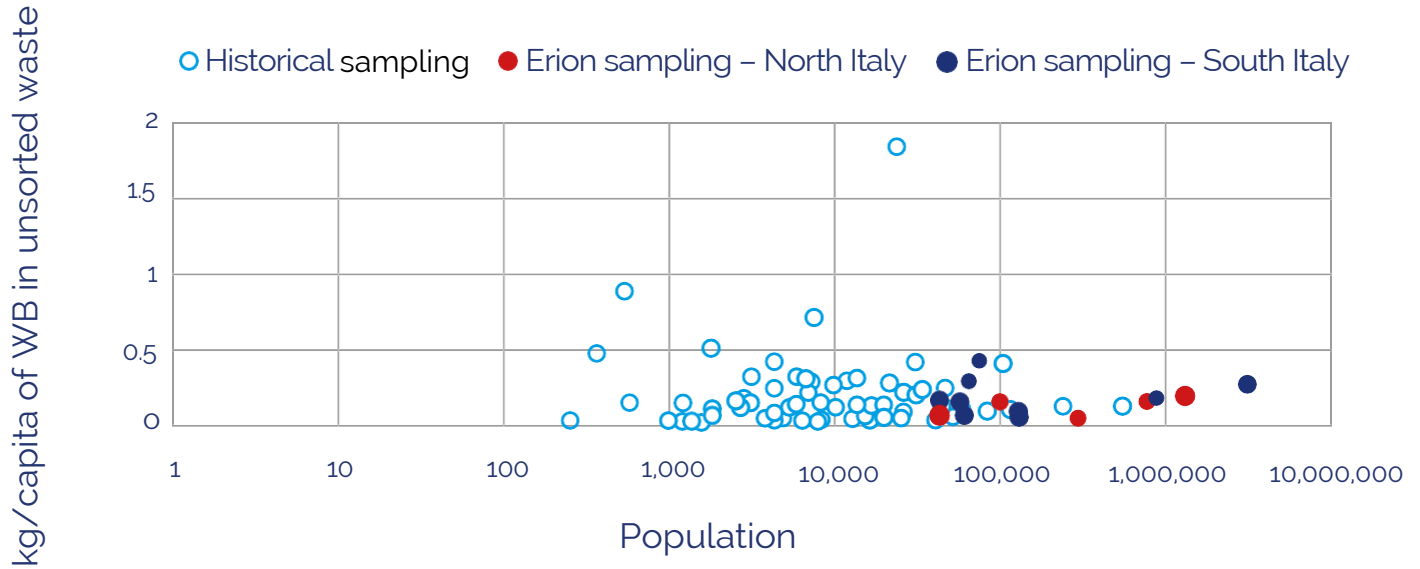
Firstly, the data highlights the significant proportion of WEEE that is still being disposed of incorrectly in the unsorted waste stream, confirming the fundamental ineffectiveness of current collection systems. Secondly, the official collection system

intercepts a smaller proportion of WEEE from larger cities than from smaller ones (45% for cities with fewer than 100,000 inhabitants compared to 31% for cities with more than 100,000 inhabitants), corroborating the findings of Figure 11.

3.4.2. WB

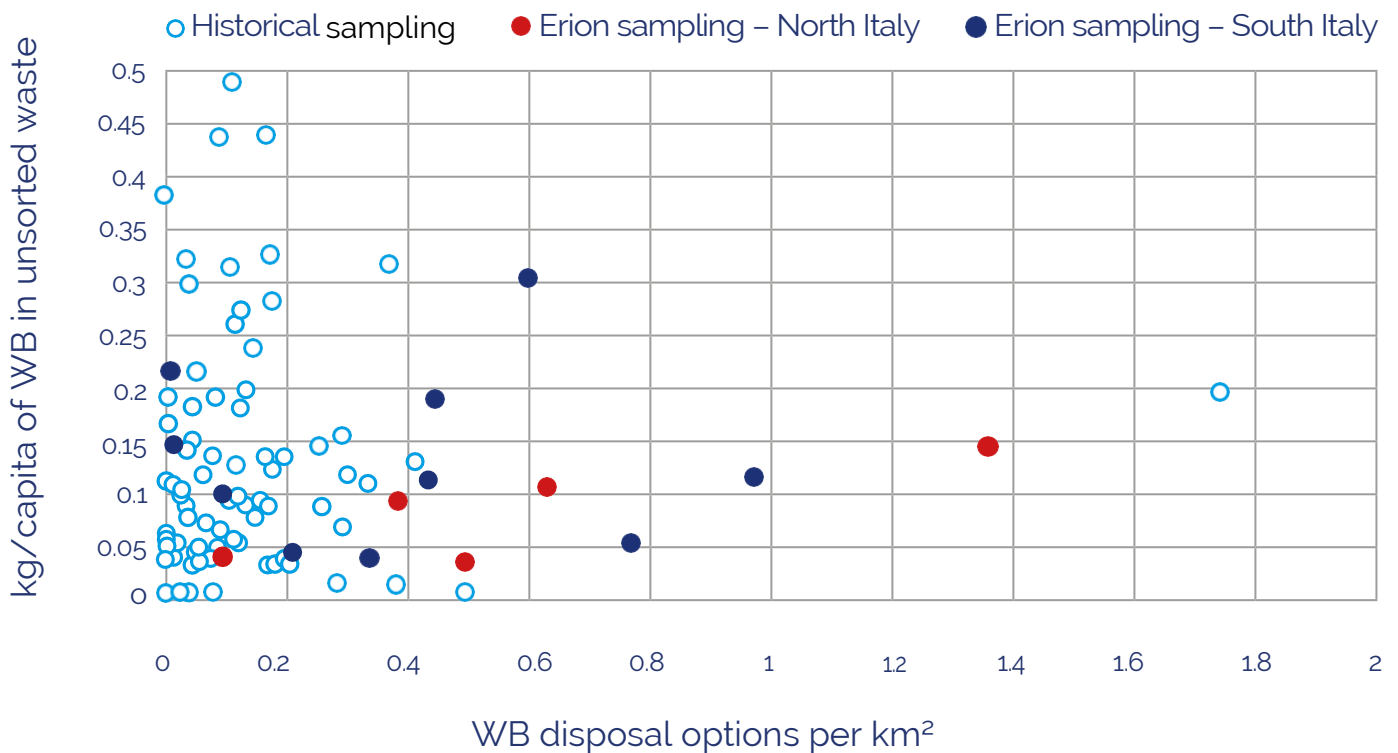
Unlike WEEE, there is no increase in the per capita volume of waste disposed of as unsorted waste in the case of WB as the population increases.

Figure 16. Comparison of kg/capita/year of WB found in the unsorted waste stream with population size



The sampling results also indicate lower WB concentrations in the unsorted waste stream when there are numerous disposal options available, which corroborates a trend that was already apparent in previous data analyses (see Figure 17).

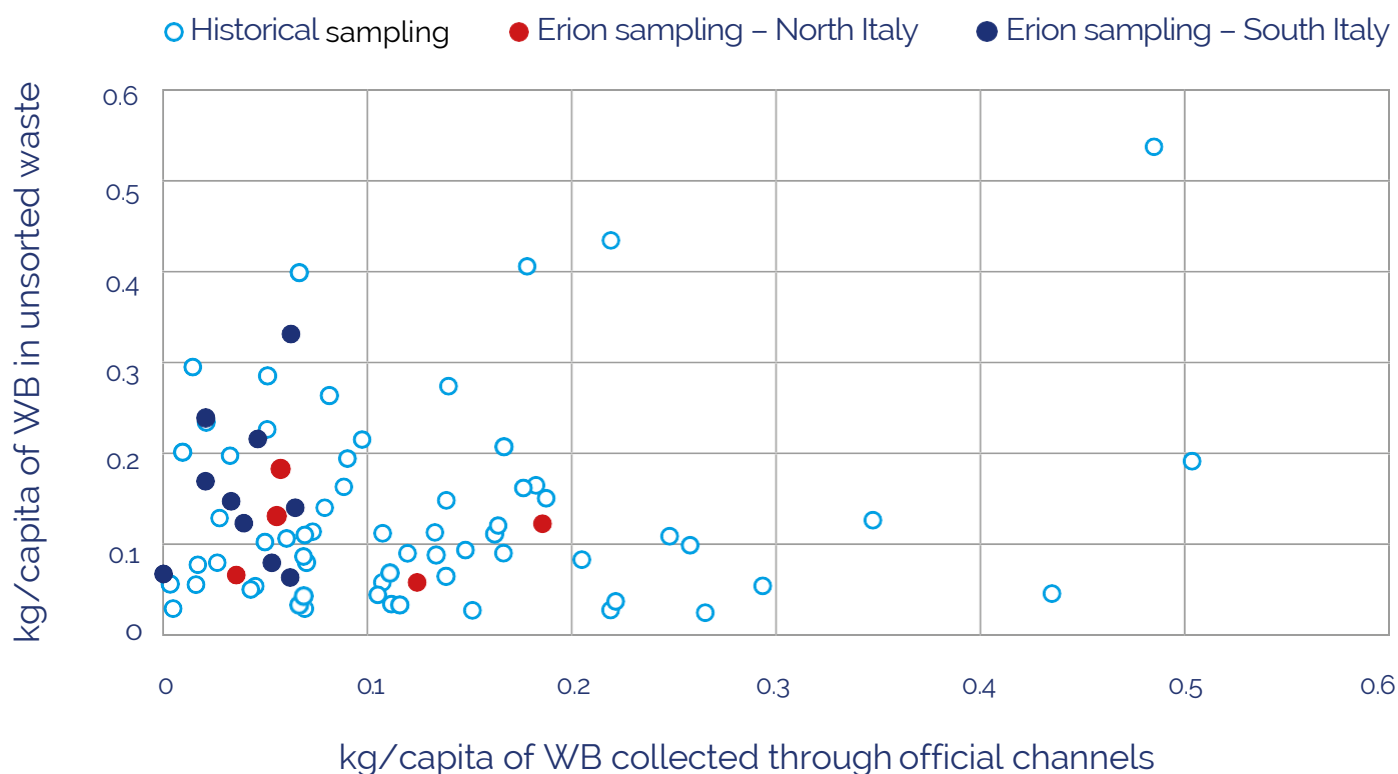
Figure 17. Comparison of the volumes of waste found in the unsorted waste stream with the number of disposal options per km²



Comparing the per capita volumes of WB found in unsorted waste with those collected through official channels reveals high concentrations at lower values, similar to findings regarding WEEE. Recent studies promoted by the CDCNPA have also revealed the presence of batteries in various waste

streams, including mixed plastics, metal collections, and small WEEE (CDCNPA, 2024). Unlike WEEE, the low concentration of WB in both the unsorted waste stream and the official collection suggests that they are disposed of in other waste streams too, which makes this data more difficult to interpret.

Figure 18. Comparison of the official collection with the volume of waste found in the unsorted waste stream (kg/capita/year)



Also in the case of WB it was possible to compare the volumes (expressed in kg/capita produced annually) collected by official channels, those found in unsorted waste, and the estimated annual waste production for clusters above and below 100,000 inhabitants, according to the JRC estimate (Bobba, Manni, Orefice & Mathieu, 2024).

Clearly, the official waste collection service is struggling to intercept most of the waste that citizens dispose of. However, unlike with WEEE, there is an inverse trend between small and large urban centres. In the case of WB, only 26% of waste disposed of in the official collection system is intercepted in cities with fewer than 100,000 inhabitants. By contrast, large urban centres reach an average of 41%. Interestingly, two cities exceed

with the amount of waste disposed the estimated average waste generated: City 8 for the amount of waste disposed of in the official channels, and City 7 for the amount of waste found in unsorted waste. These two cases were analysed in more depth through interviews with municipal companies operating in the area and via the *junker* app. This revealed differences in behaviour between the two cities. In City 8, there are many widely publicised disposal stations for portable batteries, leading to a high official collection rate. In contrast, City 7 has no widespread options for disposing of waste batteries.

Figure 19. Comparison of the quantities of WB found in unsorted waste collected by official channels with the estimated annual waste generated by cities with more than 100,000 inhabitants.

Cities with more than 100,000 inhabitants

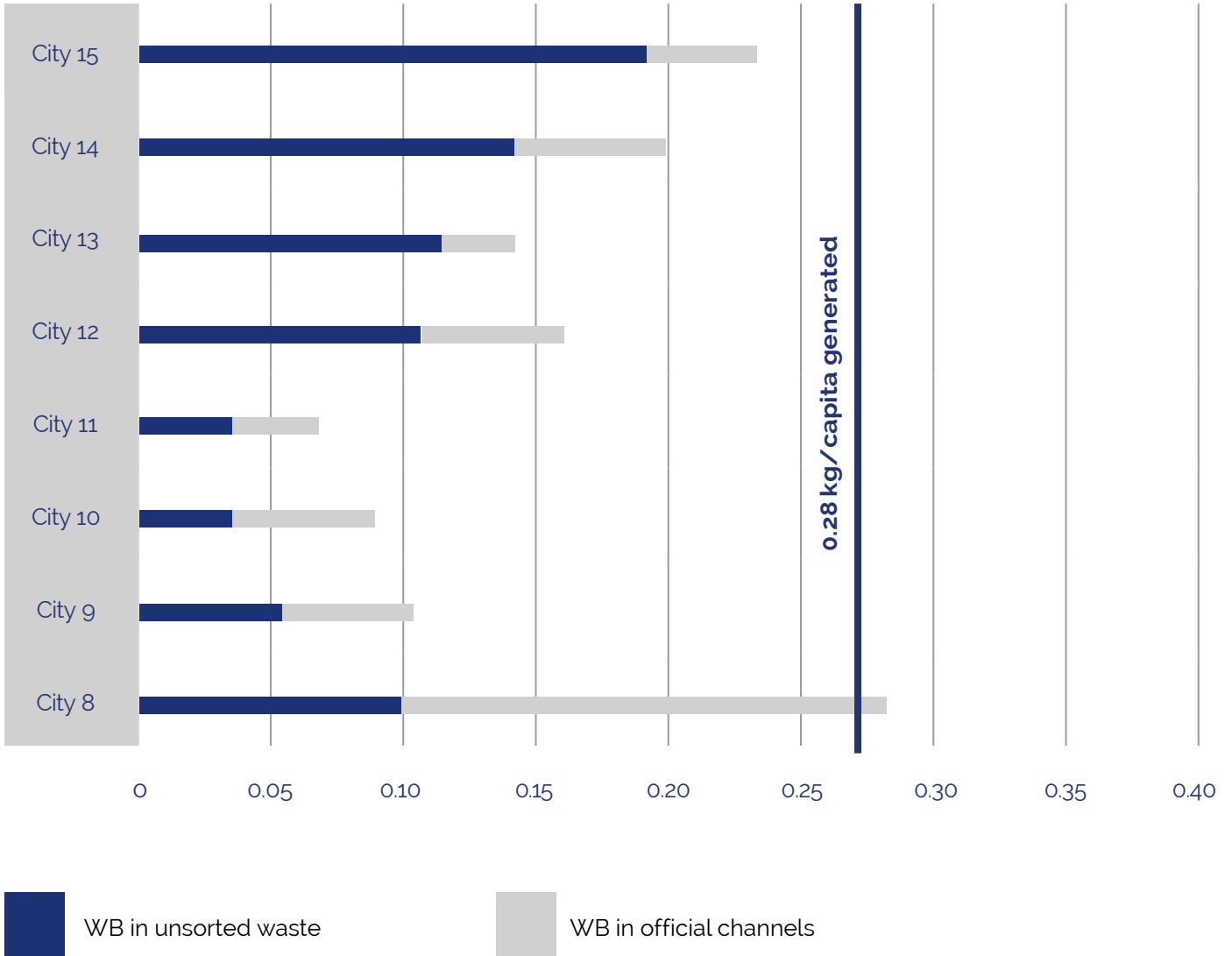
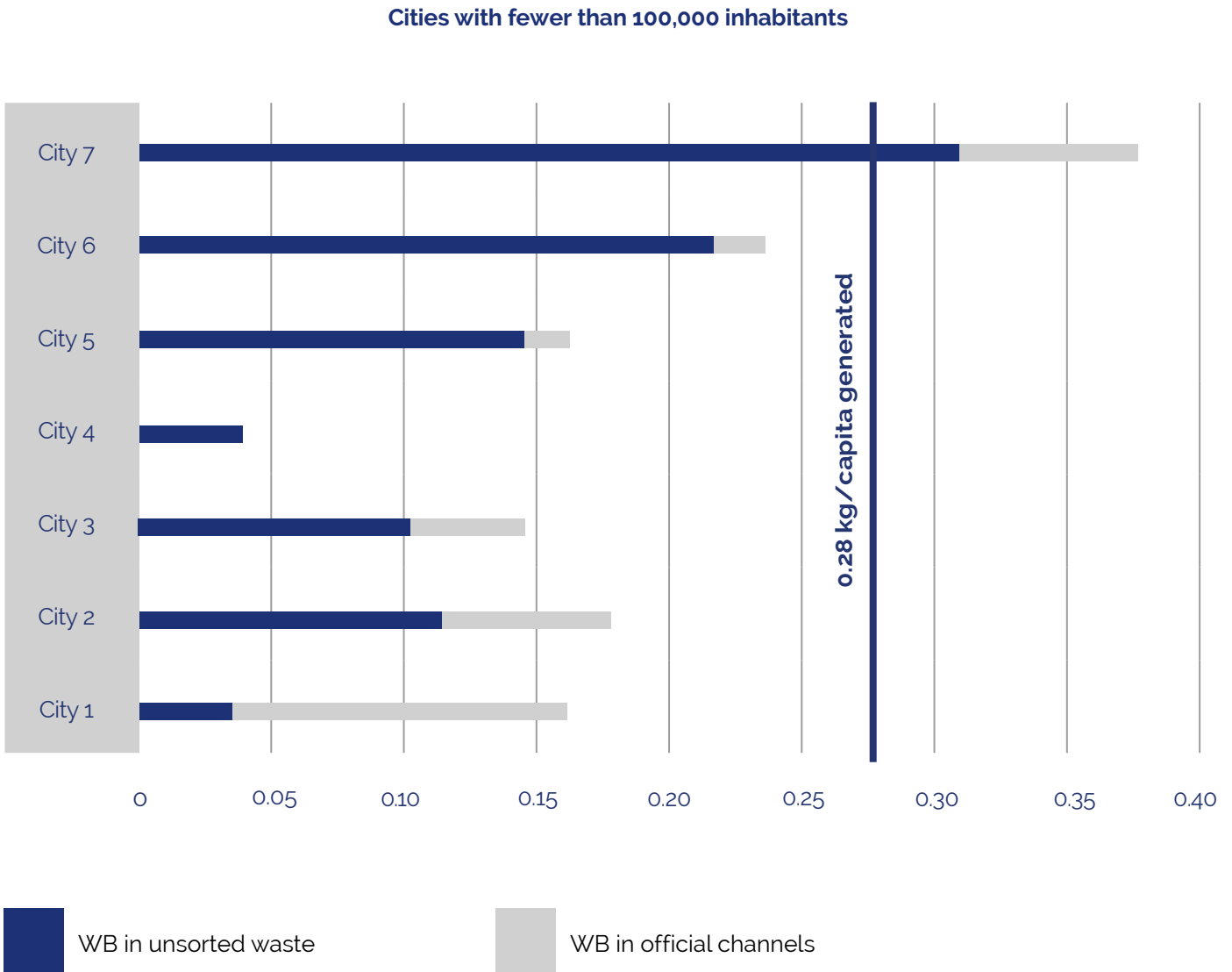


Figure 20. Comparison of the quantities of WB found in unsorted waste collected by official channels with the estimated annual waste generation for cities with fewer than 100,000 inhabitants.

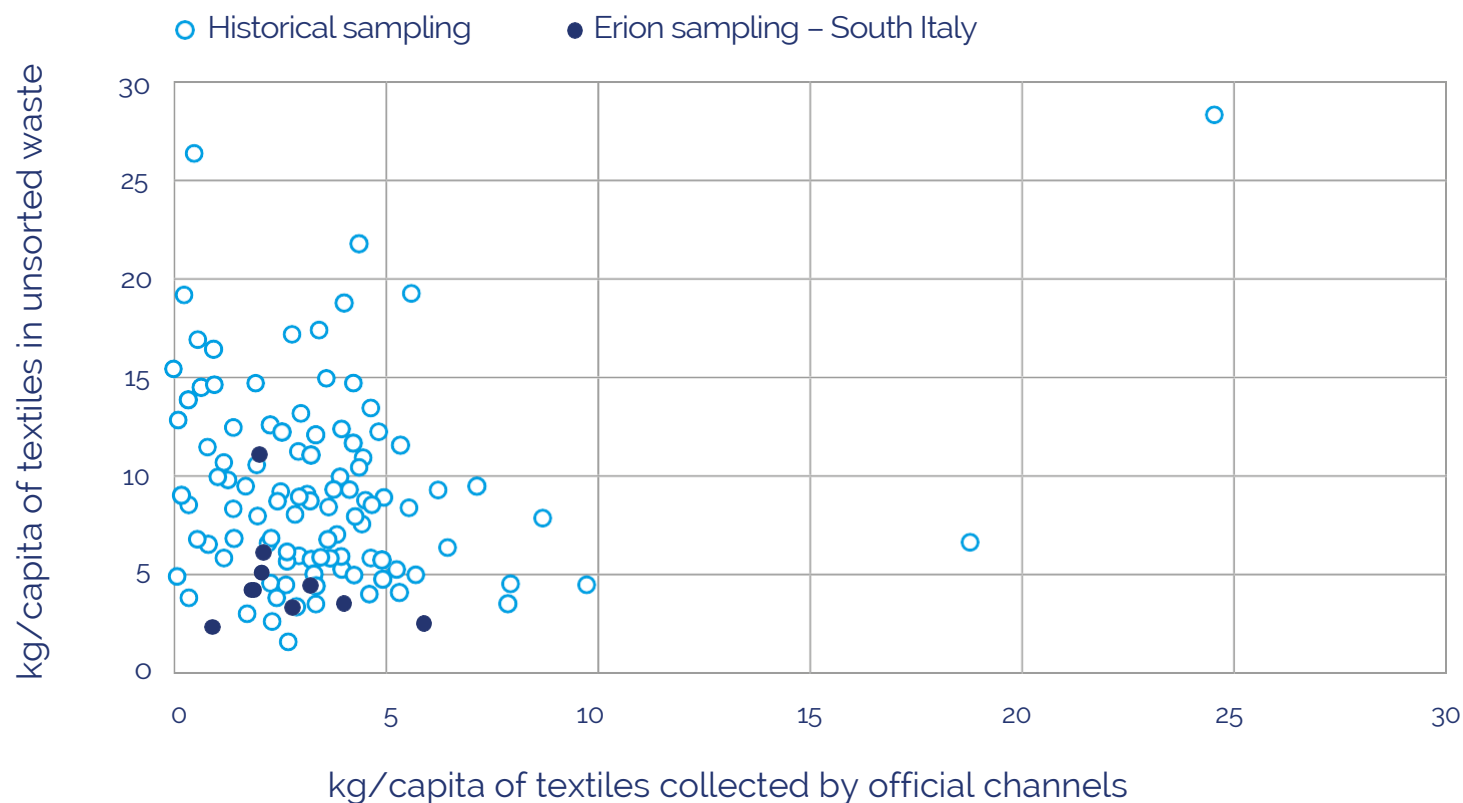


3.4.3. Textile waste

With regard to textile waste, the samples taken are consistent with the historical trend. Although significant quantities are recorded through the official collection system, which has been in place in Italy since 2023, disposal in the unsorted waste

stream remains the most common practice. The urban mining phenomenon is therefore less significant given the existing tendency to dispose of this type of waste.

Figure 21. Comparison of the official collection with the volumes of textiles found in the unsorted waste stream (kg/capita)



Finally, a comparison with waste generation levels shows that these often exceed the current Italian estimate of 22 kg per capita per year. This figure exceeds the European average of 18 kg per capita (European Environment Agency, 2025).

Lower quantities of textile waste were found among the unsorted waste streams in the sampled cities where door-to-door collection services were in place (see City 9 in Figure 23).

As with WEEE, differences in behaviour regarding textile waste can be observed between large and small urban centres. Figure 23 shows that cities with more than 100,000 inhabitants only manage to

intercept 9% of disposed textile waste through official channels, compared to an average of 17% in cities with fewer than 100,000 inhabitants (Figure 22).

Figure 22. Comparison of the quantities of textile waste found in unsorted waste collected by official channels with the estimated annual waste generated by cities with fewer than 100,000 inhabitants.

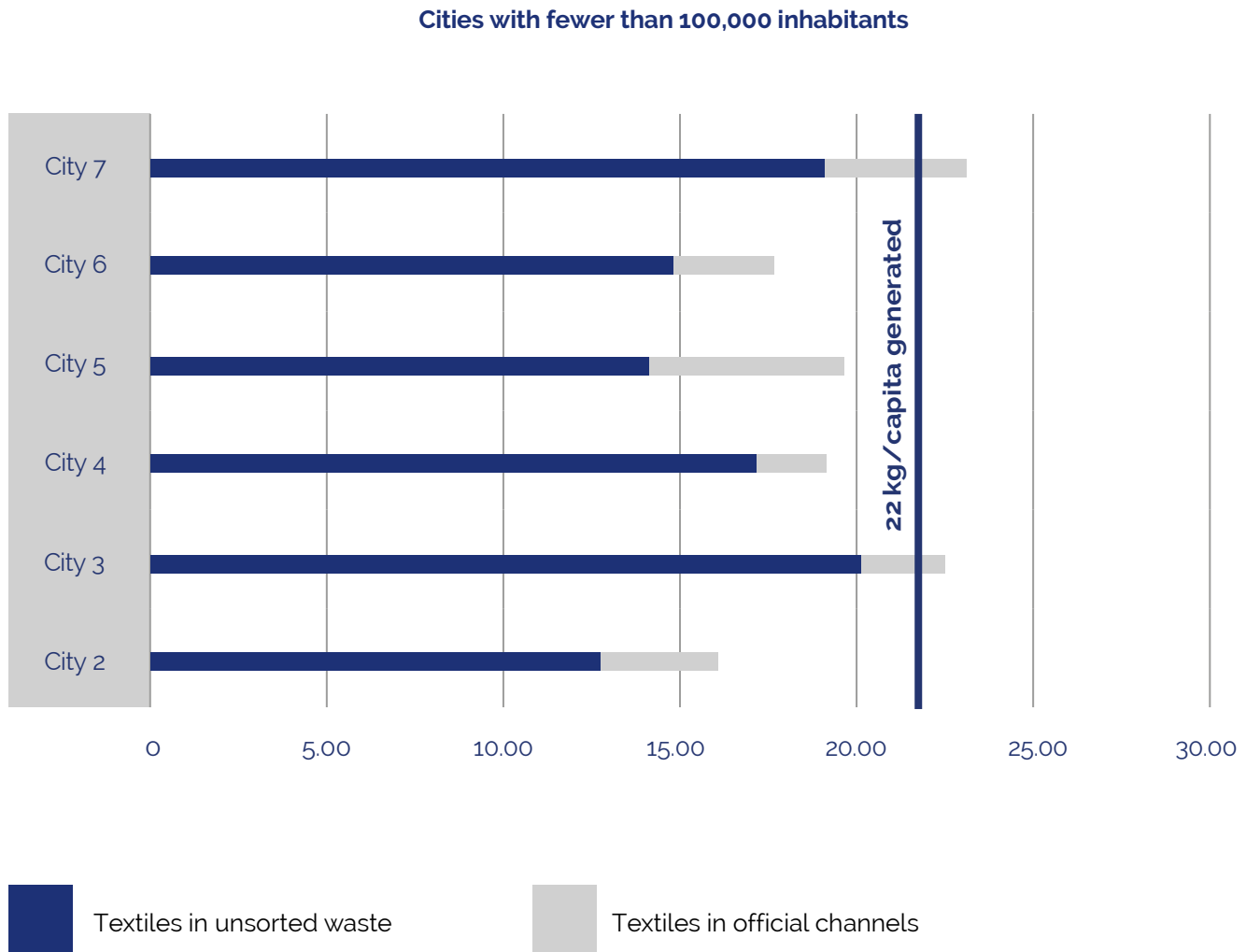
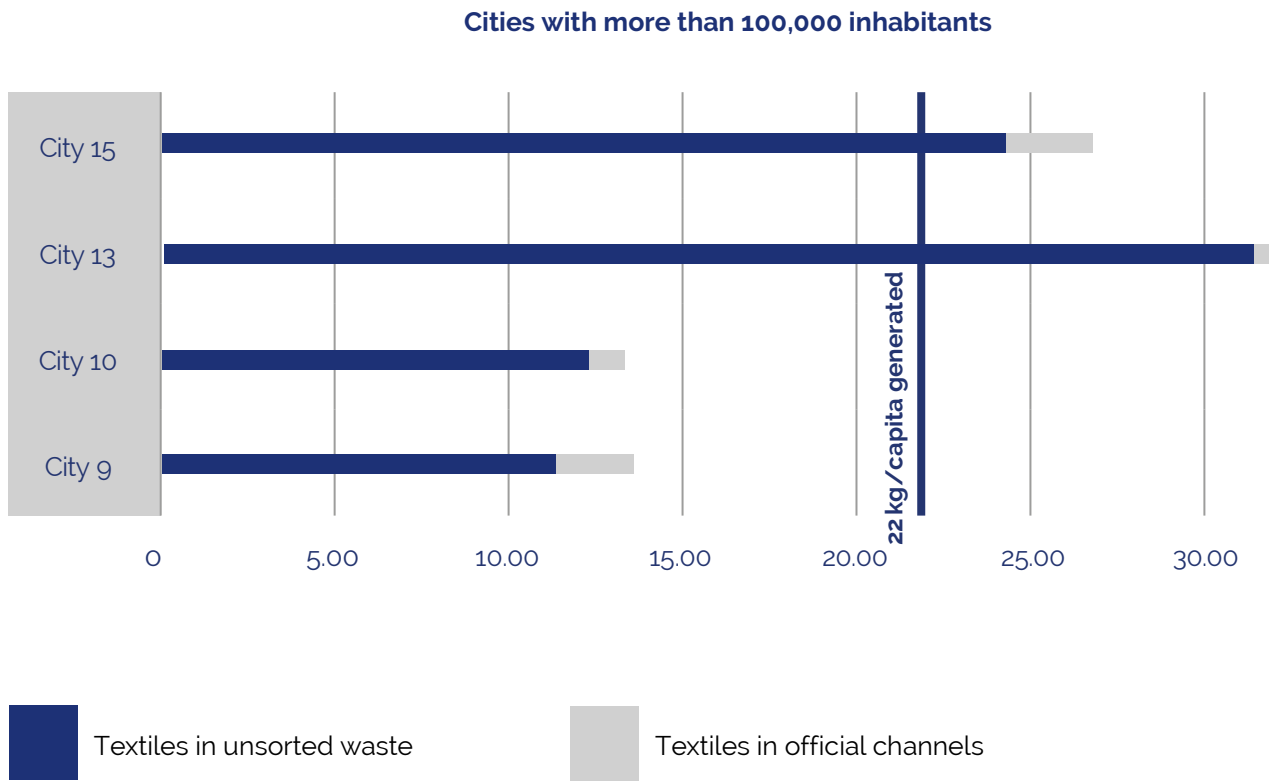


Figure 23. Comparison of the quantities of textile waste found in unsorted waste collected by official channels with the estimated annual waste generated by cities with more than 100,000 inhabitants



4. Discussion

4.1 Failure to properly dispose of waste

The analysis reveals that a significant amount of waste remains 'unaccounted-for' when estimated waste generation is compared with volumes collected by official channels and contained in unsorted waste. However, this varies for WEEE, WB and textile waste. Accurate estimation of the data hinges entirely on quantifying waste generated by the three streams. This, in turn, depends on the quantities placed on the market in previous years. Therefore, reliable data on these quantities is essential for accurately estimating the volume of unintercepted waste.

The reasons for failing to intercept waste can be attributed to various well-known infrastructural and cultural phenomena.

- (i) In the case of WEEE, waste that has been disposed of correctly may be managed by non-accredited facilities that ignore reporting obligations, or it may be managed through untracked channels.
- (ii) As preliminary studies by the CDCNPA (National Quality Consortium, 2024) have indicated, waste may be present in other fractions of sorted municipal waste. These studies quantified the volumes of WB in the metal and plastic fractions.
- (iii) The final unaccounted-for fraction is that attributable to the urban mining phenomenon described above. As far as can be ascertained, this phenomenon is much more prevalent for

WEEE and WB than for textile waste. In the latter case, it is unusual for the total quantity of textiles in unsorted waste, or those collected by official channels, to be less than 3 kg per capita. However, in the case of WEEE and WB, the majority of urban centres have very low values for both analysed streams. In this sense, an effective strategy for intercepting incorrectly disposed of waste and waste remaining in citizens' homes could involve communication campaigns and studies and analyses to identify strategic collecting points, thereby improving the existing infrastructure.

- (iv) Unlike WEEE and WB, clothing is not forgotten in drawers or wardrobes, but disposed of in street containers or, mostly, as unsorted waste. This is because the waste chain that currently manages textile waste is mainly oriented towards reuse, and the resulting communication to citizens asks them to place only clothing in good condition in street containers. This indirectly conveys the message that non-reusable textiles should be disposed of as unsorted waste. The introduction of the future Extended Producer Responsibility (EPR) legislation for textiles will make producers responsible for managing textile waste. In collaboration with their collective schemes, they will launch initiatives to collect all unwanted clothing, accessories, home textiles and footwear and will develop recycling solutions, including for non-reusable items.

4.2. The separate collection

The significant discrepancy between the quantities of waste intercepted through official channels and those found in the unsorted waste stream suggests that collection systems are not yet effective enough to support a circular economy.

Cigarette butts (see Appendix I) are an exception and should be disposed of as unsorted waste. All other analysed waste is found in higher concentrations in unsorted waste than in the correct collection channels.

4.3. Focus on cities

Analysis of the data provided by the new samples, alongside the historical data made available by IPLA, indicates that the focus should be on large urban centres. These centres exhibit divergent yet equally intriguing behaviours in the various analysed waste streams. They are also ideal locations for awareness-raising initiatives and pilot waste collection schemes, as they offer the greatest potential for waste interception.

As the size of the city increases, the amount of WEEE in the unsorted waste stream increases. This suggests a lack of awareness of waste disposal methods, insufficient proximity of collecting points to key locations in the city, and a lack of personal connection to disposal sites, which are often not widely publicised. However, this is not the case for WB, as they do not show an increase in kg per capita as the size of the urban centre increases. This is probably because WB collection options are widespread,

modular and visible in local shops in both small urban centres and large city neighbourhoods. However, this does not mean that the infrastructure is sufficient to guarantee an official waste stream that will help to achieve collection targets. Clearly, this is not the case. Even if more waste is disposed of through official channels, or if the number of disposal options increases, this will not directly result in a reduction in unsorted waste. Therefore, providing the necessary services to ensure that citizens can dispose of this waste properly once they are adequately trained and informed is a priority. However, raising awareness and effective communication must not be overlooked. For example, the only outlier for WB intercepted by official channels in the large urban centre category (with over 100,000 inhabitants) has a large number of dedicated disposal options. This city is also one of the 30% of cities covered by the study that are registered with the *junker* app, which provides citizens with a detailed map showing these options.

4.4. Recovery potential

In order to quantify the phenomenon of WEEE, WB and waste being disposed of in unsorted waste, it is helpful to estimate the total volumes that could potentially be recovered from the unsorted waste fraction in Italy. These figures can then be compared with the official collection rates for these three types of waste. Extrapolating the sampling results to cover

Italy as a whole — bearing in mind that the sampled areas may not be statistically representative — enables us to estimate a new collection rate for WEEE, WB and textile waste, assuming that all waste currently disposed of in the unsorted fraction is intercepted.

Table 2 shows the current collection rate values, which are calculated using the average quantities of products placed on the market (for WEEE/WB) over the last three years, as well as an estimated Italian textile waste consumption rate of 23 kg/capita/year (Köhler, 2021). It also shows updated collection rate

values that take waste found in unsorted waste into account. The volume of waste in the unsorted waste was estimated by multiplying the percentage found in the samples by the total amount of unsorted waste in Italy (9.7 million tonnes).

Table 2. Estimated collection rates obtained by intercepting volumes of unsorted waste.

Fractions	Total official collection volume in Italy in 2024 (t)	Estimated total volume present in unsorted waste (t)	Current collection rate	Collection rate based on volumes intercepted in unsorted waste	Collection target under applicable legislation
WEEE (R4 and R5)⁴	84,352	100,872	17%	37%	65%
Portable Waste Batteries⁵	5,497	5,820	25%	52%	45%
Textile waste⁶	171,539	838,983	13%	74%	N/A

For all waste fractions, the volumes of waste that can be traced in unsorted waste exceed the official collection figures. Therefore, this would significantly help to bring the Italian system closer to achieving its collection targets. As has been widely highlighted, intercepting this waste can certainly be achieved through more effective public awareness campaigns on waste disposal, in addition to normal separate waste collection. However, this must be accompanied by the development of a more efficient and widespread infrastructure comprising

well-publicised and visible disposal points in strategic locations in cities with high footfall. Consequently, in the long term, it is essential to focus on public awareness initiatives aimed at reducing the amount of these streams in unsorted waste. Ultimately, this problem could be approached as a technological challenge, requiring the development and implementation of innovative sorting systems to intercept and separate the desired waste from the unsorted waste stream.

⁴ CDC RAEE data

⁵ The total annual collection and the current collection rate are derived from data provided by the CDCNPA and adjusted to exclude lead batteries, since they are no longer categorised as portable batteries under Regulation (EU) 2023/1542.

⁶ Data on waste generation used to calculate the collection rate were obtained from the ISPRA Waste Registry (ISPRA, 2024) and JRC data (Köhler, 2021).

5. Conclusion

This study provides valuable insights into the effectiveness of existing collection networks in different urban contexts. It offers a solid basis for further research into determining which solutions are effective and which are not. The evidence gathered can therefore be used to inform targeted infrastructure projects and communication initiatives, enabling strategies to be adapted to the specific characteristics of each city based on concrete data.

This approach offers the greatest potential for minimising unintercepted waste and achieving collection targets.

The study highlights the significant potential for recovering materials from unsorted waste, particularly in large urban centres, where incorrectly disposed waste tends to be concentrated. It is clear that a significant proportion of WEEE, WB and textile waste end up in the unsorted waste stream, having not been intercepted by official collection channels. This data reveals shortcomings in both the management of waste disposal systems and citizens' awareness of how to dispose of waste properly. Despite being strategic intervention points, cities with higher population densities and larger sizes have not yet fully exploited their collection potential, particularly with regard to electronic equipment and waste batteries.

Failing to intercept these waste streams can result in economic losses and serious environmental damage. Improper waste disposal, fuelled by cultural and infrastructural factors, is one of the main causes of inefficiency.

Future actions could focus on two main areas:

- 1. Awareness and communication campaigns:** informing citizens about the benefits of correctly disposing of WEEE, WB and textile waste, and raising awareness of the locations and accessibility of dedicated collecting points.
- 2. Enhancing collecting points:** investing in creating and promoting well-distributed, easily accessible collecting points, particularly in densely populated urban areas.

This study therefore establishes a foundation for exploring the most effective actions and areas with the greatest potential for improving the collection and proper disposal of waste across all five streams. Further sampling will therefore be necessary in future studies to collect more robust and representative data, and to improve the accuracy of estimates. This is particularly important with regard to waste streams involving cigarette butts and EEE packaging. In addition, regular sampling could be planned, especially after measures to raise awareness and improve collection points have been introduced, to verify their effectiveness.

Further studies are also needed to refine waste generation estimates for all streams, in order to more accurately assess the efficiency of our current infrastructure at intercepting waste more accurately.

Appendix I: Cigarette butts

Of all the waste types examined, cigarette butts require an introduction to the analysis. Unlike other types of waste, they can be disposed of in unsorted waste, as there is no legal obligation to collect them separately.

As there is a limited amount of available data, which prevents any statistical inference, the results of the campaign are presented as a range for waste produced per capita reconstruction (Figure 25).

The disposal of cigarette butts in household waste differs significantly from other waste streams: it does not occur consistently and across the entire population. Instead, cigarette butts tend to accumulate in homes and other private spaces before being sporadically disposed of as unsorted waste. This irregularity means that the size of the sample used for analysis is critical.

Figure 24. Percentage of cigarette butts by weight in unsorted waste per individual sampling

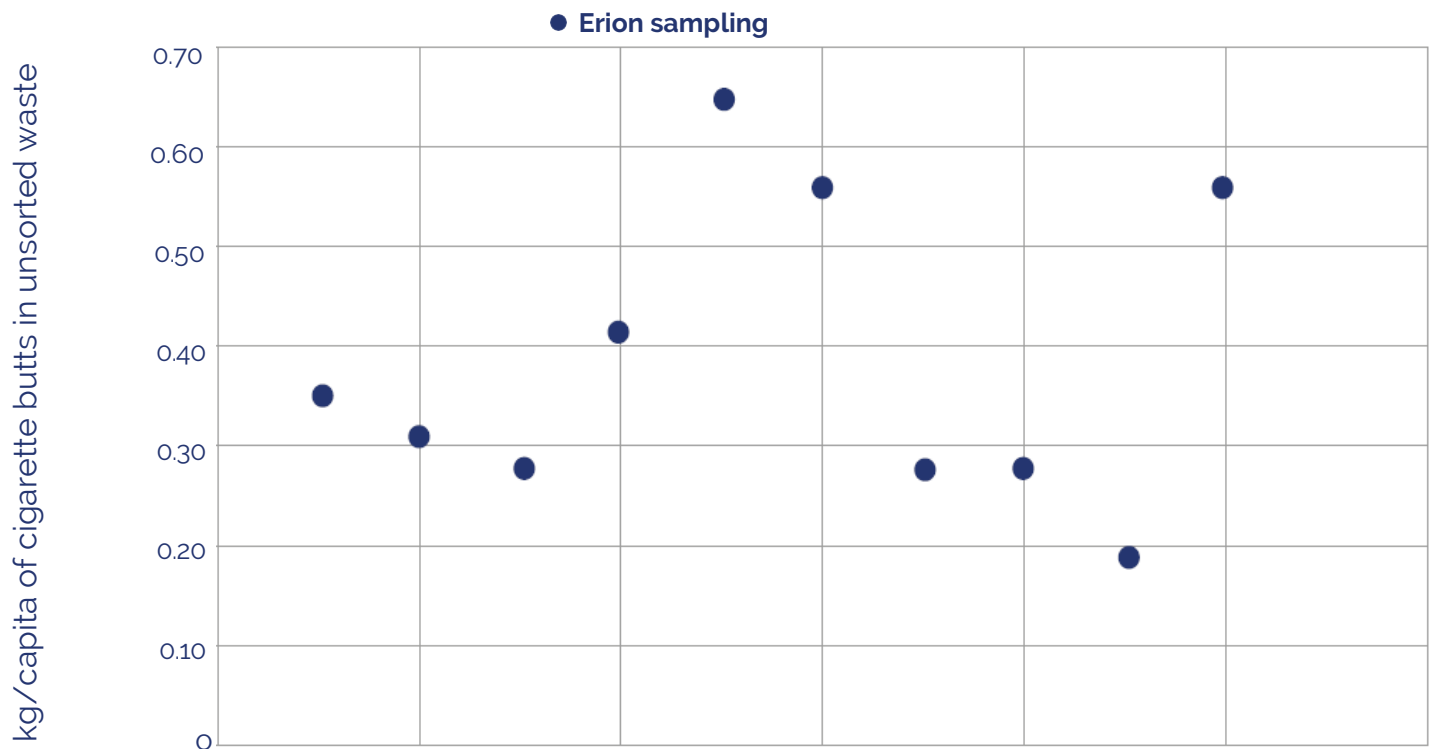
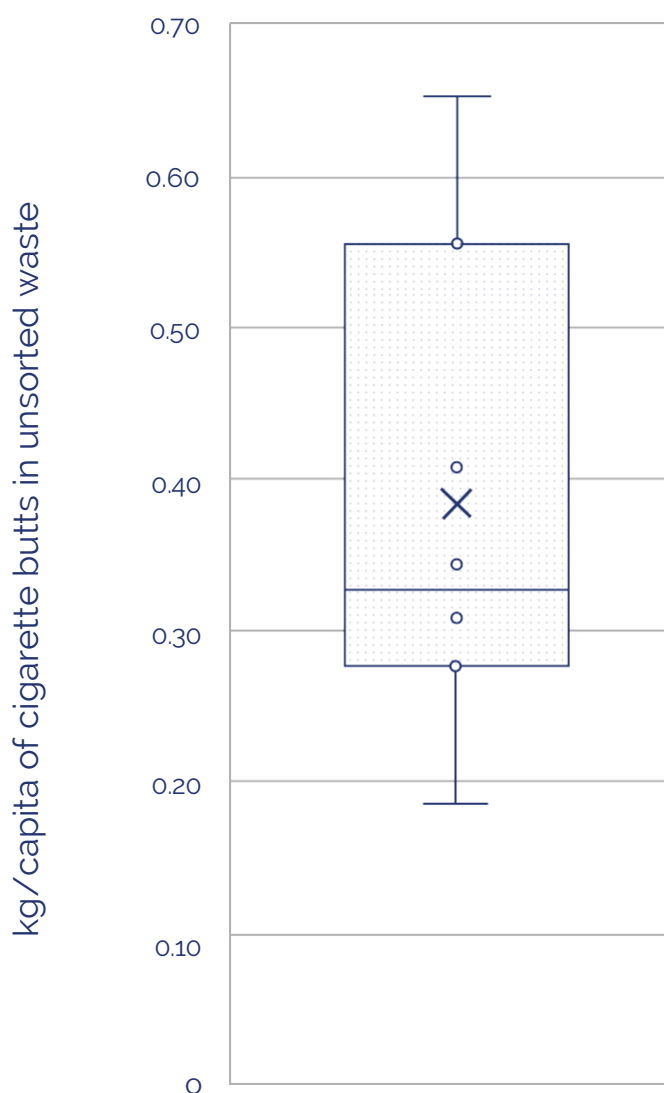


Figure 25. Range of values (kg/capita/year) derived from the various sampling data



Based on estimates of the number of filters marketed in combination with tobacco products and the average weight of cigarette butts, Italy's annual per capita production of cigarette butts is around 0.4 kg. For the purposes of this study, a pilot sampling phase was conducted to determine the prevalence of

cigarette butts in unsorted waste. To assess the operational and methodological feasibility of the analysis, ten batches of waste from four cities, evenly distributed between northern and southern Italy (two cities for each geographical cluster), were analysed.

Figure 26. Cigarette butts found in a sample after further analysis of the undersize fraction



As expected, the small sample size means that it is not possible to draw statistically representative conclusions. Nevertheless, the results collected are indicative. It is important to note that the minimum recorded value is 0.28 kg per capita, even when accounting for outliers. Taking into account that unsorted waste may include waste from street bins and street cleaning, as well as household waste, this

result supports the hypothesis that approximately one third of products are discarded on the ground, while the remainder are disposed of correctly. This situation underscores the importance of awareness campaigns that encourage citizens to properly dispose of this type of waste and prevent its abandonment in the environment.

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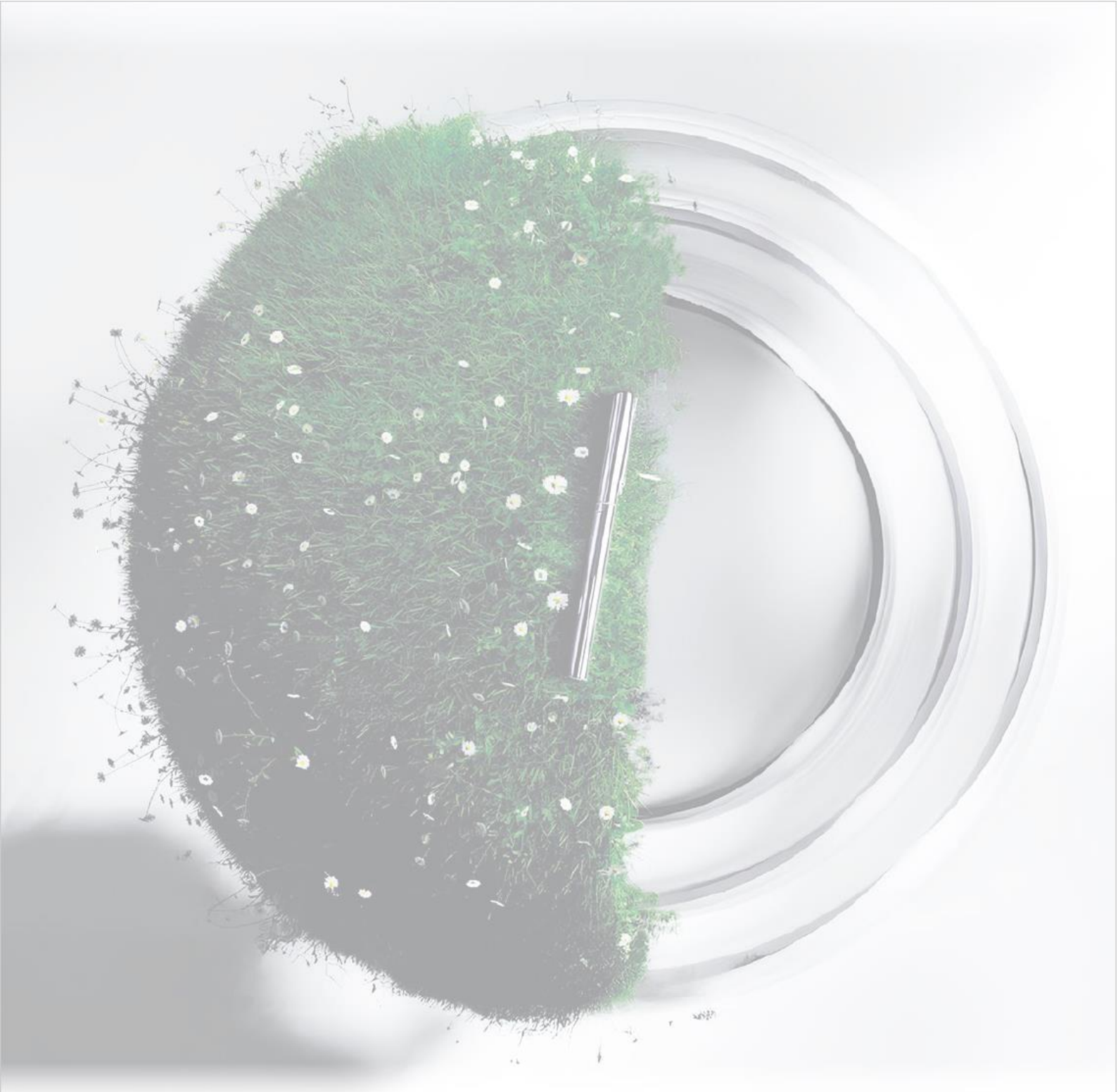
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