paper and packaging waste collection systems

An analysis by the ACR+ European Observatory on municipal waste performances

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The report is based on data collected within the framework of the H2020 COLLECTORS project. More information: www.collectors2020.eu

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Executive summary

This study contributes to the ACR+' Waste Observatory, whose objective is to allow consistent comparisons among local and regional authorities, in order to provide benchmark on municipal waste management, and identify effective waste strategies enabling quality recycling.

It takes advantage of the H2020 COLLECTORS project that aims at identifying good practices to improve the quantity of sorted municipal waste leading to high quality recycling. The COLLECTORS project focuses on three waste fractions: paper and packaging waste (PPW), waste electrical and electronic equipment (WEEE), and construction and demolition waste (CDW).

In its early stage, COLLECTORS collected data on municipal waste management across Europe, which led to the documentation of 135 PPW collection systems. This report proposes an analysis of the collected data, to provide an overview of the different organisations and an analysis of the local performances of these waste collection systems (WCS).

Overview of the WCS covered

The collected data on paper and packaging waste cover EU Member States and represent about 12% of the total EU population, mixing different territories: big cities, remote areas, or islands. The panel covers a great diversity in terms of population density, tourism activity, and GDP.

The overview highlights the great diversity of collection systems across Europe, with many different sorting systems and combination of collection modes.

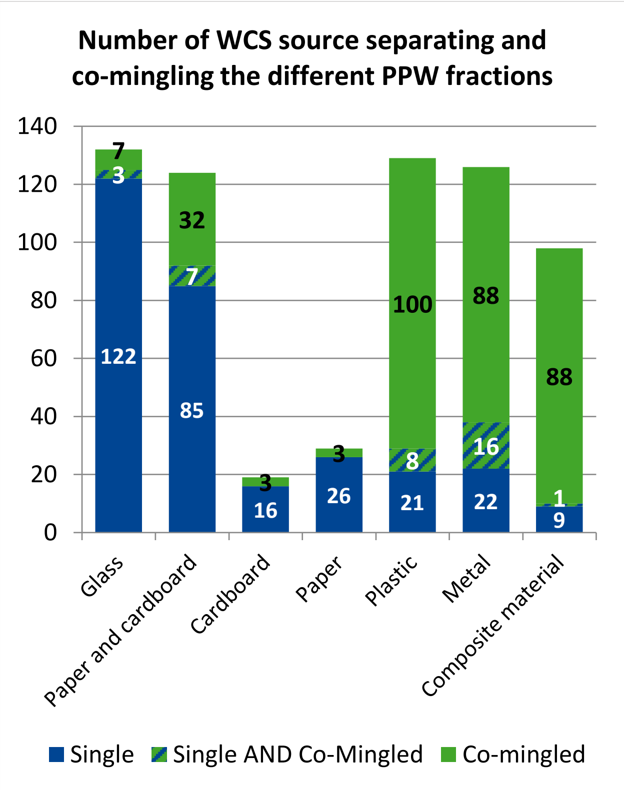

Figure 1: Level of separation for the different waste fractions

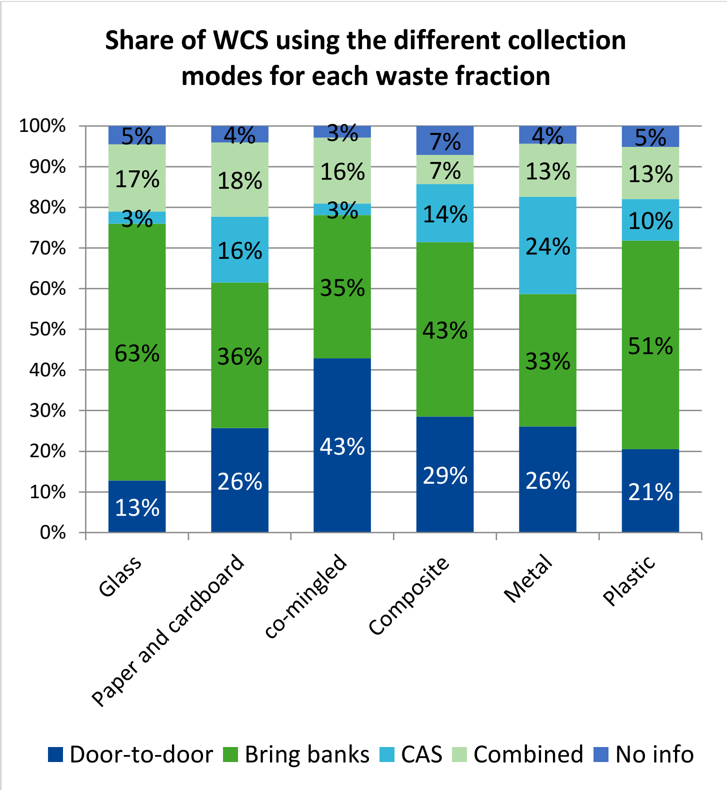

Figure 2: Share of WCS using the different collection modes for each waste fraction

Overall, glass and paper/cardboard are more commonly source-separated, while plastic, metal, and composite packaging ("PMC") are more commonly co-mingled. Different collection modes can be used in the same waste collection systems. To classify the different WCS, they were labelled according to their main collection modes ("door-to-door", "bring bank", and so on) as soon as it is used to collect more than 60% of the collected PPW. In case that no collection mode is dominating, the WCS is labelled as "combined".

There are some common trends: the use of bring system for glass packaging is quite widespread, and the "PMC" system (source-separating glass and paper/cardboard, and co-mingling the other packaging) is the most widespread across the different Member States.

While some Member States seem to have common separation systems, others encompass very diverse schemes.

When it comes to specific context, it appears that door-to-door systems are more widespread in WCS with high GDP, while bring bank systems are a bit more common in average and low-GDP areas. Besides, the implementation of the different collection modes varies among the WCS, with very different collection frequencies for door-to-door systems, and significant differences regarding the density of collection points among bring bank systems.

PPW generation

The significant number of documented WCS and the diversity of the panel allow the identification of correlations between the local context and the total generation of PPW. In general, municipal waste generation is the result of many different factors (consumption patterns, local conditions, scope of municipal waste, impact of the non-resident population, imports and exports, etc.).

When it comes to PPW, several parameters seem to impact the waste generation. The most noticeable one is tourism activity: in extremely touristic areas, e.g. where the number of non-resident waste producers is significant compared to the resident population, the generation of PPW per capita is significantly higher than in the other WCS.

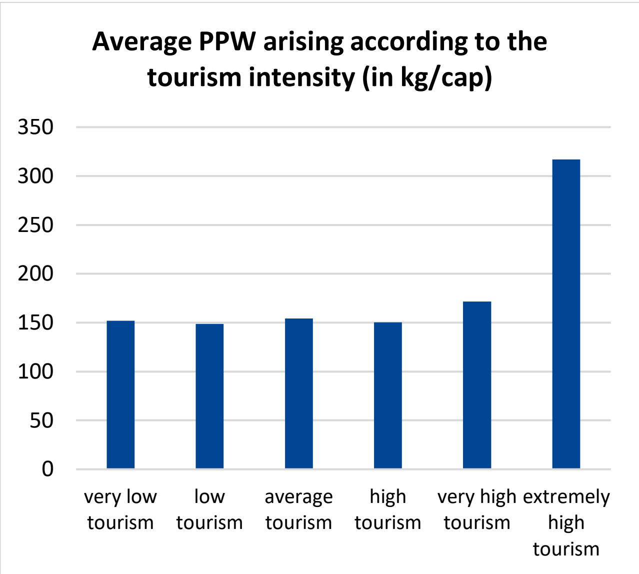

Figure 3: Average PPW arising according to the tourism intensity (in kg/cap)

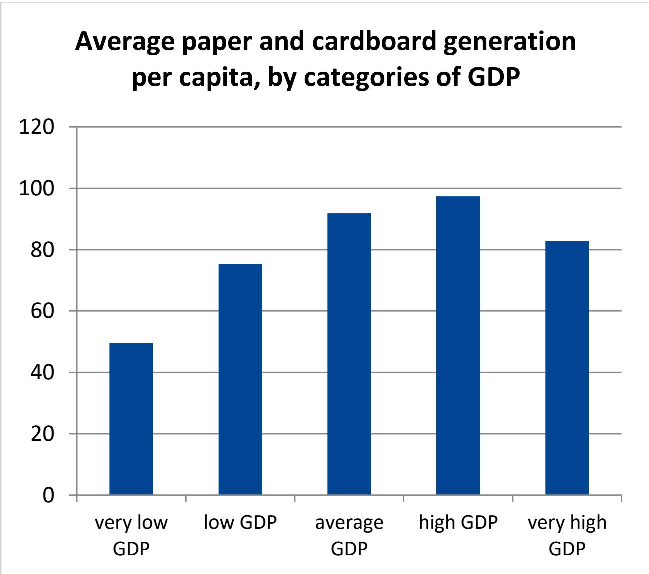

Figure 4: Average paper and cardboard generation per capita, by categories of GDP

Likewise, paper and cardboard generation per capita seems to be higher in high-GDP areas, which might reflect the impact of non-household activities on municipal waste generation.

Performance of PPW management

Two external parameters can be associated with lower performances: territories with very high population and areas with very low GDP generally present lower recycling performances.

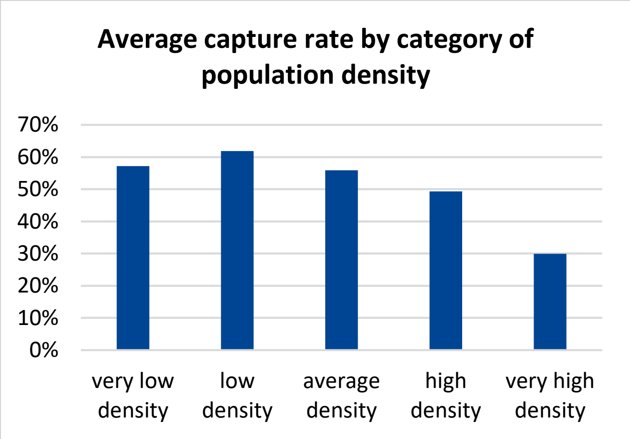

Figure 5: Average capture rate by category of population density

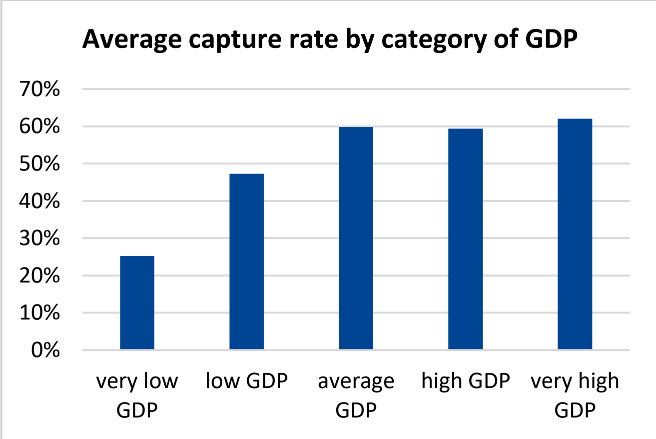

Figure 6: Average capture rate by category of GDP

When it comes to successful waste strategies, the analyses tend to show that the key to success seems to lie in the combination of various instruments:

- **Source separation**: system source-separating glass and paper/cardboard tend to present better performances, while the source-separation of PMC does not seem to be correlated with higher performances;
- **Collection mode**: interestingly, "door-to-door" systems and "bring bank" systems present on average comparable performances, and it seems that both types of collection enable very high performances. It does not necessarily mean that both collection modes would give the same performances in one given territory;
- For **bring bank systems**, a higher density of containers (i.e. the number of containers per km²) tends to lead to higher capture rates, while there is no correlation between the number of containers per inhabitant. It reflects the fact that the proximity is a key factor of success;
- For **door-to-door systems**, WCS having a higher collection frequency for residual waste than PPW tend to have lower capture rates;
- **PAYT**: systems using PAYT present higher capture rates and lower generation of residual waste. Almost all of the top-performing territories have implemented such as system.

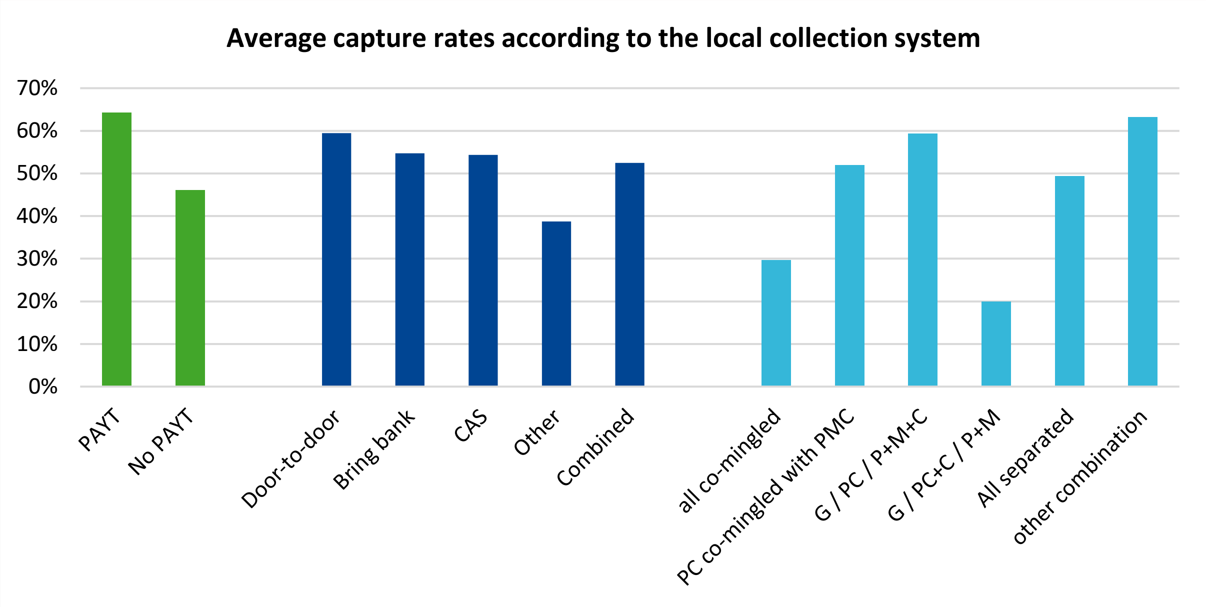

Figure 7: Average capture rates according to the local collection system

However, none of these instruments can explain or guarantee high performances. This reflects the fact that successful waste strategies rely on a consistent mix of instrument, including communication and incentives.

Conclusion

The available data do not allow to obtain a complete understanding of success factors. Some important elements could not be documented, such as communication, the organisation of pre-collection, or how incentive the different PAYT systems are, among others. Besides, little is known on the outcome of sorted fraction after the final sorting stage. Data on impurity rates and actual use of sorted materials are generally not available, which limits the possibilities of understanding the contribution of well-performing system to the circular economy.

The national or regional framework also plays an important role of enabling high-performing WCS: regulation, taxes on incineration and landfilling, extended producer responsibility scheme. Top-performing systems are located in a limited number of Member States, which might reflect the importance of a framework promoting recycling over disposal.

The COLLECTORS project will address the questions of quality and use of sorted materials, by conducting in-depth analysis of well-performing systems to better understand their environmental and economic impact. These findings will contribute to improve the knowledge of the Observatory.

Abbreviations

ACR+	Association of Cities and Regions for sustainable Resource Management
CDW	Construction and Demolition Waste
Cap	Capita
C	Composite
CAS	Civic Amenity Site
DREC	Destination Recycling
EPR	Extended Producer Responsibility
G	Glass
GDP	Gross domestic product
Inh.	Inhabitants
M	Metal
N.A.	Not Available
Nb.	Number
P	Plastic
PC	Paper and Cardboard
PPW	Paper and packaging waste
PAYT	Pay-as-you-throw
PET	Polyethylene terephthalate
PMC	Plastic Metal Cartons
RDF	Refuse-derived fuel
WCS	Waste Collection System
WEEE	Waste Electronic and Electrical Equipment

Table of content

List of figures

List of tables

Foreword - ACR+ European Observatory on municipal waste performances

Launched in 2010, ACR+ European Observatory on municipal waste performances was created following a strong demand from ACR+ members to allow consistent comparisons among local and regional authorities. The Observatory was established to serve several purposes:

- Define methods for common comparisons based on common scope and definitions;
- Identify effective practices and measures to improve recycling performances;
- Allow benchmarking among territories sharing the same constraints (high density, tourism…);
- Compare local performances with EU targets.

The Observatory has led to the production of several reports:

- ACR+ developed a Waste Data Matrix, completed by approximately 17 members of the Observatory with their data for 2009. This first set of calculation with a harmonized methodology led to interesting comparisons and conclusions summarized in the Observatory Report published in early 2013;
- Cross-analysis of "Pay-As-You-Throw" schemes in selected EU municipalities;
- Report on bio-waste selective collection schemes;
- Report presenting data from 17 European cities and proposing a cross-analysis.

Between, 2012 and 2014, ACR+ took advantage of the R4R project to consolidate its work on the Observatory. The main outputs of the projects were:

- The definition of a common language for local and regional authorities wishing to share good practices, based on a common method for data comparisons, a list of local instruments to detail waste strategies, as well as external factors impacting waste performances and strategies;
- The identification of 39 good practices detailing successful implementations of local instruments and documented with quantitative data;
- An online tool allowing any public authority to input and compare its data based on the R4R method;
- A final report drawing the main conclusions on effective instruments and good practices when it comes to municipal waste recycling.

In December 2017, the H2020 COLLECTORS project was launched. It focuses on how to improve selective collection of paper and packaging waste, WEEE, and construction and demolition waste. The COLLECTORS project involves collection of municipal waste data and in-depth analysis of local waste collection systems, and thus is an interesting asset for the Observatory.

1. Introduction

This report proposes a study of municipal waste data collected within the framework of the H2020 COLLECTORS project, as a part of the ACR+ Observatory.

The COLLECTORS project aims to identify good practices in order to improve the collection of municipal waste, focusing on three fractions: paper and packaging waste (PPW), WEEE, and construction and demolition waste (CDW). More specifically, the main objective of the COLLECTORS project is to harmonize and disclose available information on different waste collection systems; to gain better insight into the overall performance of systems; and to support decision-makers in shifting to better-performing systems. To reach this goal, COLLECTORS will create an inventory of waste collection practices, assess the performance of twelve case studies, and establish implementation guidelines and policy recommendations for decision-makers.

The COLLECTORS consortium collected a large number of datasets on municipal waste collection systems (WCS) focusing on the three waste fractions. The collection of data focused on local authorities in charge of municipal waste collection (e.g. municipalities and groups of municipalities), according to a common template. Data were collected from publicly-available sources and through direct contacts with competent authorities. The collected data are for the most part presented in the COLLECTORS Web platform.

The project does not foresee to publish a report presenting an analysis of the collected data, therefore it was decided to publish an analysis of the data related to the PPW, which encompass 135 different waste collection systems (WCS). This report is published within the framework of the ACR+ Observatory.

The analysis of data was conducted after an important work on the COLLECTORS database to harmonise the terminologies and ensure the quality and consistency of the data. However, considering the large number of waste collection systems and the fact that the data were collected by many different people, it is possible that some inconsistencies remain.

The report focuses on the presentation of the collected data and a cross-analysis of the local recycling performances, and of correlations between the level of performance, local instruments in place, and the local context.

2. Overview of the WCS covered

2.1 Member states

The collected data on paper and packaging waste covers 135 systems in 21 EU Member States, as presented in the list below:

Table 1: Member States and population covered by the WCS documented by the COLLECTORS project for PPW

Member States	Number of WCS	Number of inhabitants	Total population	% of the national population covered	% of population within the panel	% of the population within the EU
Austria	5	2,215,847	8,822,267	25%	4%	2%
Belgium	8	3,307,905	11,413,058	29%	5%	2%
Bulgaria	4	2,164,660	7,050,034	31%	4%	1%
Croatia	9	1,331,147	4,105,493	32%	2%	1%
Cyprus	1	55,014	864,236	6%	0%	0%
Czech Republic	1	1,296,829	10,610,055	12%	2%	2%
Denmark	1	602,481	5,781,190	10%	1%	1%
Finland	2	1,477,535	5,513,130	27%	2%	1%
France	21	12,280,079	67,221,943	18%	20%	13%
Germany	13	9,261,873	82,850,000	11%	15%	16%
Greece	1	664,046	10,738,868	6%	1%	2%
Hungary	2	1,809,631	9,778,371	19%	3%	2%
Italy	9	6,233,551	60,483,973	10%	10%	12%
Lithuania	3	960,864	2,808,901	34%	2%	1%
Luxembourg	1	115,227	602,005	19%	0%	0%
Malta	1	450,415	475,701	95%	1%	0%
Poland	4	3,170,309	37,976,687	8%	5%	7%
Portugal	1	135,845	10,291,027	1%	0%	2%
Slovakia	1	425,923	5,443,120	8%	1%	1%
Slovenia	5	538,345	2,066,880	26%	1%	0%
Spain	8	6,384,090	46,659,302	14%	11%	9%
Sweden	2	1,264,113	10,120,242	12%	2%	2%
The Netherlands	25	2,305,020	17,118,084	13%	4%	3%
UK	7	2,162,025	66,238,007	3%	4%	13%
Grand Total	**135**	**60,612,774**	**512,647,966**	**12%**	**100%**	**100%**

The population covered by the documented WCS represents about 12% of the total EU population. Some Members States seems over-represented in the panel (Bulgaria, France, Spain…) while other seems underrepresented (the UK, as well as the 4 Member States for which no data was collected).

It is important to keep this in mind when analysing the collected data. While the number of documented WCS is significant, the panel might not be regarded as completely representative of the

European situation as a whole (e.g. the distribution of the different collection methods or systems of source separations might not be representatives of the actual European situation).

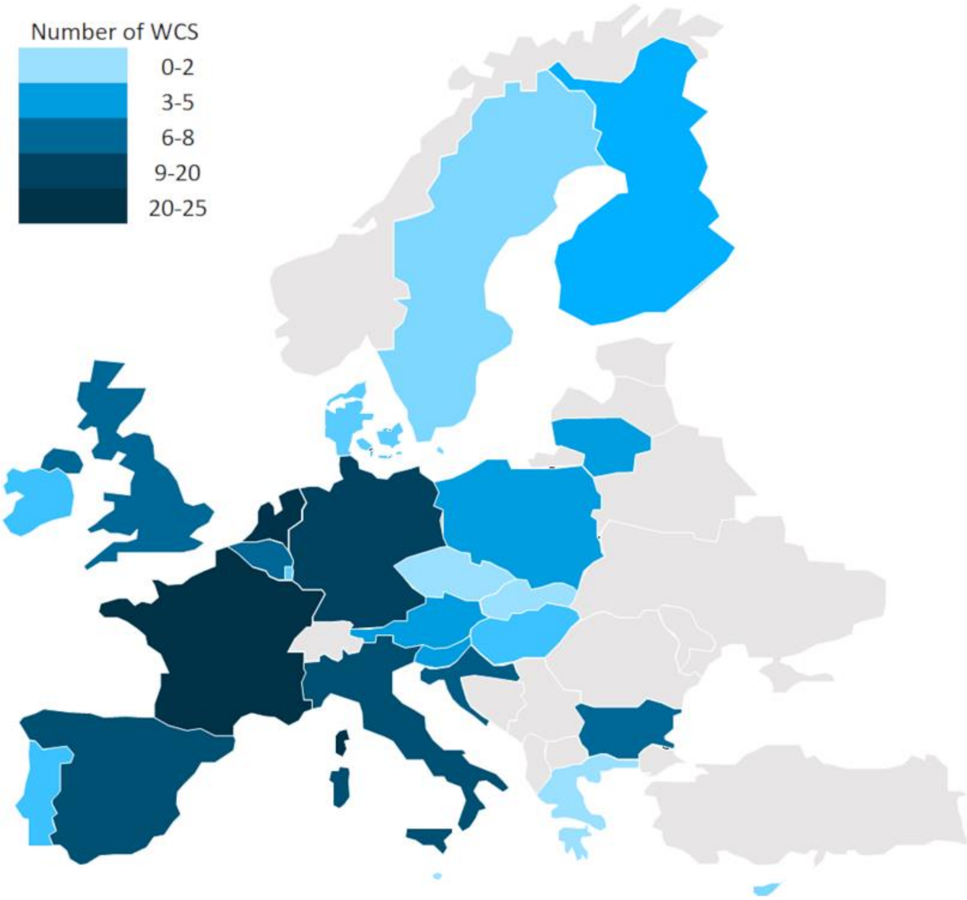

Figure 8: Member States where datasets were collected

2.2 Type of local authorities

The documented WCS concerns local authorities, e.g. municipalities or consortium of municipalities. Their distribution is presented in the following scheme:

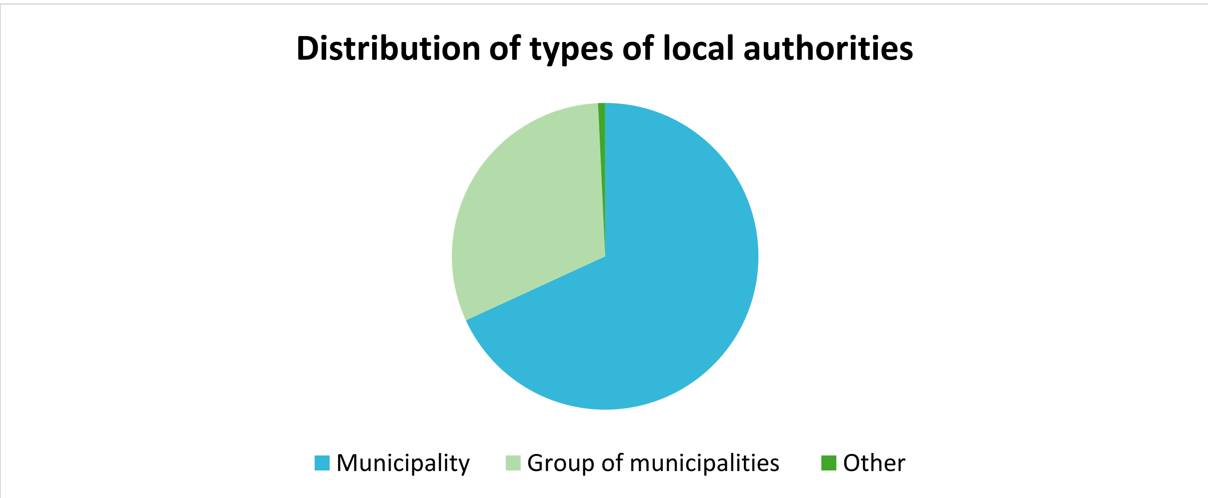

Figure 9: Distribution of the types of local authorities covered by the WCS

The “other” system is actually a district of a city. Group of municipalities can be found in 11 Member States, and half of them are in France, where the very high number of communes (and thus their median area and population is lower than in the other Member States) can explain the high presence of groups of municipalities compared to other members states.

2.3 Typology of territories

The WCS for which data were collected are classified according to their typology. The WCS were classified by each COLLECTORS partner in a qualitative way. The distribution of typologies is presented below:

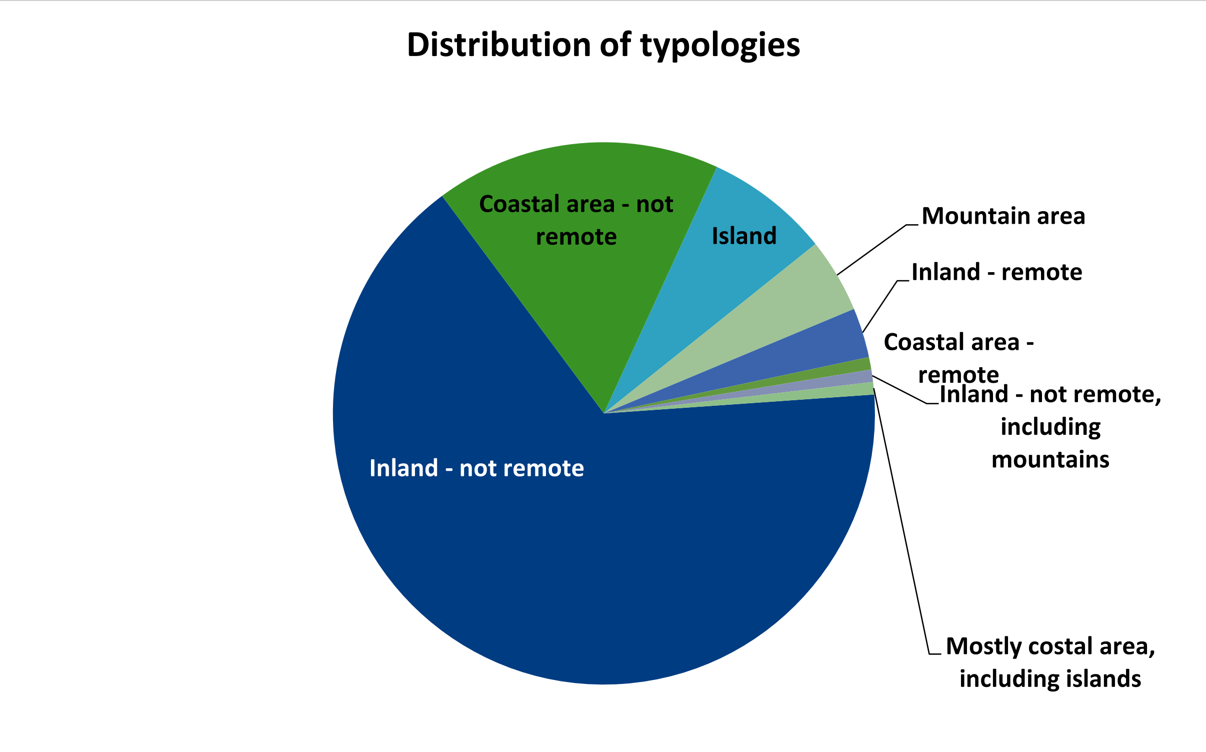

Figure 10: Distribution of typologies among the documented WCS

Most areas are not remote and located inland. Remote and mountains areas only represent 11 documented WCS.

2.4 Socio-economic characteristics

Various data regarding the local context were collected for the different territories: population, density, GDP, tourism-related information. For some of them, it was not possible to find exhaustive data. For several of them, data could be collected for most of the WCS. However, it is important to note that some of the values might not be calculated using the same methods, so the values might not be entirely reliable and comparable.

When it comes to population density, the panel is quite diverse. Densities range from 18 inh./km² (Oulu Region, Finland) to 21,000 in./km² (Paris, France). Three cities stick out in terms of population density: Paris, Athens, and Barcelona.

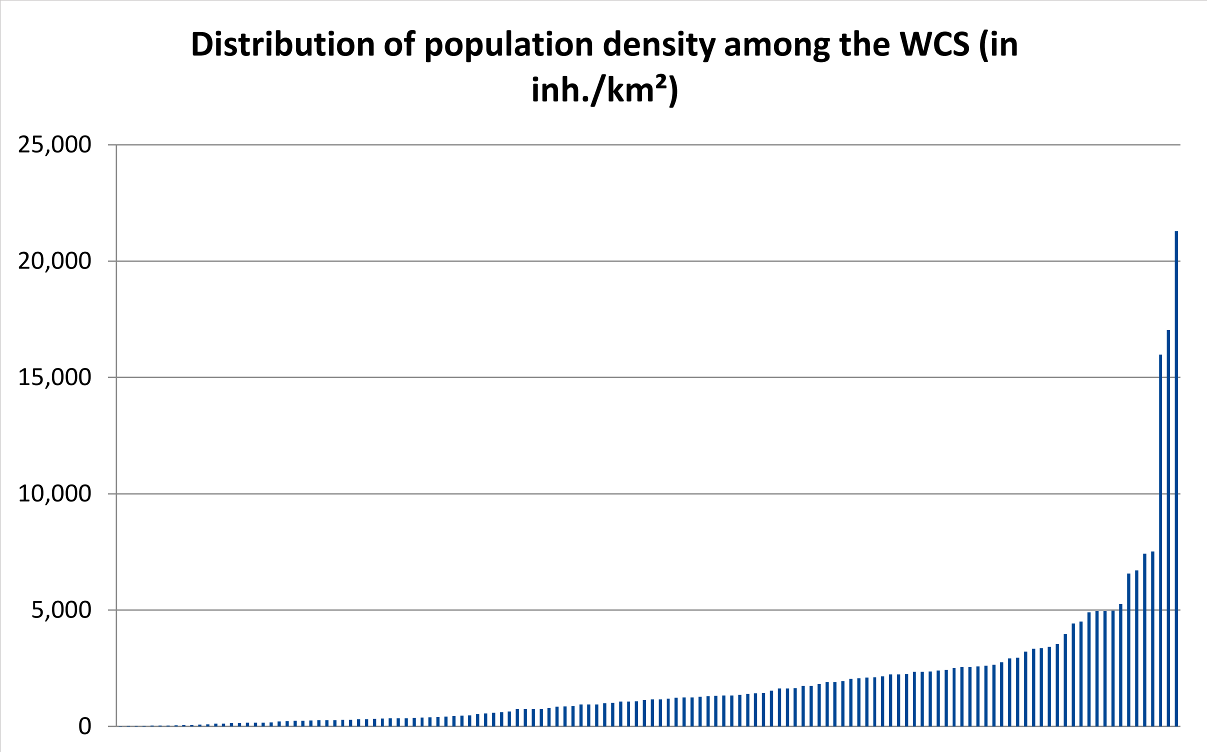

Figure 11: Distribution of population density among the WCS (in inh./km²)

The same diversity can be observed for Gross Domestic Product (GDP) per inhabitant, with a panel ranging from about 8,000 (Burgas, Bulgaria) to 90,000 €/cap (City of Luxembourg).

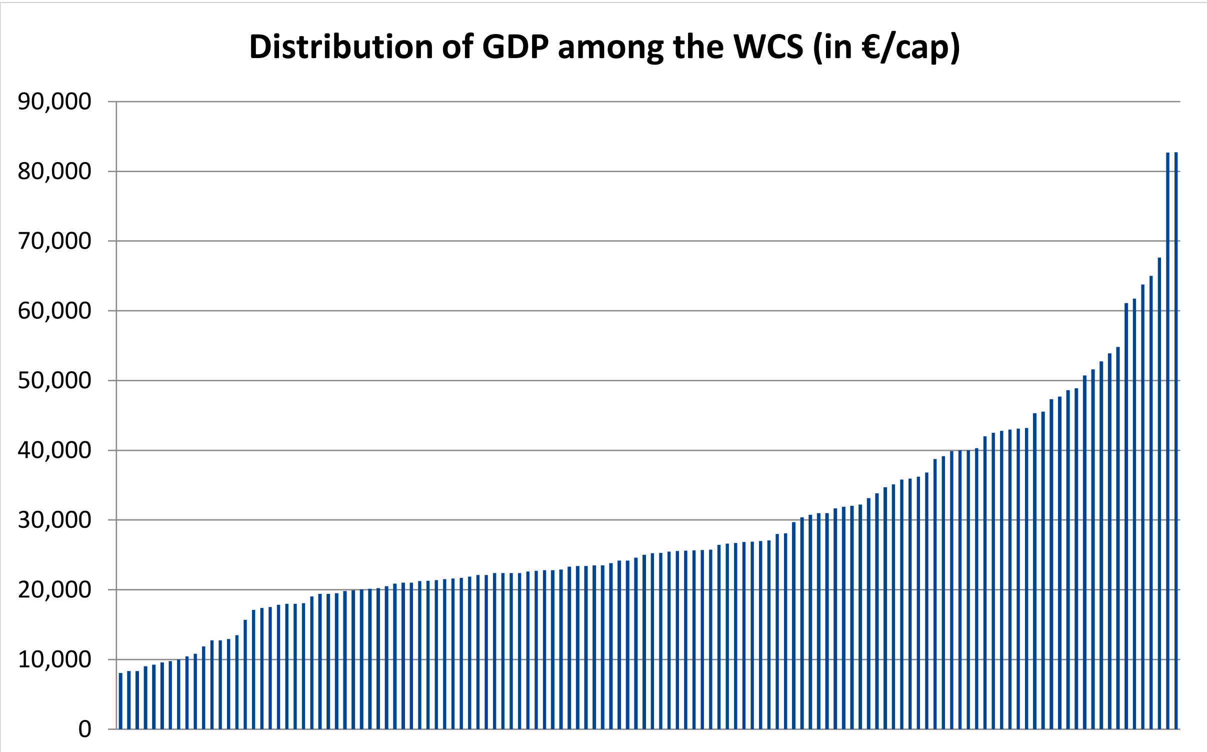

Figure 12: Distribution of GDP among the WCS (in €/cap)

There is no ideal indicator that allows a precise assessment of tourism activity. The only indicator for which data could be found for most WCS is the number of overnight stays in tourism accommodation compared to the resident population. There are some uncertainties regarding the exact definitions and calculation methods in use at local levels, which might limit the relevancy of comparisons. Moreover, this indicator overlooks part of the non-resident population that potentially produces waste, such as commuters or 1-day stays. While these data were included in the data collection, its low availability does not allow any analysis. Therefore, the “overnight stays per resident” indicator is the best available option to assess the tourism activities in the different WCS.

The distribution of values for this indicator is presented in the chart below:

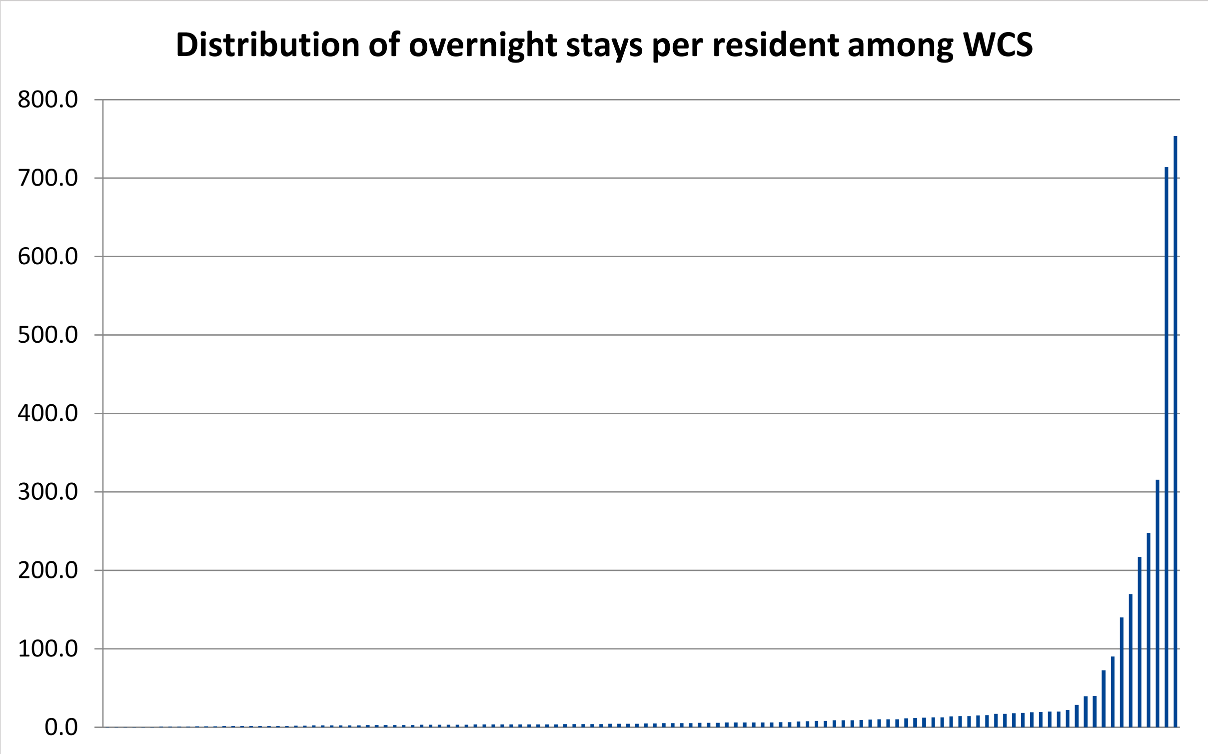

Figure 13: Distribution of overnight stays per resident among WCS

70% of the WCS are below 10 overnights per inhabitant, and about 90% are below 20. The territories where the tourism intensity is the highest are not necessarily the most well-known tourism destinations, but rather territories where the resident population is rather small compared the number of overnight stays. For instance, seven WCS have overnight stays per inhabitant above 100: they mainly in small islands and mountainous areas.

Categories were established to classify the WCS according to the density, GDP, and tourism activity. The categories were set to ensure a proper distribution of WCS among them and that there are sufficient numbers of WCS in every category, but also to reflect specific contexts that potentially impact waste collection. For instance, the “very low density” category includes territories below 100 inh./km², to represent territories encompassing remote populations. An “extremely high tourism” category was also created on top of the “very high tourism” category to include the few territories with significantly higher number of overnight stays per resident population, and for which the impact of tourism is likely to be more visible than the other territories. These categories are presented in the following tables:

Table 2: Population density categories

Name of the category	Range	Number of WCS
Very low density	0 – 100 inh/km²	12
Low density	100 - 500 inh/km²	33
Average density	500 – 2,500 inh/km²	60
High density	2,500 – 7,500 inh/km²	25
Very high density	> 7,500 inh/km²	4

Table 3: GDP categories

Name of the category	Range	Number of WCS
Very low GDP	0 – 10,000 €/cap	8
Low GDP	10,000 – 20,000 €/cap	22
Average GDP	20,000 – 35,000 €/cap	64
High GDP	35,000 – 50,000 €/cap	23
Very high GDP	> 50,000 €/cap	13

Table 4: Tourism categories

Name of the category	Range	Number of WCS
Very low tourism	0 – 2.5 stays/inh.	27
Low tourism	2.5 – 5 stays/inh.	33
Average tourism	5 – 10 stays/inh.	26
High tourism	10 - 15 stays/inh.	11
Very high tourism	15 - 50 stays/inh.	14
Extremely high tourism	> 50 stays/inh.	9

3. General organisation of PPW management

3.1 Scope and responsibilities

Municipal waste generally include waste generated by inhabitants along with non-household waste similar in quantities and composition to household waste from small commercial activities, public institutions… Besides, waste collected in public areas might or might not be included. The rules for non-household waste to be included in municipal waste are generally set at local level, for instance by setting a limit of the generated volume per week. It is also possible that the municipality also set specific services to commercial activities depending on their size and/or waste production. Regardless of the rules set by the local authorities, how it is enforced will also impact the scope, as commercial activities might not respect the rules and use the municipal service regardless of their waste generation. Commercial waste might be included or not in the municipal waste statistics.

The information is not available for 3 WCS. Among the 132 WCS for which the information is available, 97 local authorities collect household waste and similar, and 35 reported to only collect household waste. Most of them are located in the Netherlands, Italy, and the United Kingdom.

The responsibilities and handling of PPW are different across the documented WCS; usually, the general schemes are homogeneous within each Member States. Municipalities are generally in charge of organising municipal waste collection, or transfer their responsibility to an intermunicipal organisation or the county they depend on, which is very common in France and in Belgium. Municipalities can either operate the collection, or entrust the operations to a public or private company(ies). In several Member States, the organisation and operational implementation of collection and sorting fall under the responsibility of the extended producer responsibility organisations (PRO). This is the case in Austria, Germany, Finland, Greece, and Sweden. In Bulgaria, PRO can either fund or operate PPW collection. There can be shared responsibilities for specific fractions such as paper and cardboard (which mixes packaging and non-packaging waste).

Some WCS also report the existence of “parallel” collection schemes organised by e.g. local associations.

3.2 Separation systems

There is an important diversity of separation systems among the documented WCS, and many different combinations could be identified. However, there are also some trends when it comes to separation at the source and co-mingling.

Firstly, it is important to note that in some Member States, the separation system is common to all municipalities, as in Belgium. In others such as France, each municipality or group of municipalities can set its own separation system, meaning that they can decide to source separate or co-mingle the different PPW fractions.

The following chart presents the system of separations used for the various waste fractions:

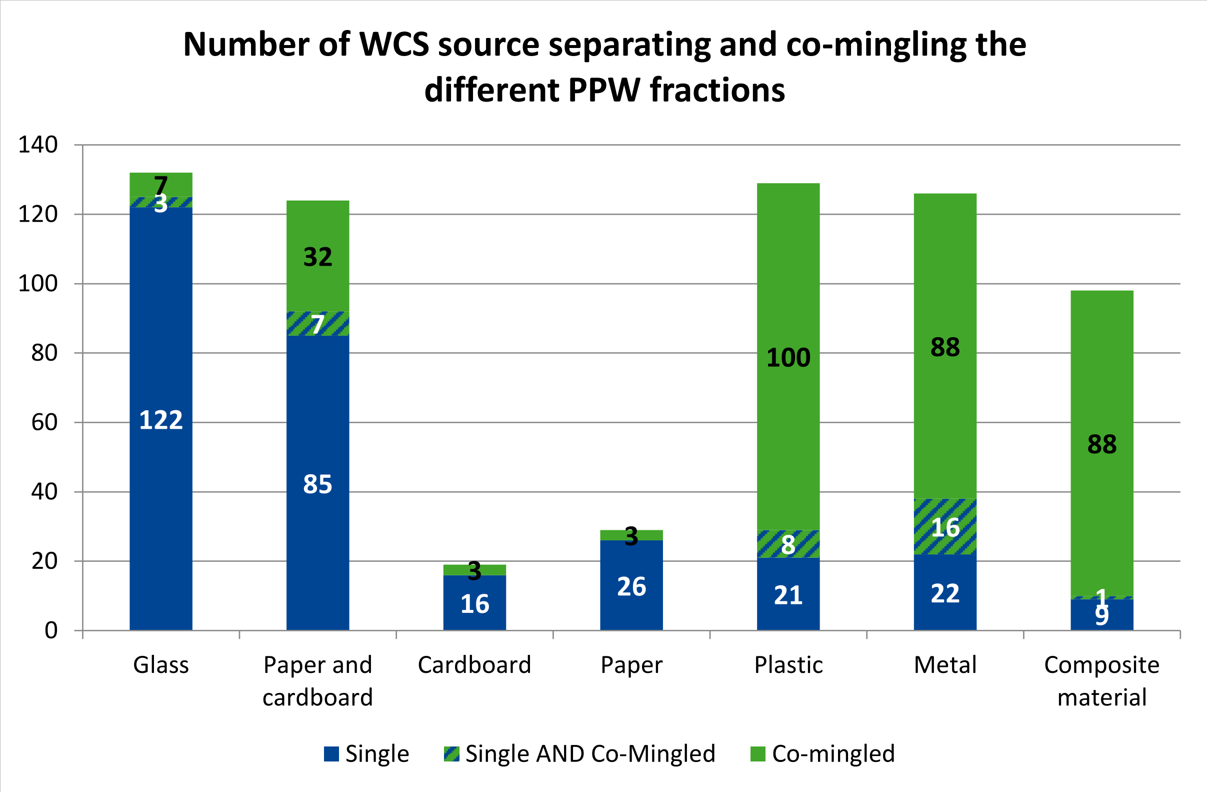

Figure 14: Level of separation for the different waste fractions

In some WCS, different separation systems are used for the same waste fraction: differentiated systems might be available depending on the location, on the waste producers (e.g. commercial waste having access to a specific cardboard collection system), or different collection schemes offered (e.g. co-mingled collection for metal packaging in bring banks and source separation of metal in CAS).

Glass and paper/cardboard are mostly source-separated, while plastic, metal, and composite packaging are mostly collected in co-mingled streams.

The co-mingled collection of glass and paper/cardboard is not as widespread as the source-separation collection, and, while the panel might not be representative of the European situation, it is interesting to note that the systems co-mingling these fractions with other packaging were identified in a limited number of Member States: France, Greece, Italy, Poland, and the UK for glass, and Bulgaria, Croatia, France, Greece, Italy, Malta, Poland, Spain, and the UK for paper and cardboard.

In the following part of the report, acronyms will be used to designate the different waste fractions and combinations. They are listed below:

- G refers to glass;
- PC refers to paper and cardboard;
- P refers to plastics;
- M refers to metal;
- C refers to composite packaging (mainly drinking cartons);
- "+" is used when fractions are comingled, while "/" is used to distinguish the fractions that are separated.

For instance, a system source separating glass, and co-mingling on one hand paper/cardboard with composite packaging, and on the other hand plastic and metal, will be designated as follows: "G / PC+C / P+M".

The distribution of sorting systems among the documented WCS is presented on the following graph, for several Member States:

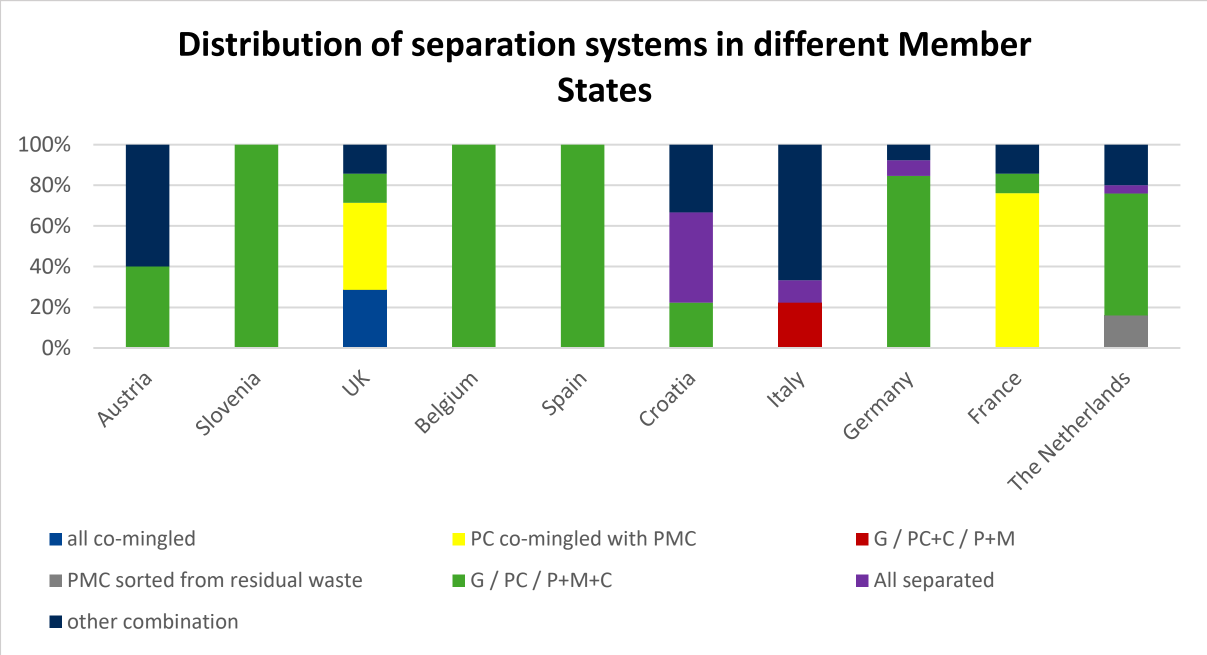

Figure 15: Distribution of separation systems in different Member States

While the number of documented WCS might not allow to have a representative view of the different national situations, the graph shows several elements:

- The “PMC” system (source separation of glass and P/C, co-mingling of PMC) is very widespread in Slovenia, Belgium, Spain, Germany, and the Netherlands);
- The co-mingling of paper and cardboard with PMC is widely used in the WCS identified in the UK and France.

These elements are also presented on the following graphs showing the number of WCS for each separation system for glass, then for paper and cardboard:

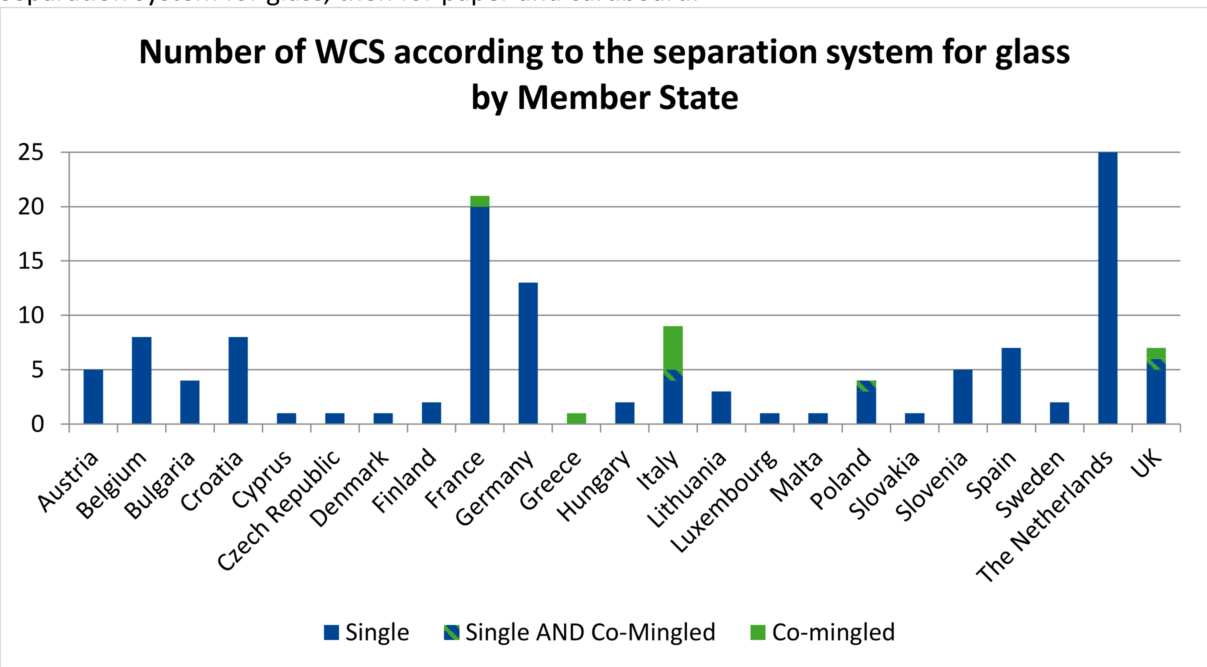

Figure 16: Number of WCS according to the separation system for glass by Member State

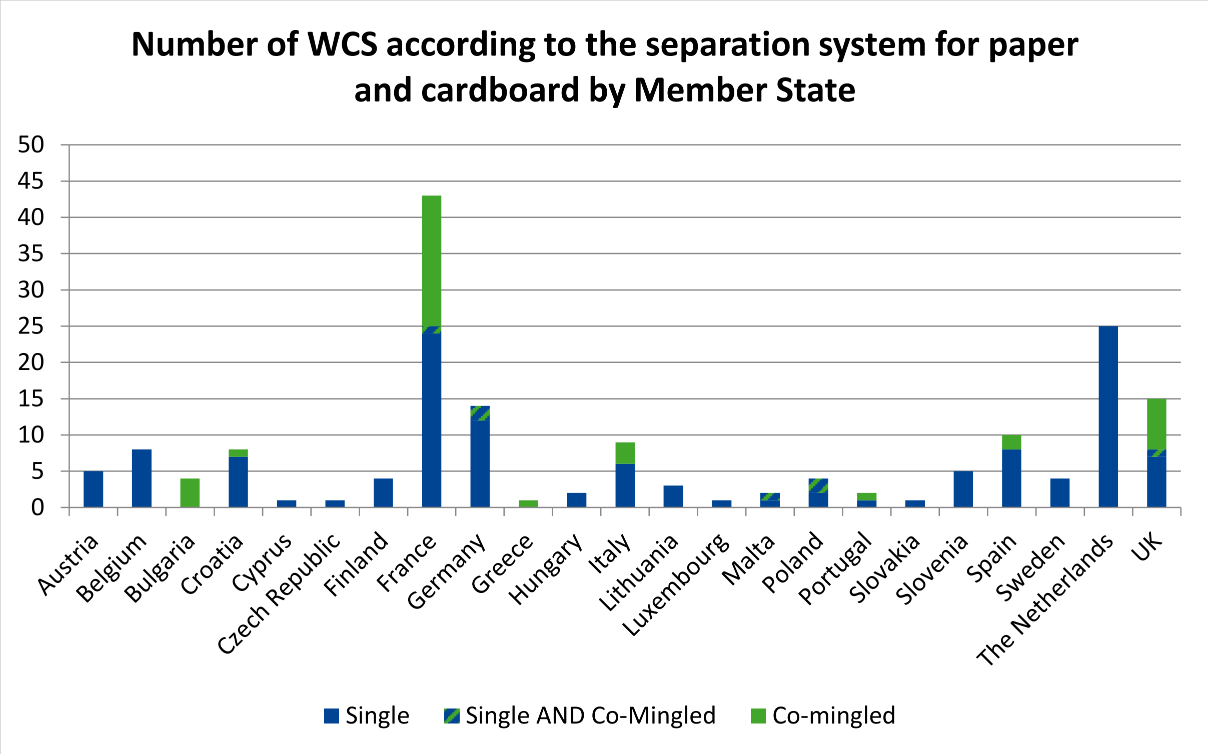

Figure 17: Number of WCS according to the separation system for paper and cardboard by Member State

Listing the different separation systems is challenging, due to the high diversity of schemes, the fact different sorting systems can be offered in the same WCS depending on the type of producers (e.g. households or commercial activities), the housing types (e.g. vertical housing or single-family housing), the collection systems (e.g. door-to-door schemes or bring banks). Different options can be offered to the users, such as comingling packaging waste in bring points or source-separating them in CAS. Among the documented WCS, seven of them run parallel separation schemes (either depending on the collected areas, or the collection methods). Moreover, many WCS have set a source-separated collection of cardboard for commercial activities, in addition to the traditional municipal waste systems.

Besides, the sorting guidelines might also differ from one city to another. In some places, only plastic bottles are collected as plastic packaging, while in other places, plastic collection includes all plastic packaging.

The most widespread collection scheme is used by about 40% of the documented WCS: it consists in the source separation for glass and paper/cardboard, and co-mingling collection for plastic, metal, and composite packaging. The other separation systems are very diverse, with many different combinations: 39 different systems could be identified, ranging from all packaging waste comingled to full source separation. However, it is possible to identify common co-mingled streams:

- Paper and cardboard mixed with packaging waste (PMC) in 24 systems;
- Plastic packaging mixed with either metal packaging or composite packaging, or both;
- In 8 systems, composite packaging is collected together with paper and cardboard.

The other combinations are less common. Four WCS reported source separating glass and paper and cardboard, and sorting PMC from residual waste prior to incineration, without offering any selective collection for this fraction.

3.3 Collection modes

Information was gathered on the collection modes applied to the various waste fractions, along with the collected quantities via the different collection methods, as well as more details on the collection systems for door-to-door and bring banks.

The collection modes covered by the study are the following:

- Door-to-door collection (where the collector picks up the waste from each different housing);
- Bring bank collection (where waste producers have to dispose of their waste in containers located on the public space);
- Civic amenity sites;
- “Other” (re-use centres, collection on demand…).

The classification between door-to-door and bring bank collection systems can be challenging. Here, a system resorting to containers located on the public space and not allocated to a very specific group of housing is regarded as a “bring bank” system. A set of containers located within the premises of one given group of vertical housing and dedicated to this group will be regarded as a door-to-door system. Civic amenity sites are guarded, fenced-off areas where inhabitants can dispose of and sort out their household waste into receptacles in order to be recycled or otherwise treated.

The level of precision for the data on collection modes differs from one WCS to another; in some cases, the collected quantities are not available for each collection mode.

Besides, it is important to note that some waste collection systems rely on mechanical sorting of residual waste prior to treatment (incineration) to separate some of the PPW fractions. As explained above, four WCS make the inhabitants separate glass and paper/cardboard, while PMC are extracted from the residual waste prior to incineration. Other WCS combine separation of PMC by the inhabitants and an extraction of recyclables (mainly plastics and metal) from the residual waste before treatment. All the WCS reporting this practice are located in the Netherlands.

3.3.1 Collection modes per waste fractions

It is possible to analyse the most commonly-used collection modes for each waste fraction. However, collection modes can be multiple for one single waste fraction in a given WCS, either because waste producers are offered different possibilities (e.g. bring banks and CAS), the collection methods differ depending on the locations (e.g. bring bank system in the dense inner city and door-to-door system in the outskirts), or because a different system is proposed to commercial activities.

The collection systems were classified according to the share of collected quantities for each collection methods:

- If more than 80% of the waste is collected by one type of waste collection method, it is labelled as “mostly door-to-door”, “mostly bring bank”, etc.;
- If more than 60% of the waste is collected by one type of waste collection method, it is labelled as “mainly door-to-door”, “mainly bring bank”, etc.;
- If no collection system falls into these criteria, the collection is labelled as “combined”.

For systems for which no data were available on the share of collected quantities according to the collection methods, the labelling was achieved according to the other information available (usually qualitative information provided by the WCS).

By doing so, it is possible to identify the main collection modes used by the different WCS, as presented in the following chart:

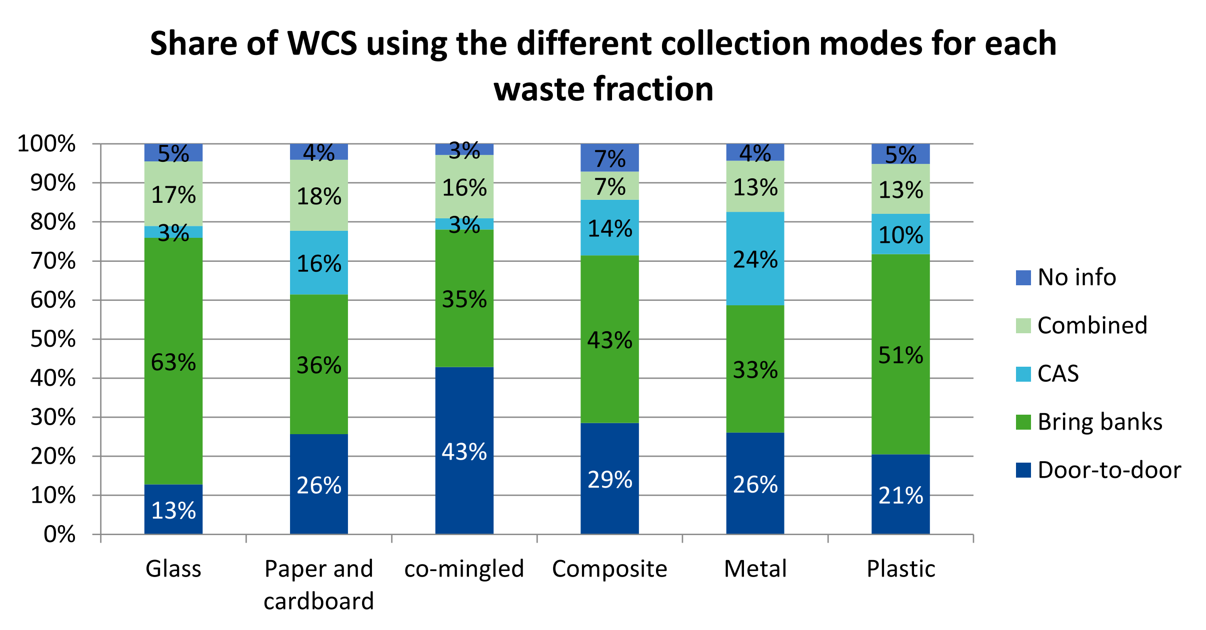

Figure 18: Share of WCS using the different collection modes for each waste fraction

Bring bank systems are widely used for glass, as well as for plastic and composite when they are source-separated. They are also a bit more widespread for source separated paper and cardboard. Door-to-door systems are a bit more popular for co-mingled fractions. Civic amenity sites are mostly used for paper/cardboard and metal, as well as composite packaging.

3.3.2 Collection modes and context

Several external factors (e.g. density, tourism, geographical location, etc.) were put in parallel with the main collection modes in use in the different WCS. Few correlations were identified. The distribution of main collection modes for WCS according to their GDP is presented below:

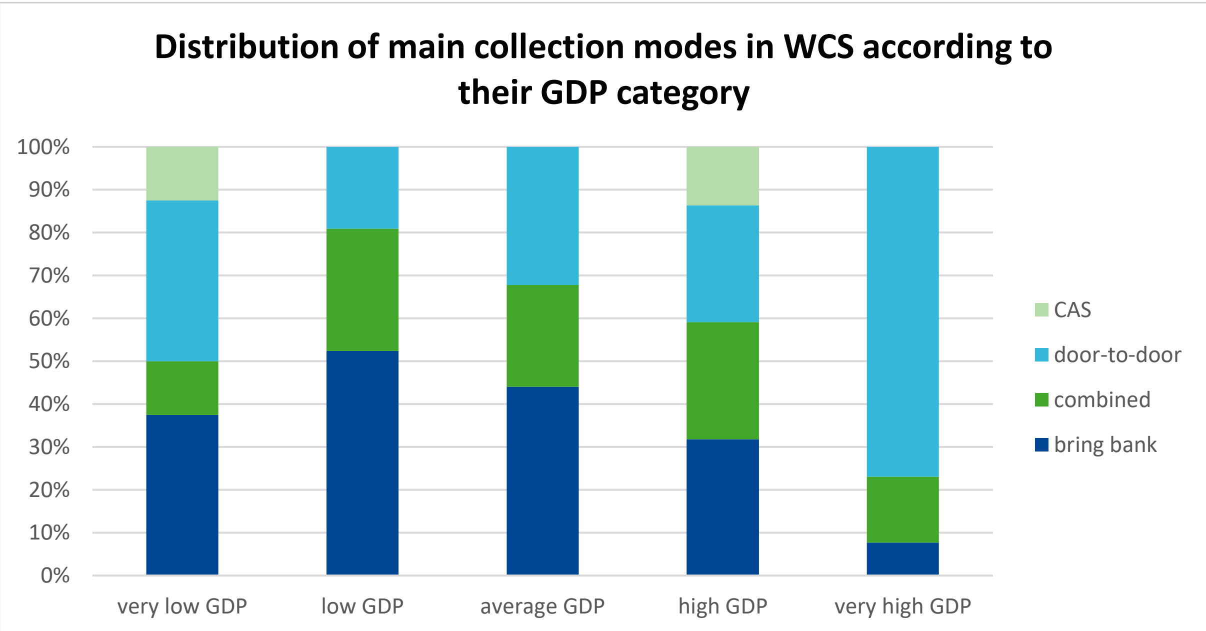

Figure 19: Distribution of main collection modes in WCS according to their GDP category

The graph shows that door-to-door systems are more widespread in WCS with high GDP, while bring bank systems are a bit more common in average and low-GDP areas.

3.4 Door-to-door collection

Information on door-to-door collection was collected, especially on the collection frequency for the various waste fractions, including residual waste. It is challenging to process such data, as collection frequency might vary within the WCS, i.e. various locations or waste producers might be offered different collection frequency (for instance more frequent frequency in urban centres than in the suburbs). Average values were determined to make the analysis possible, yet it might not always accurately depict the local situation.

Collection frequency is rather heterogeneous among the documented WCS, ranging from once a month for all fractions, up to once a day for residual waste. In average, residual waste is collected a bit more than once a week, while other PPW fractions are collected in average every two weeks to once a week, as presented in the following chart:

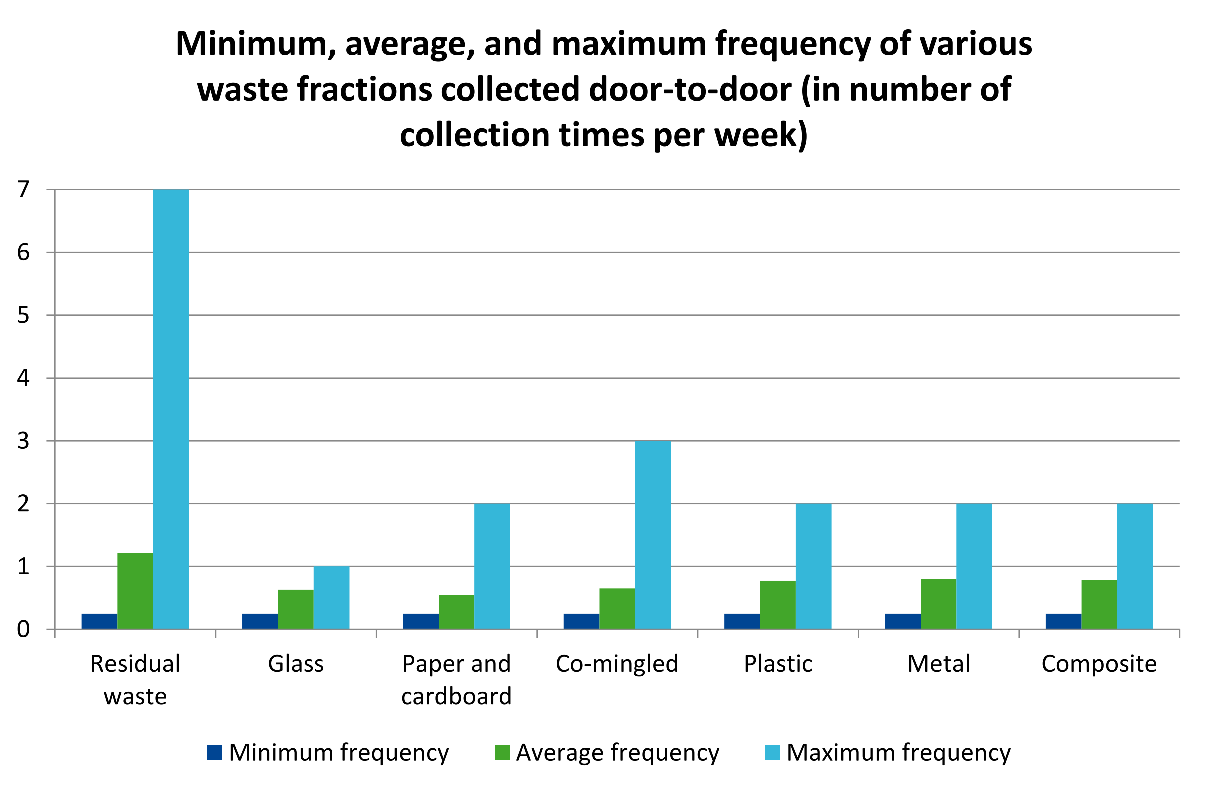

Figure 20: Minimum, average, and maximum frequency of various waste fractions collected door-to-door (in number of collection times per week)

The collection frequency of the various PPW fractions was compared with the frequency of residual waste collection in the documented WCS using door-to-door collection. The results are presented in the following graph:

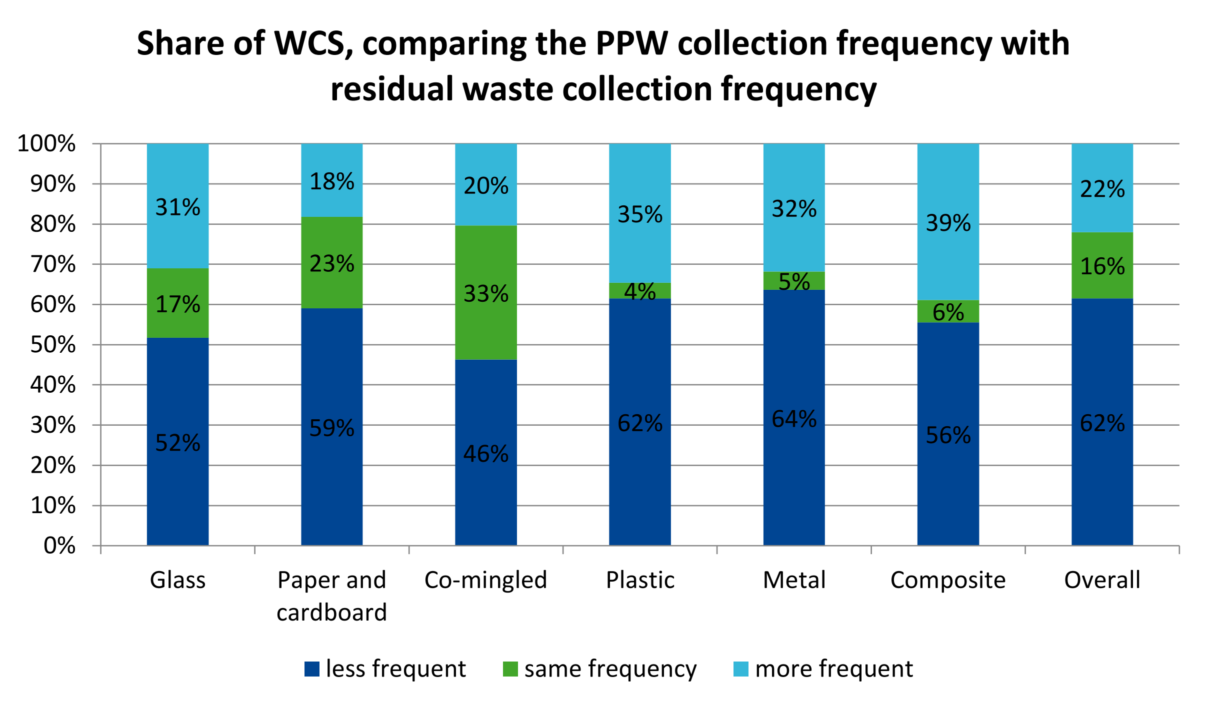

Figure 21: Share of WCS, comparing the PPW collection frequency with residual waste collection frequency

For most waste fractions, PPW is collected less frequently than residual waste in a majority of WCS. Overall, PPW collection frequency is more commonly lower than residual waste collection frequency.

3.5 Bring bank collection

Several information could be collected on bring bank collection, mainly the number of containers used for each waste fraction. The collected data show significant differences across WCS, even for collection where the main collection system is based on bring banks, as shown in the table below:

Table 5: Minimum, average, and maximum number of inhabitants per containers for WCS belonging to the "mostly bring banks" category, per waste fraction

	Min of No. of inh. per bring point	Average of No. of inh. per bring point	Max of No. of inh. per bring point
Glass	13	1,809	33,202
Paper and cardboard	13	2,129	14,767
Co-mingled	83	2,997	17,116
Plastic	13	1,349	6,360
Metal	13	1,378	5,763

By using the population density, it is also possible to assess the density of bring points by calculating the number of bring points per km². These figures are presented in the following table:

Table 6: Minimum, average, and maximum number of containers per km² for WCS belonging to the "mostly bring banks" category, per waste fraction

	Min of No. of bring point per km²	Average of No. of bring point per km²	Max of No. of bring point per km²
Glass	0.02	3.97	62.18
Paper and cardboard	0.02	5.33	54.85
Co-mingled	0.01	10.64	62.18
Plastic	0.02	1.78	6.74
Metal	0.02	2.38	14.97

Both tables show significant discrepancies regarding the density of bring points among the different WCS.

4. PPW generation

By combining data on sorted quantities and information on the capture rate and on the residual waste composition analysis, it is possible to assess the total production of PPW. The unsorted quantities are assessed either by using the capture rate provided by the WCS (when available and when the collected quantities for the different fractions are available, which might not be the case when streams are co-mingled), or by using data from the composition analysis of residual waste.

There are potential uncertainties when assessing the unsorted fractions, linked with uncertainties of the data on composition analysis collected (for instance how precise these data are, or the exact scope of the unsorted fractions reported by the different WCS (some might include non-packaging materials, making the unsorted quantities more important).

4.1 Parameters behind PPW generation

PPW generation is the results of various factors:

- The scope of the PPW: municipal waste can include a share of non-household waste (e.g. commercial activities), which can represent a significant share of the collected waste in very commercial areas;
- The scope of the reported data: part of the PPW generated on the territory might not be reported in the municipal waste data, either because of the existence of parallel collection schemes (e.g. deposit systems), or because of illegal practices (e.g. littering, backyard burning, scavenging);
- External factors: local consumption patterns can also explain the differences in PPW generation across Europe. Weather conditions or tourism can boost the production of packaged products and thus of PPW.

The following parts present the collected data and establish correlation between the generated quantities and several parameters.

4.2 Collected data

Data on PPW arising are available for about 110 WCS, and range from about 50 kg/cap to 500 kg/cap, with 80% of the collection systems ranging between 100 and 300 kg/cap.

Decomposed by waste fractions, the total arising reported by the different WCS are presented in the following graph:

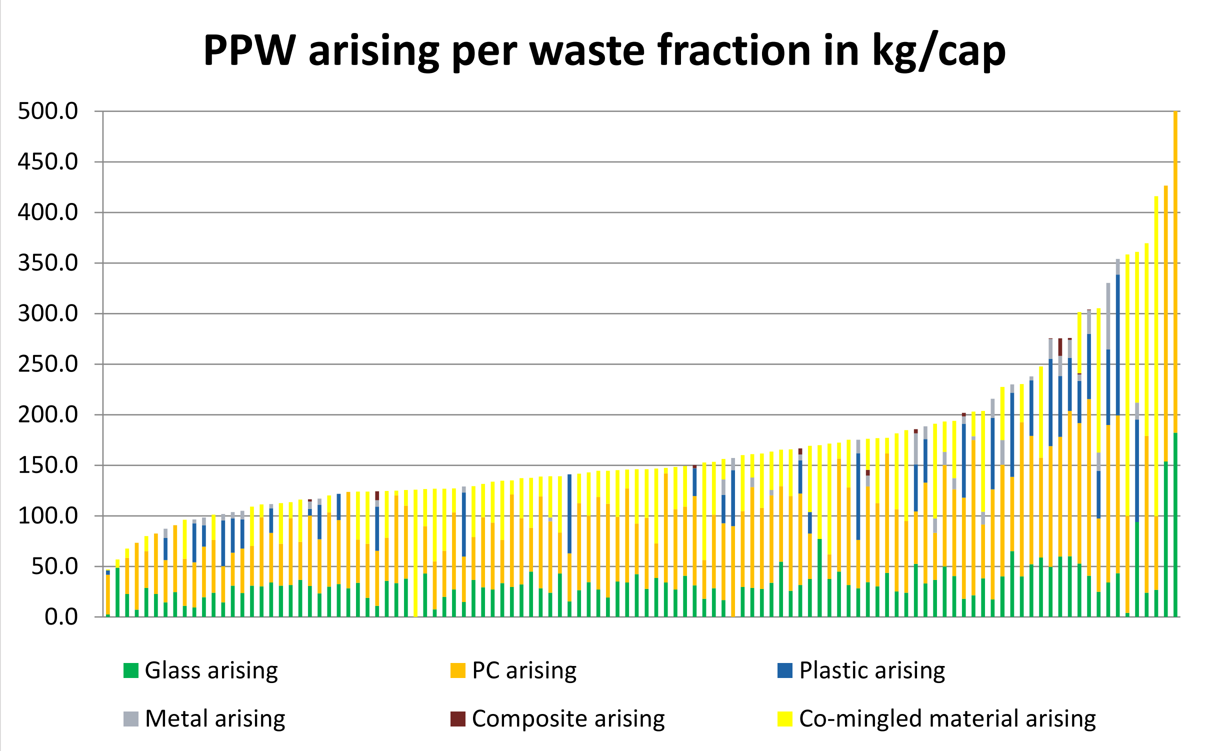

Figure 22: PPW arising per waste fraction in kg/cap

While paper and cardboard and glass are generally the two main material fractions, it is interesting to note the very high heterogeneousness of the composition of PPW across the documented WCS.

4.3 Correlations

There is little to no correlations between the total PPW arising and external factors such as GDP, population density, average size of households, or rate of multi-family housings. The impact of tourism seems to be visible for very touristic areas, i.e. with significant overnight stays per residents, as shown in the following graph:

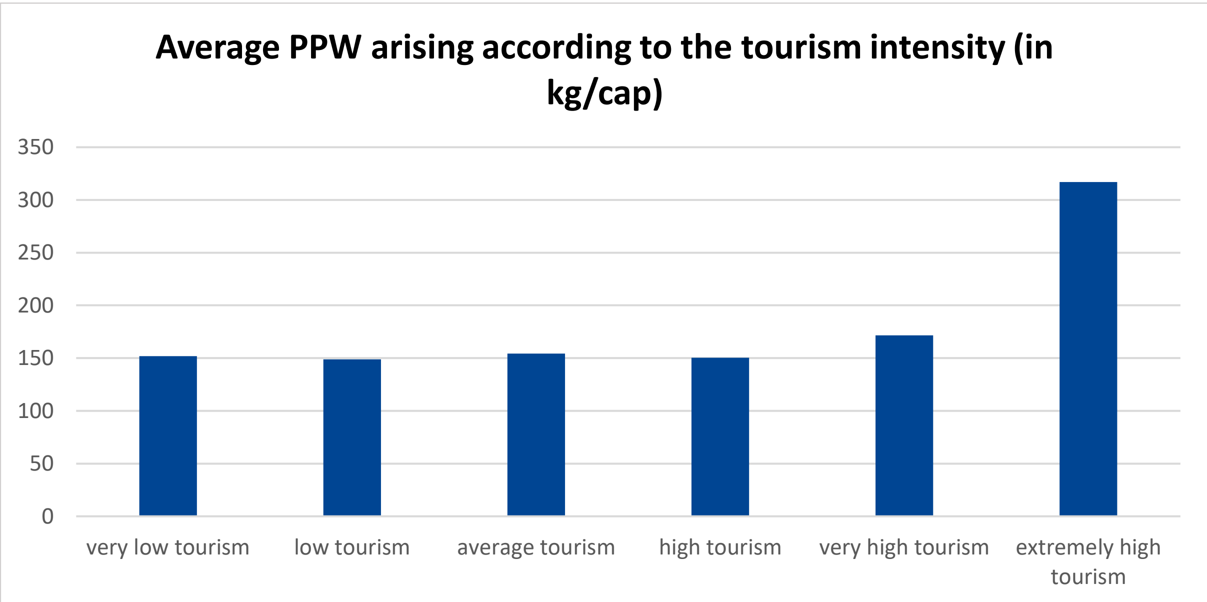

Figure 23: Average PPW arising according to the tourism intensity (in kg/cap)

Besides, WCS using pay-as-you-throw systems present in average small generation of PPW than the one using only fixed-fee systems (respectively 164 kg/cap and 175 kg/cap). It must be noted that the information on the different financing systems labelled as PAYT could not allow more detailed subcategories; what is included as PAYT might be very different and more or less incentivising, thus explaining the small differences.

There are little correlations found between the various external parameters and the arising for the different fractions, but for the typology of territory, as presented in the following chart:

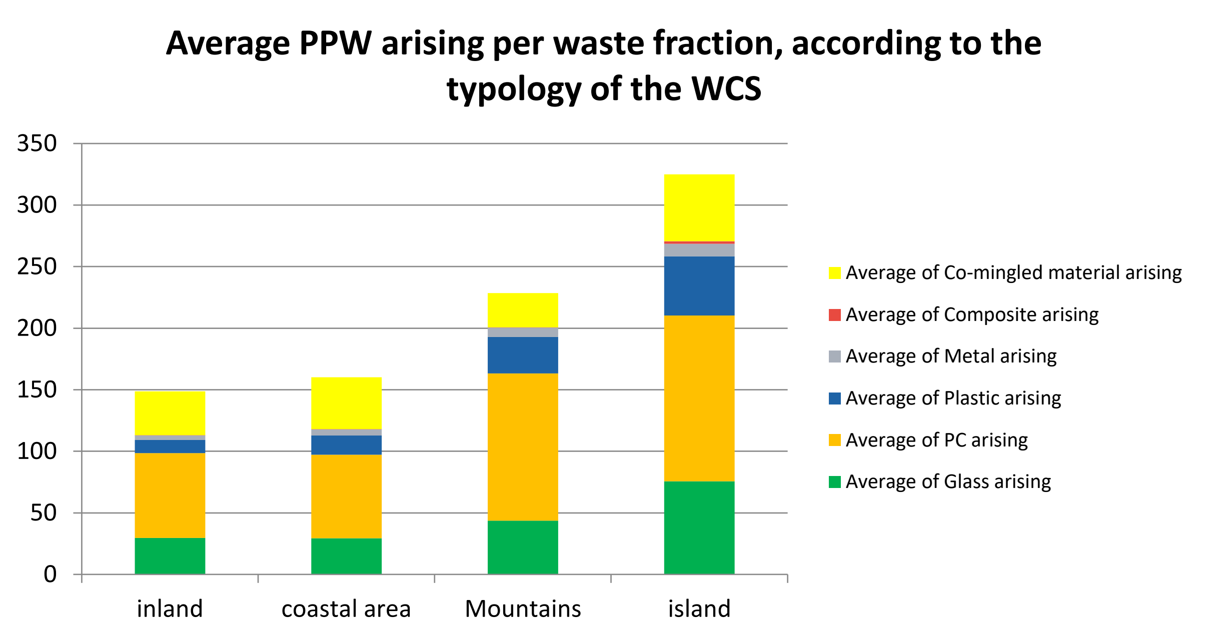

Figure 24: Average PPW arising per waste fraction, according to the typology of the WCS

Total PPW quantities are significantly more important for island and mountains than for both inland and coastal area, with more glass, paper and cardboard, and plastics being produced. One explanation might be the weight of tourism compared to the resident population, as shown in the following chart:

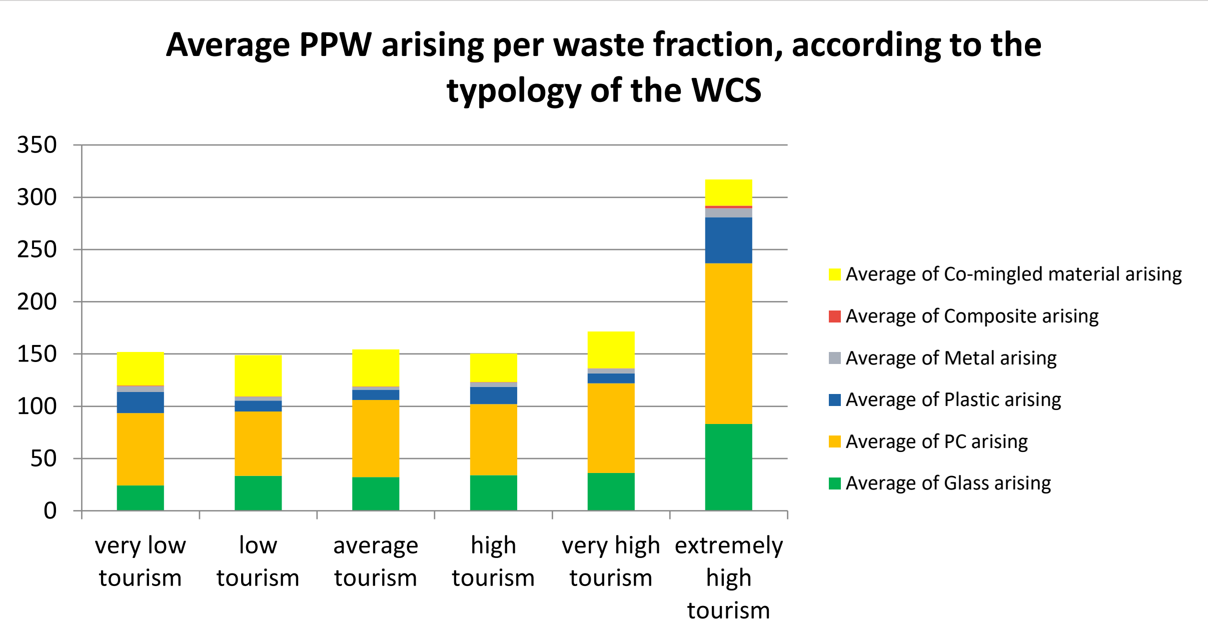

Figure 25: Average PPW arising per waste fraction, according to the typology of the WCS

The graph shows quite comparable average arising for WCS regardless of touristic activities, but for "extremely high touristic areas", e.g. territories with overnight stays per resident above 50 stays/resident population. The differences are especially significant for glass, paper/cardboard, and plastic packaging.

This is confirmed when analysing the 20 WCS with the highest PPW arising and the 20 WCS with the lowest generated quantities. There is an over-representation of island and mountains, highly touristic areas, as well as very low to average density in the top 20, while the bottom 20 mainly include inland and coastal area, average to high density of population, and few high touristic areas.

In conclusion, these observations reflect the fact that PPW generation is linked with various factors, whose impact is difficult to monitor. The only clear parameter seems to be the presence of non-resident population (such as tourists), whose impact is very visible when this presence is very significant compared to the resident population.

This corroborates the findings of the H2020 Urban-Waste project, which also noted a correlation between monthly waste quantities and tourism activities in very touristic areas[1].

4.3.1 Glass

Glass packaging generation is very heterogeneous across the documented WCS, ranging from 11 to 180 kg/cap, as presented in the following chart:

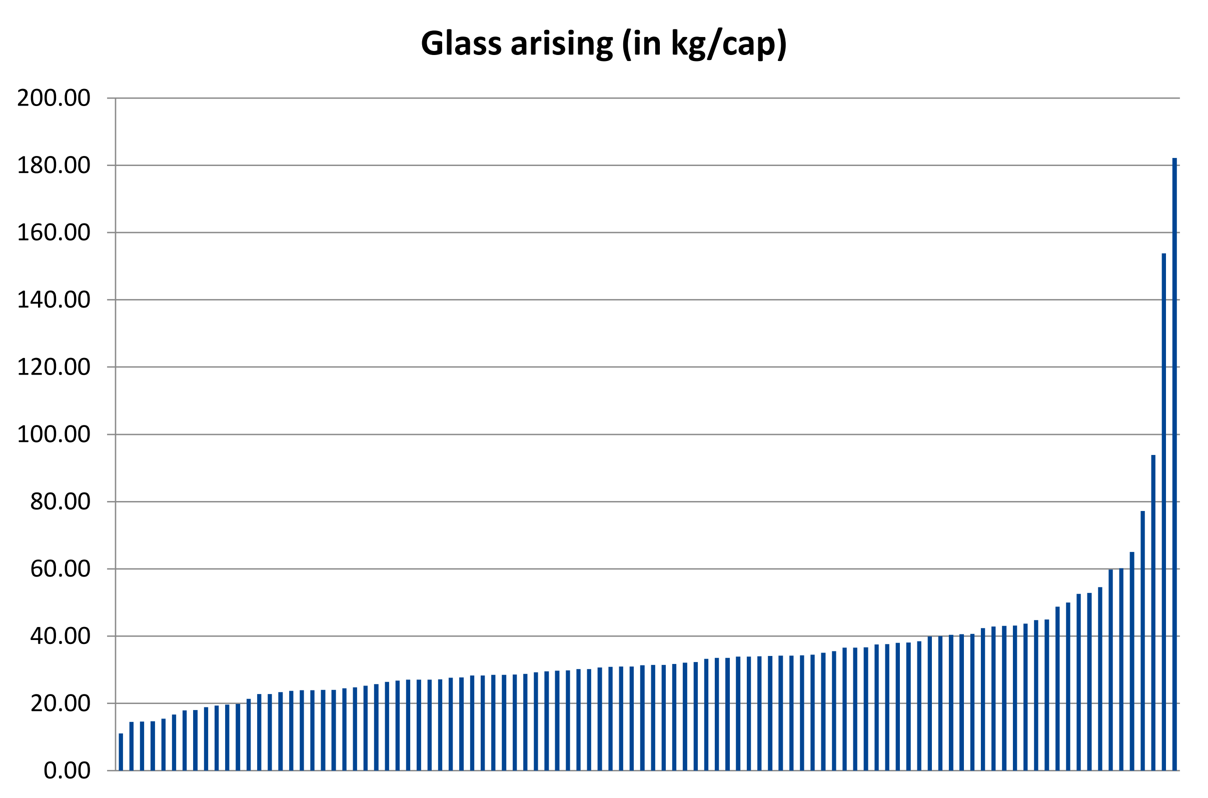

Figure 26: Glass packaging arising in kg/cap

It is important to note that most WCS range between 11 and 60 kg/cap. If the "extreme" values are put aside, the average production of glass packaging is about 32 kg/cap. The top 3 WCS are all cities with "extremely high tourism" activities. This is shown in the following graph:

[1] Urban-Waste, 2016, Status quo (baseline) assessment report, available here: http://www.urban-waste.eu/wp-content/uploads/2018/10/D2.5-Status-quo-assessment.pdf

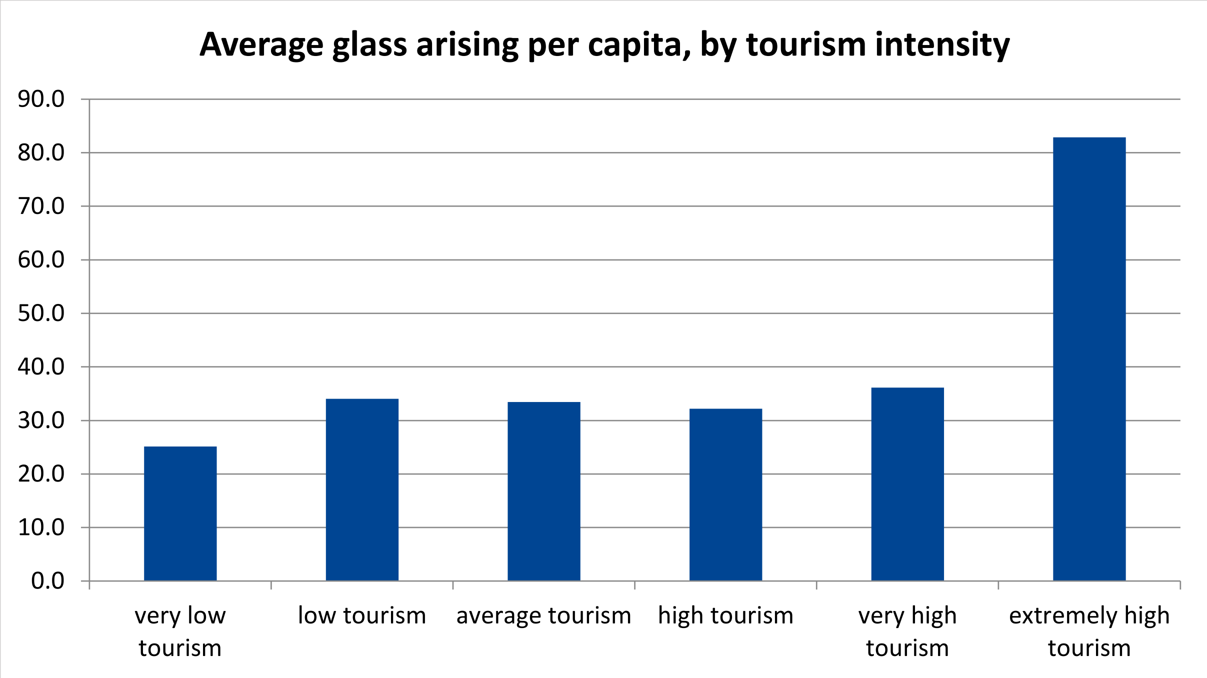

Figure 27: Average glass arising per capita, by tourism intensity

Glass arising seems to be impacted by extremely high tourism activity, while for other WCS, tourism does not seem to have a noticeable impact.

When putting aside the WCS labelled as "extremely high tourism", some further observations can be made concerning the potential correlations between various factors and the glass packaging production:

- Glass packaging tends to be higher in very high-density areas and lower in very low-density areas; this might be linked with the presence of commercial activities (especially catering) that might be included in the scope of municipal waste. However, no data was collected on the intensity of commercial activities that could confirm this observation;
- Glass packaging production is significantly lower in very low GDP areas (about 19 kg/cap compared to 32 kg/cap for the other WCS);
- WCS where parallel deposit systems for glass packaging have a smaller average production per capita (26 kg/cap) than WCS without deposit systems (31 kg/cap).

4.3.2 Paper and cardboard

Paper and cardboard generation ranges between 32 and 320 kg/cap among the documented waste collection systems, with an average of about 90 kg/cap. However, most WCS produce between 30 and 150 kg/cap, and two WCS present extremely high generation per capita. Both are islands located in the Netherland, with a low density and an extremely high tourism activity; these very high values might be linked with the fact that the actual number of waste producers is probably significantly higher than the number of residents, making the amounts generated per capita more important. The production per capita of paper and cardboard waste is presented in the following chart:

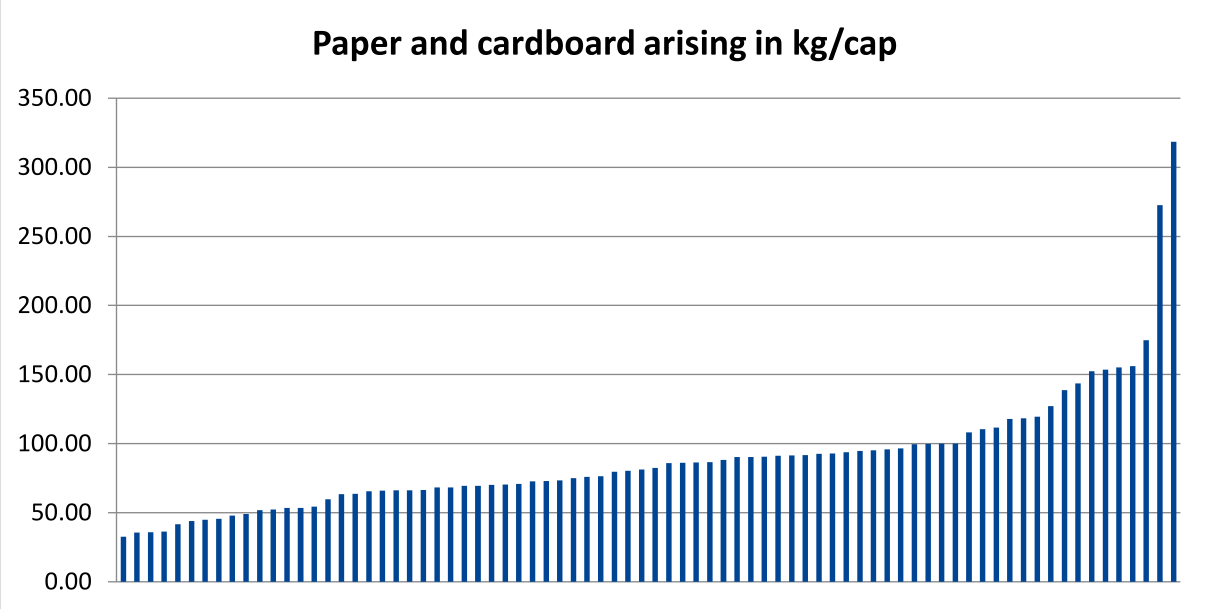

Figure 28: Paper and cardboard arising in kg/cap

The correlations between paper and cardboard arising and other parameters are very different than the ones observed with glass or plastic packaging:

- P/C arising per capita tends to be lower in low-GDP areas and higher in high GDP areas, as shown in the following chart:

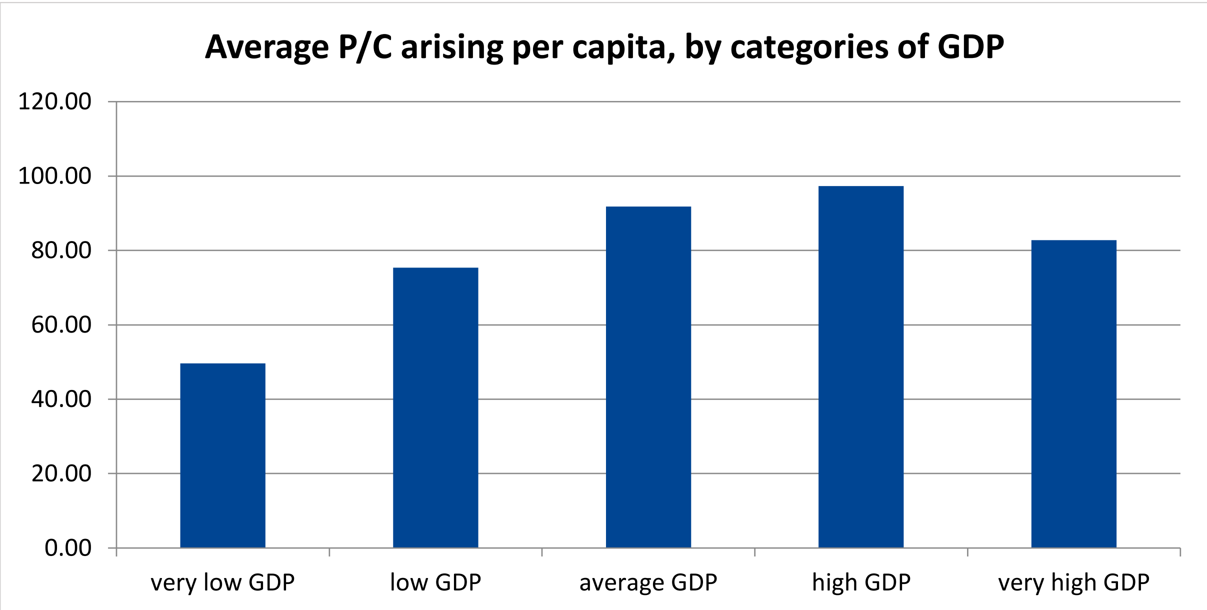

Figure 29: Average P/C arising per capita, by categories of GDP

- Very low-density territories present higher arising than the other territories (which tend to present similar average amounts generated per capita);
- WCS resorting to PAYT schemes present overall lower P/C arising (about 85 kg/cap) than the territories without them (103 kg/cap).

This is confirmed by the analyses of the territories with the highest arising and the territories with the lowest arising: there is an over representation of high-GDP, low-density territories in the WCS with the highest amounts generated per capita, while the WCS with the lowest figures include much low and very low GDP areas.

4.3.3 Plastic

There are fewer data available on the total generation for plastics, due to the fact that plastic packaging is more commonly co-mingled with other waste fractions (metal and composite packaging), and that little data could be retrieved on the fractions sorted from the co-mingled streams. Data on plastic packaging production could only be retrieved for 36 WCS. Moreover, it is possible that some further elements can limit the relevancy of comparisons, mainly linked with the scope of the data collected:

- Collection guidelines might differ from one WCS to another: some cities might only collect a small part of the plastic packaging (for instance some of the plastic bottles can be collected through a deposit-return system), while others might collect all plastic packaging, including films and polystyrene packaging. The collected information does not allow the classification of WCS according to the sorting guidelines for plastics;
- The scope of the data on the unsorted plastics might also be heterogeneous, due to the lack of information provided on the definitions. For instance, some WCS might only include unsorted plastic packaging, while other might also include non-packaging plastic products.

Plastic generation ranges between 17 and 140 kg/cap, with an average of 50 kg/cap. The collected data are presented in the following chart:

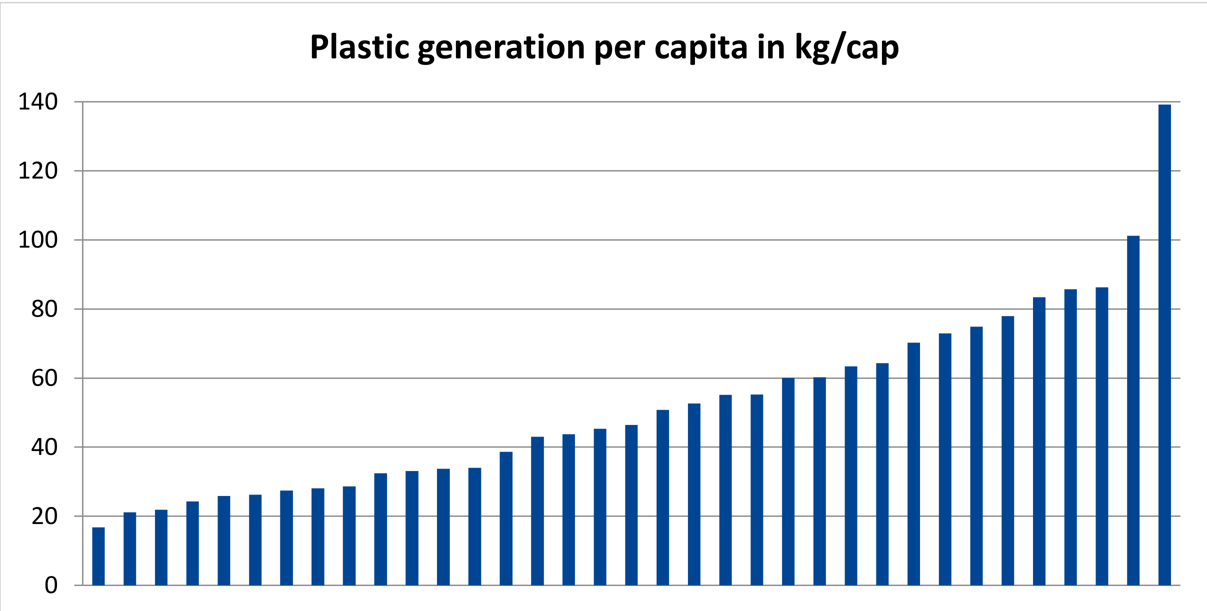

Figure 30: Plastic generation per capita in kg/cap

When it comes to correlations, the following observations can be made:

- Arising are significantly lower in Northern and Western Europe (around 38 kg/cap) than in Southern and Central/Eastern Europe (respectively 57 and 64 kg/cap);
- Arising are significantly higher in Islands (about 90 kg/cap), as well as in "extremely high tourism" areas than in other territories;
- There is no clear link between density of population and plastic waste arising;
- Territories with average to very high GDP tend to have lower arising than territories with low and very low GDP.

4.4 Conclusions on PPW arising

Interpreting the differences of arising among the different territories is challenging, due to the uncertainties of data, especially when it comes to unsorted quantities, the lack of detailed information of the scope of municipal waste collection, and the difficulty to analyse how the different elements (e.g. scope and external factors) can influence the quantities. Moreover, the indicators used to categorise the different territories might not fully reflect the parameters that impact PPW generation. For instance, GDP might reflect the presence of economic activities, but also the wealth of the population. Finally, the correlations do not necessarily mean that there is a causal relationship between the observed parameters.

In general, it can be assumed that one of the factors that impact the generated quantities per capita is the presence of non-resident waste producers, e.g. tourists and visitors for glass and plastic packaging, and commercial activities and institutions for paper and cardboard, which might explain the correlations described above.

5. Collection performances

5.1 PPW collection

The collected quantities of PPW by the different WCS are presented in the following graph:

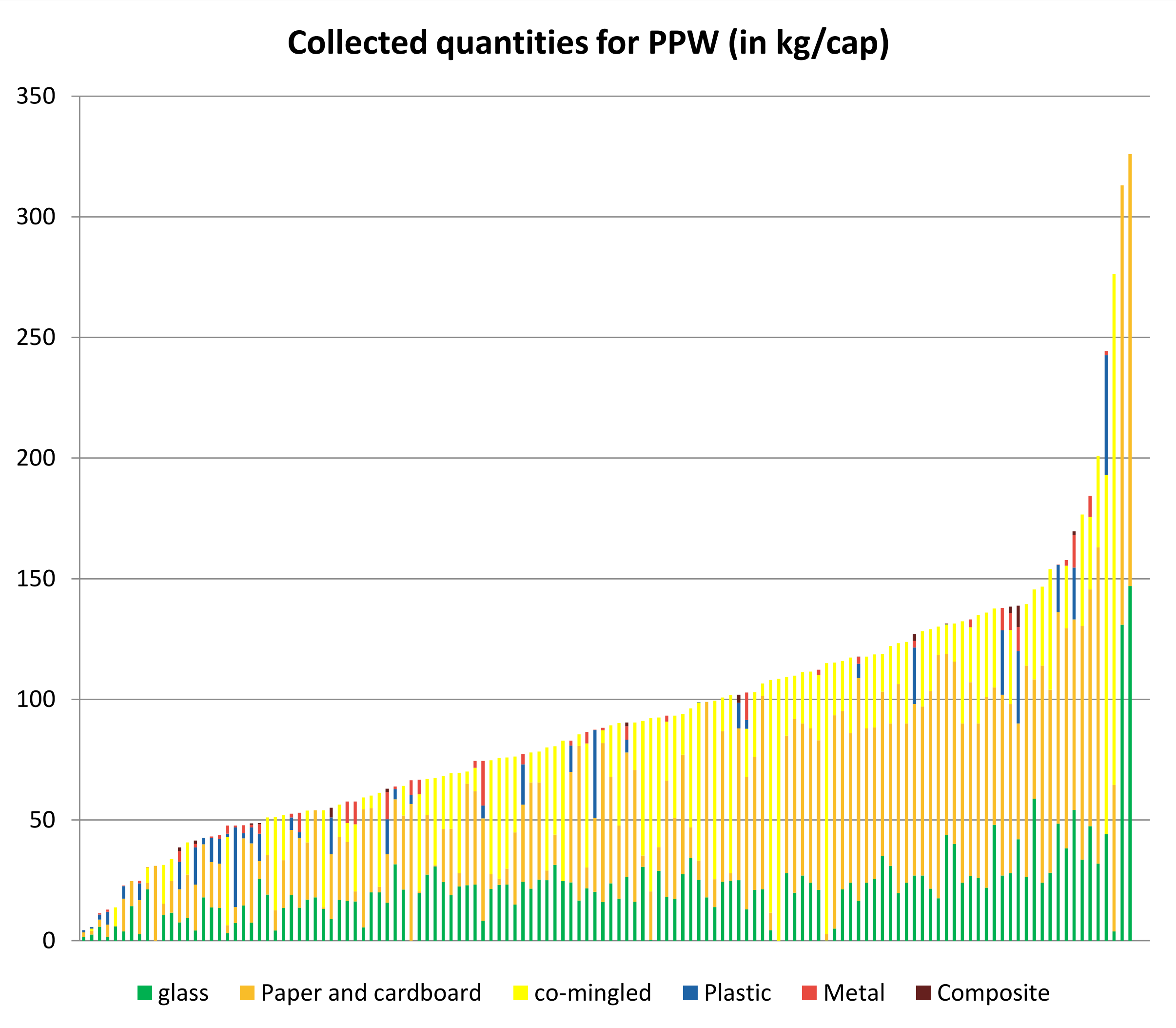

Figure 31: Collected quantities for PPW (in kg/cap)

There is a significant discrepancy among the WCS when it comes to collected quantities. For most WCS, glass and paper/cardboard are the main PPW fractions collected. In average both fractions represent about 2/3 of the collected quantities of PPW. The significant differences reflect the discrepancies regarding the total PPW generation presented in the previous part and the different levels of performance of the collection systems.

Comparing the quantities of selectively collected PPW and the collected quantities of residual waste can give a first overview of the different levels of performances among the panel. The amount of residual waste also depends on the effectiveness of biowaste collection, so this only gives a partial view of WCS performing well for PPW separation.

The following graph shows the average percentage of PPW collected quantities compared to the sum of residual waste and PPW collected quantities, according to the local organisation of collection:

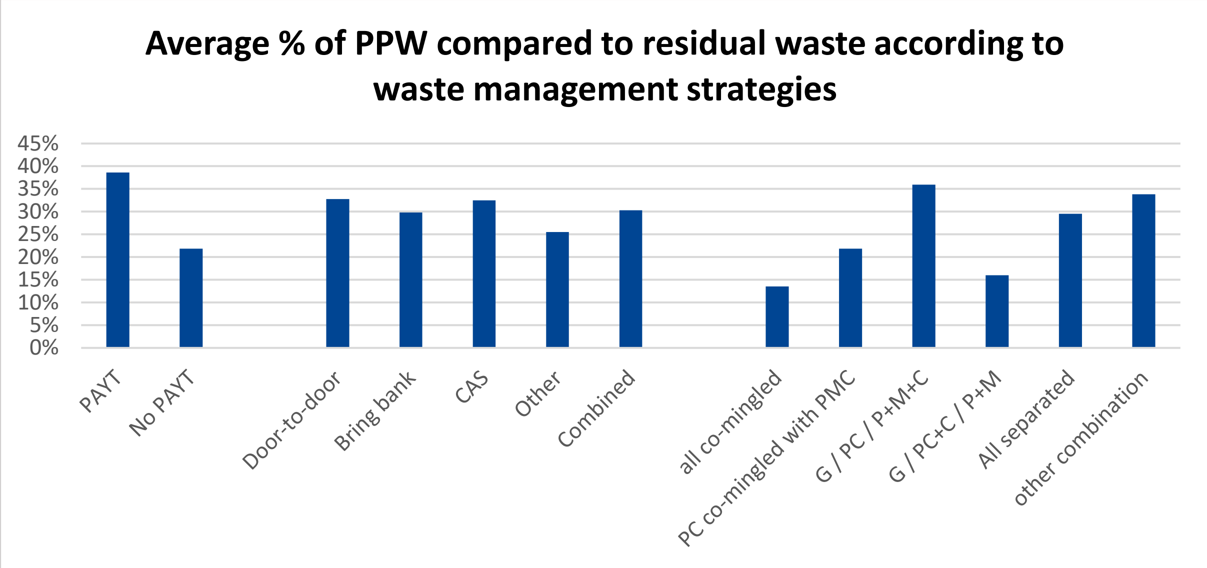

Figure 32: Average % of PPW compared to residual waste according to waste management strategies

The following observations can be drawn:

- WCS with PAYT have comparably better performances than systems without PAYT;
- The collection modes categories refer to the main type of collection used for PPW (e.g. the collection mode that is used for more than 60% of the total collected PPW). The graph shows that there are no significant differences among these different collection systems;
- Regarding sorting guidelines, “PMC” systems (source separating glass and paper/cardboard) and systems separating all fractions are the ones displaying the highest average performances, while systems co-mingling all PPW fractions have the lowest performances.

When comparing the same indicator with the local context indicators, the following elements can be observed:

- Territories with low density tend to present higher performances than high-densely populated areas;

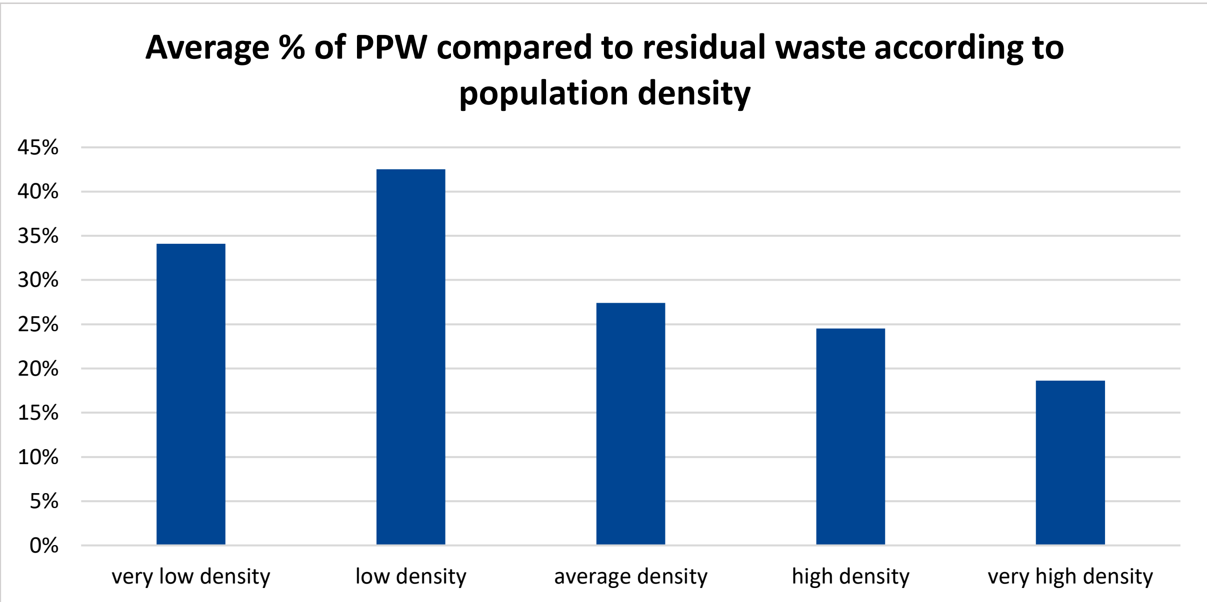

Figure 33: Average % of PPW compared to residual waste according to population density

- Territories with low GDP tend to have lower performances;

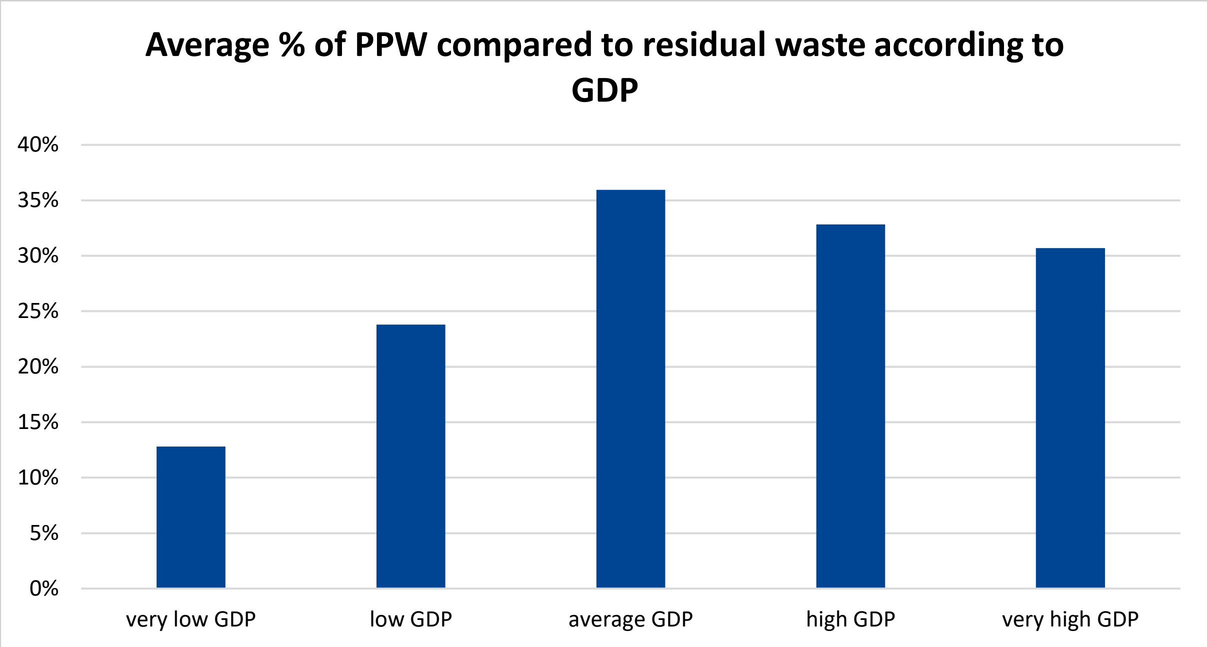

Figure 34: Average % of PPW compared to residual waste according to GDP

- For other parameters (such as tourism), no significant differences can be observed.

The data on collected quantities do not say much on the WCS' performances, considering the significant discrepancies of PPW arising across the WCS. Therefore, the analysis of performances will be focusing on capture rates and sorting rates so that these differences are taken into account.

5.2 PPW capture rates

The "capture rate" refers to the quantities of PPW collected separately compared to the total quantities of PPW generated (i.e. the PPW collected separately and the PPW collected with the residual waste). This indicator gives an indication of the performance of the systems; however, it has several limits:

- As seen previously, the total generation of PPW is generally an assessment whose precision is difficult to assess;
- The generation of PPW might not take into account all the generated quantities, especially the streams not collected by the municipal WCS (littering, scavengers, parallel collection schemes…);
- The collected quantities might include a share of impurities, especially co-mingled fractions.

There are significant differences among the 111 WCS for which a capture rate could be calculated; PPW capture rates range from 5 to 95%

5.2.1 Capture rates and external parameters

The comparison of average capture rates with external parameters gives the same observations than with the PPW/residual waste indicator presented above:

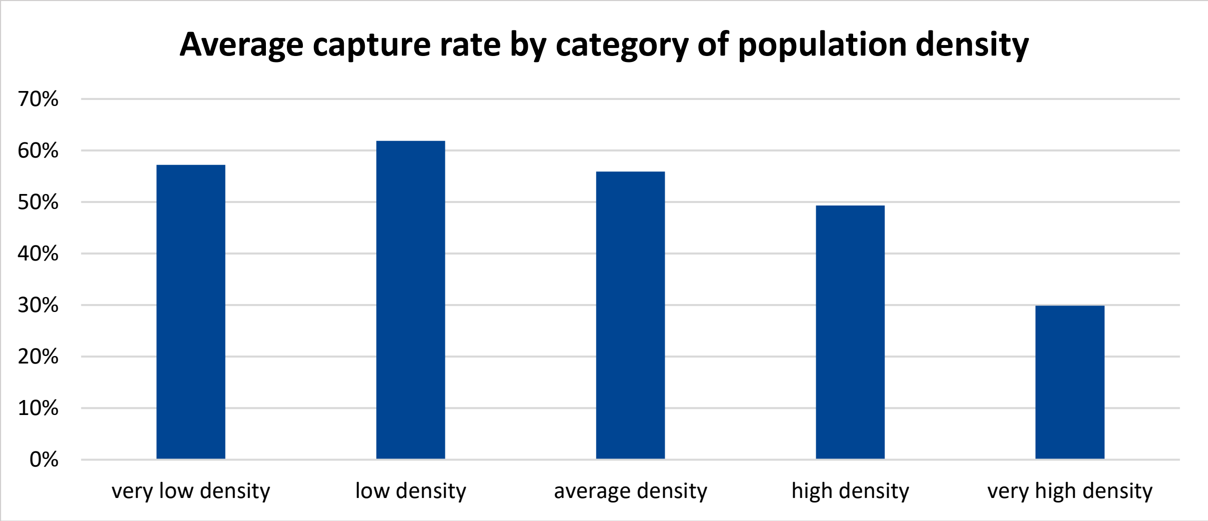

Figure 35: Average capture rate by category of population density

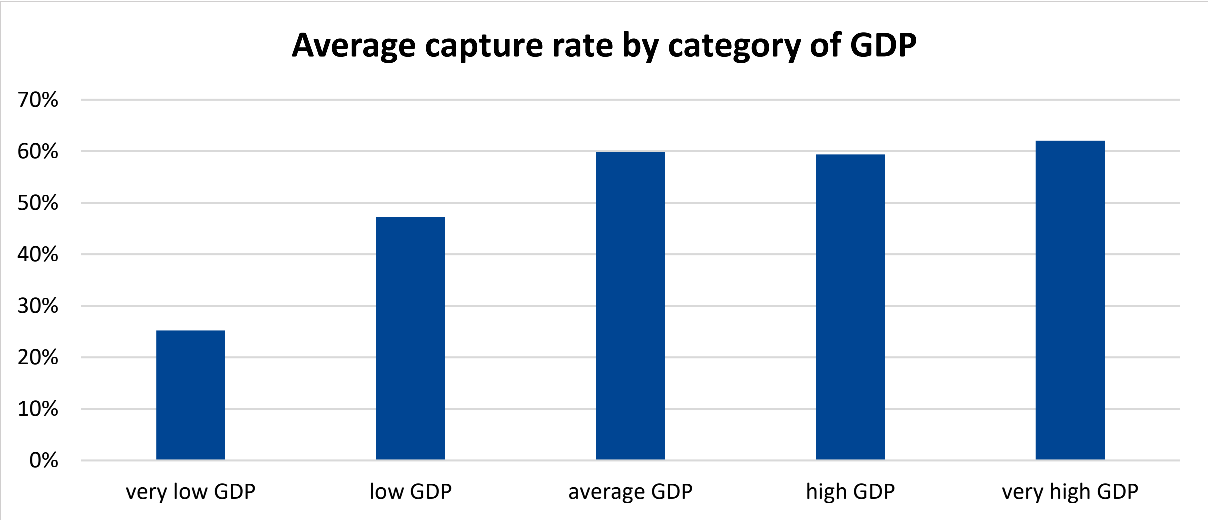

Figure 36: Average capture rate by category of GDP

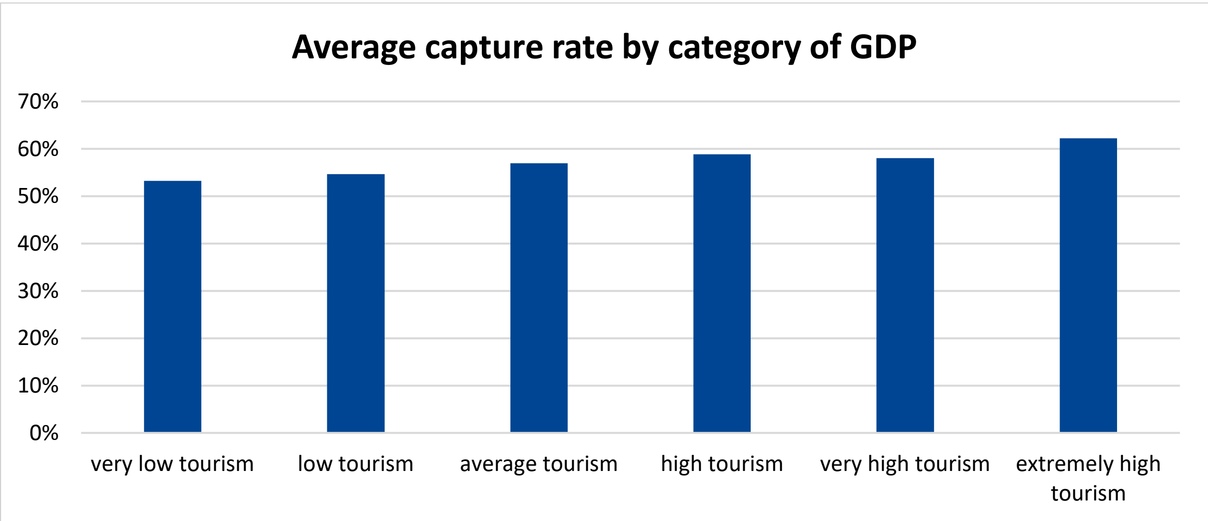

Figure 37: Average capture rate by category of GDP

The observations made here are similar to the ones made in the previous part, when comparing PPW collected quantities with residual waste collected quantities. There seems to be a correlation between capture rates and density, and with GDP: high density areas tend to have lower capture rates, so do low GDP territory. WCS with higher touristic activity seem to present higher capture rate, even though the differences among the different categories are not too significant.

5.2.2 Capture rates and collection systems

The average capture rates of WCS according to their local collection systems are presented below:

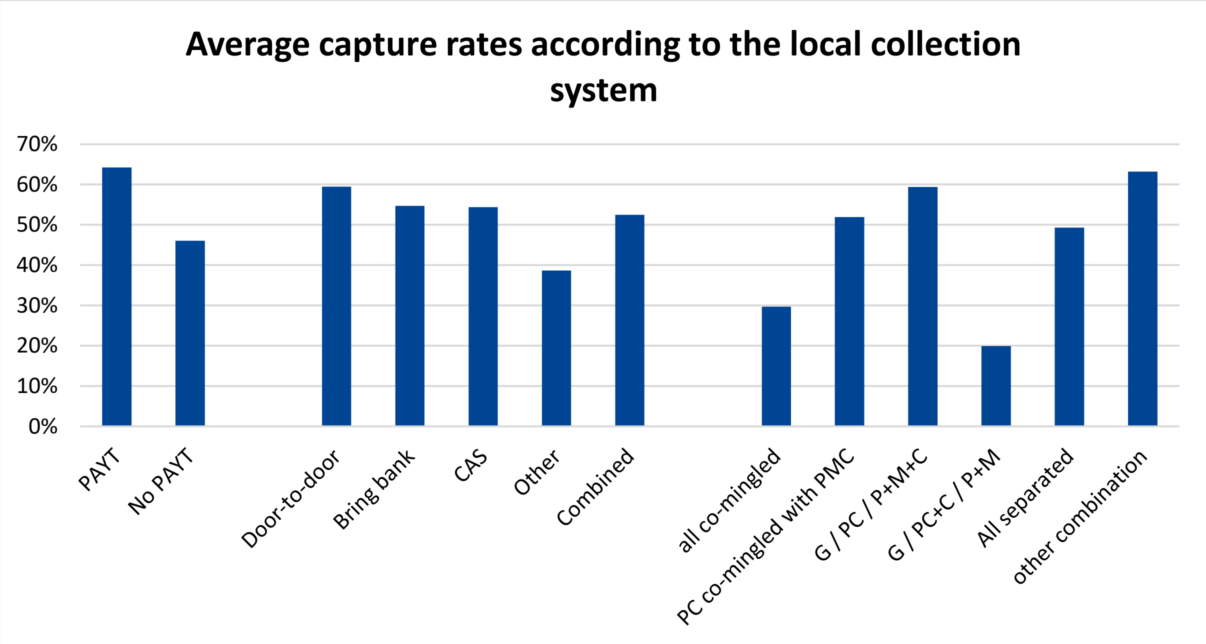

Figure 38: Average capture rates according to the local collection system

The same observations can be made than when comparing WCS with PPW/residual waste performances. Potential correlations between **the level of co-mingling and PPW capture rates** were searched. The following graph shows the average capture rate for various ranges of share of co-mingled fractions:

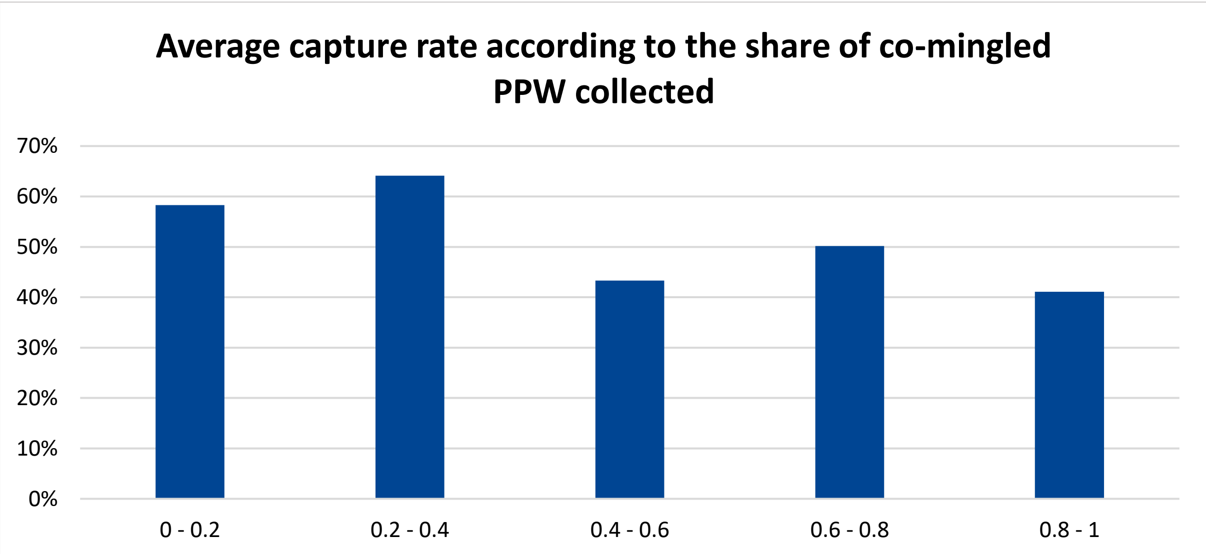

Figure 39 : Average capture rate according to the share of co-mingled PPW collected

Overall low level of co-mingling seems to provide higher capture rates. There does not seem to be a clear correlation between the level of co-mingling and the capture rate though.

The average capture rates were calculated for WCS according to their main method of collection (e.g. if a WCS collects more than 60% of PPW door-to-door, it is categorised as "door-to-door"):

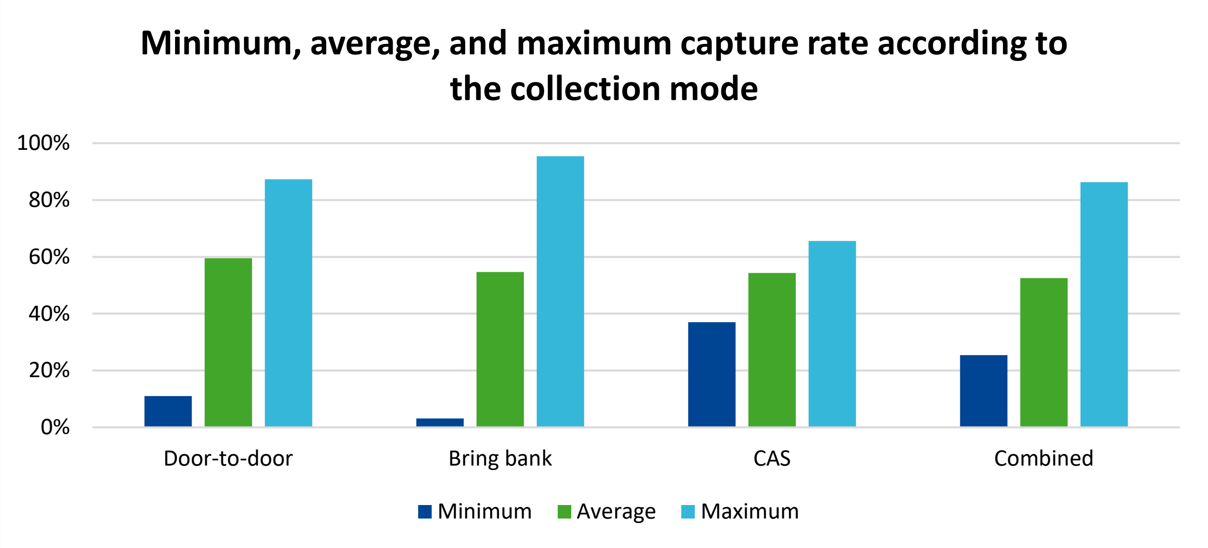

Figure 40: Average capture rate by category of GDP

It seems that the collected information does not allow the identification of a "best" collection mode; both door-to-door and bring bank systems seem to allow high capture rates, and WCS using primarly one or the other have comparable average values.

However, this does not mean that WCS can switch from one type of collection to another without impacting its performances; several documented good practices showed successful transition from a bring bank system to a door-to-door collection[2].

Comparing capture rates of WCS according to the collection frequency of PPW (compared to residual waste collection frequency) gives the following chart:

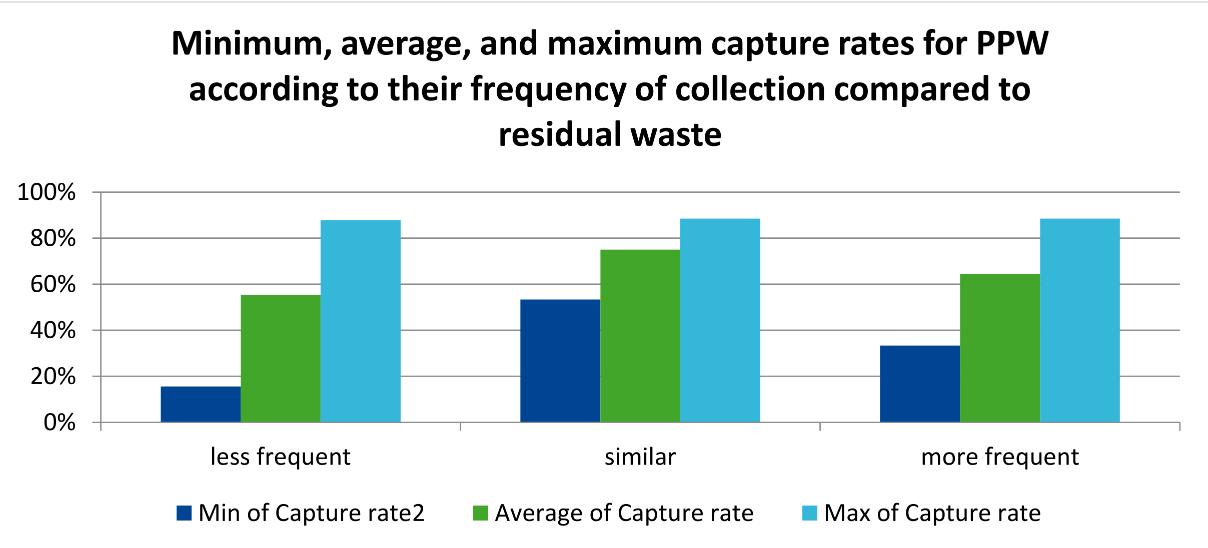

Figure 41: Minimum, average, and maximum capture rates for PPW according to their frequency of collection compared to residual waste

[2] http://www.regions4recycling.eu/upload/public/Good-Practices/GP_ARC_door2door-collection.pdf

The graph shows that WCS with similar and more frequent collection frequency for PPW than for residual waste tend to have higher capture rate in average.

5.2.3 Capture rate for glass packaging

The following chart shows the average capture rates for glass packaging according to various characteristics of the WCS:

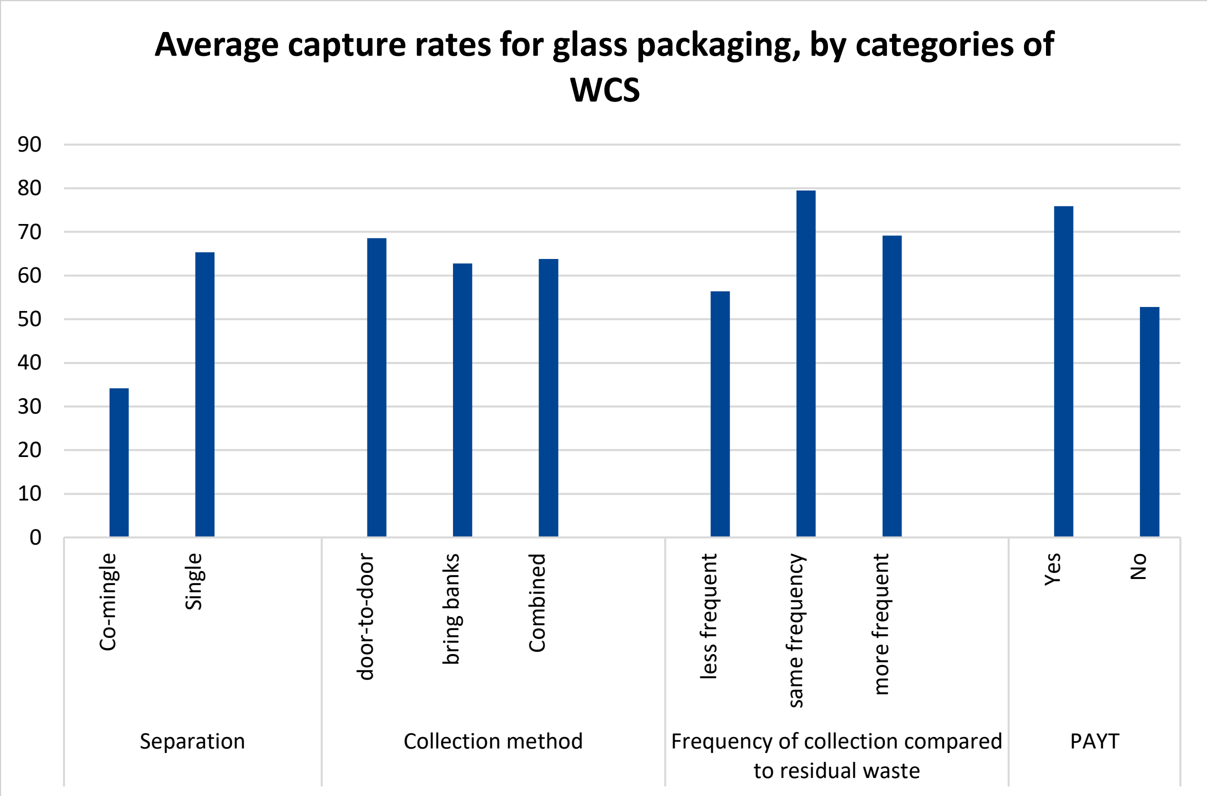

Figure 42: Average capture rates for glass packaging, by categories of WCS

The main differences can be observed between systems separating glass at the source compared to the ones co-mingling it with other materials, and between the WCS using PAYT with the ones that do not. Door-to-door collection systems tend to have slightly higher capture rates. For door-to-door systems, WCS with a similar or higher collection frequency for glass than for residual waste tend to have better performances.

The average capture rates were also compared with the density of bring banks for systems using mostly bring banks. While no correlation could be identified when comparing the number of inhabitants per bring point, the comparison of capture rates according to the density of bring points gave the following graph:

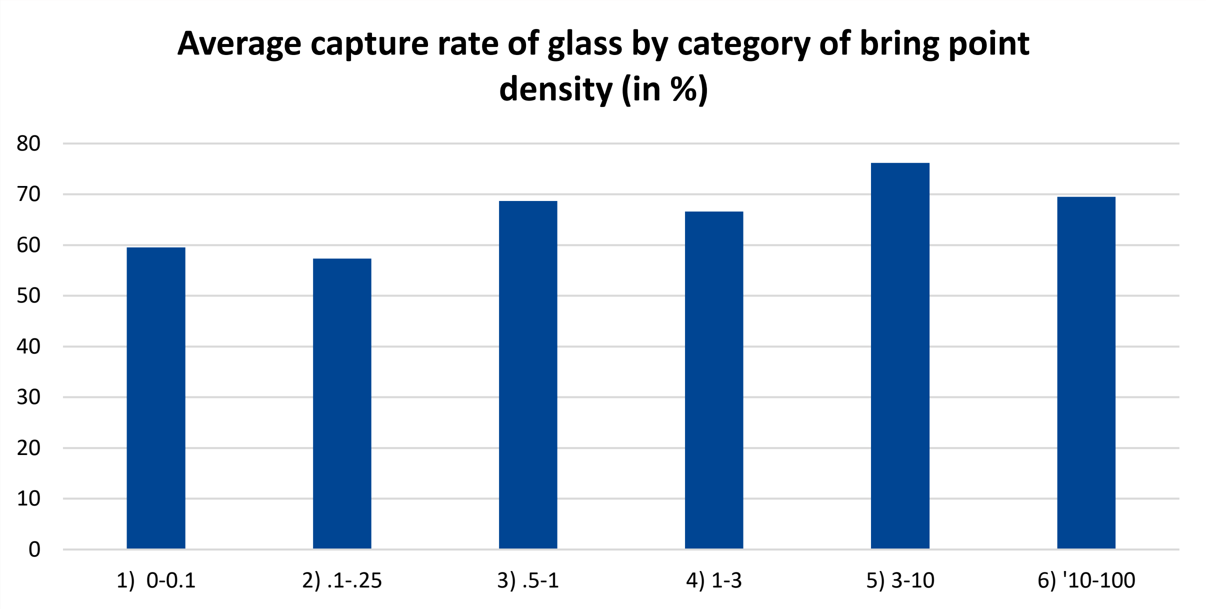

Figure 43: Average capture rates of glass by category of bring point density (in %)

The graph shows that WCS with higher density of bring points tend to present higher capture rates.

While tourism has an impact on glass waste generation, no noticeable differences among WCS belonging to the different categories of tourism intensity could be identified.

5.2.4 Capture rate for paper and cardboard

Like for glass packaging, the average capture rates of paper and cardboard were assessed for various waste collection instruments, including mode of separation, method of collection, frequency of door-to-door collection, and use of PAYT. It is presented in the following graph:

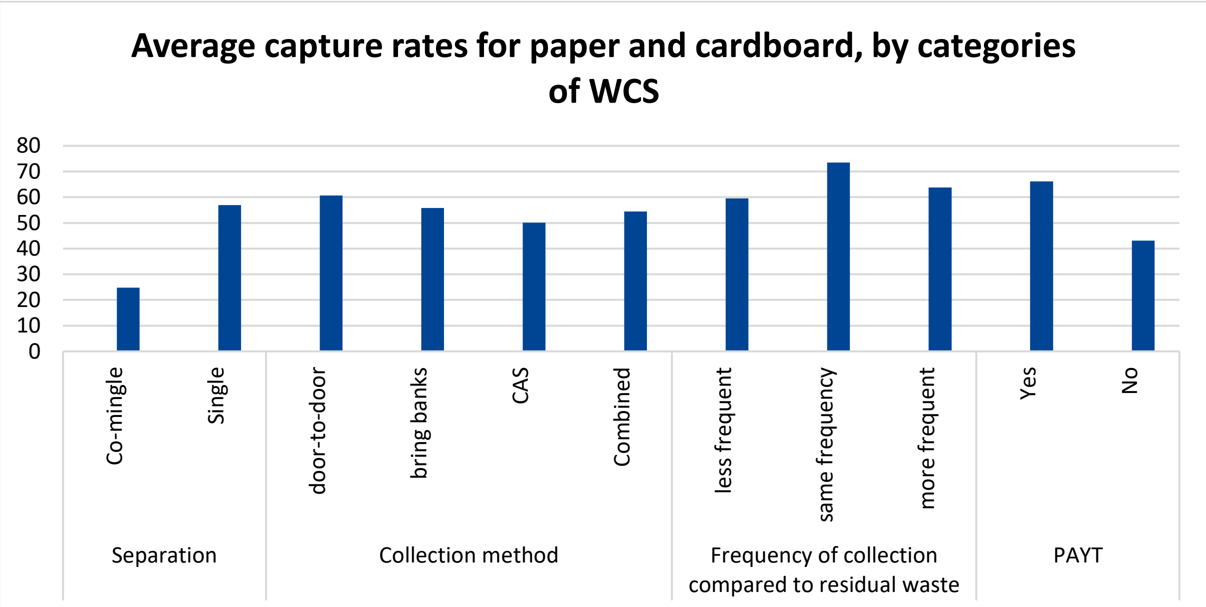

Figure 44: Average capture rates for paper and cardboard, by categories of WCS

The same observations made for glass packaging can be made for paper and cardboard: source separation, door-to-door collection with a frequency similar or higher than residual waste, and PAYT all seem to be linked with higher capture rates.

The average capture rates of bring systems according to the number inhabitants per containers were also calculated, but no clear links could be identified. However, there seems to be a link between capture rates and the density of containers, as shown in the following graph:

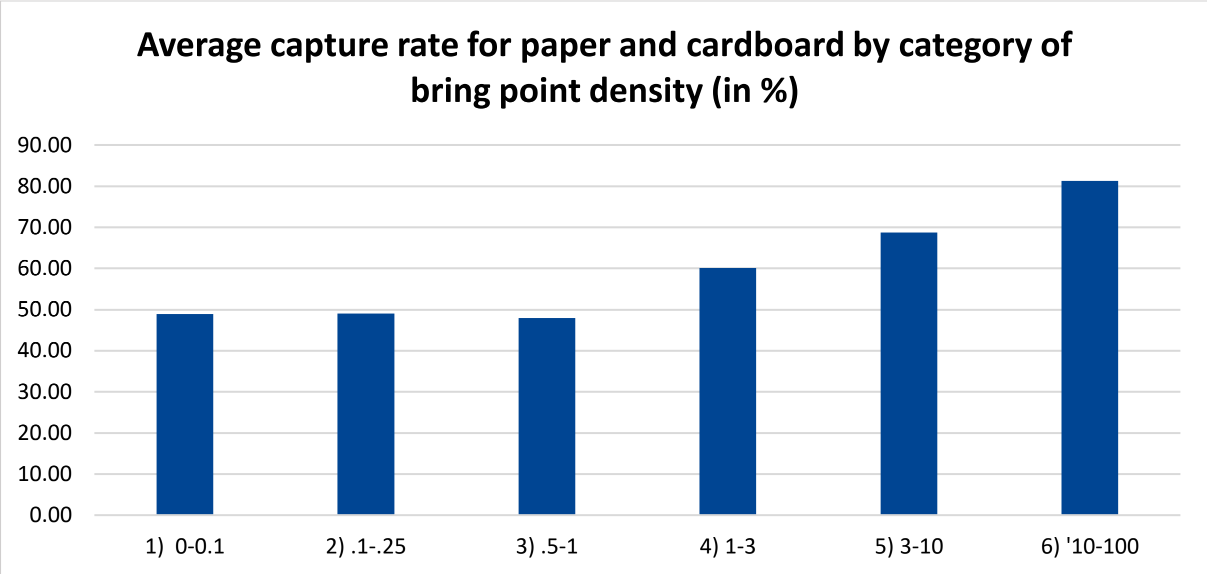

Figure 45: Average capture rate for paper and cardboard by category of bring point density (in %)

The correlation is even more noticeable that for glass. While there are not many differences below 1 collection point per km², capture rates tend to increase with the density of containers above 1 point per km². It seems that the density of containers, and thus the average proximity of collection points to inhabitants, is a key factor of success of bring bank-based systems.

5.2.5 Capture rate for plastic packaging

The same calculations were made for plastic packaging, however with less figures available. Many WCS collect plastic packaging with other fractions, making data on collected quantities for plastic packaging less common. The following figure is based on 39 WCS:

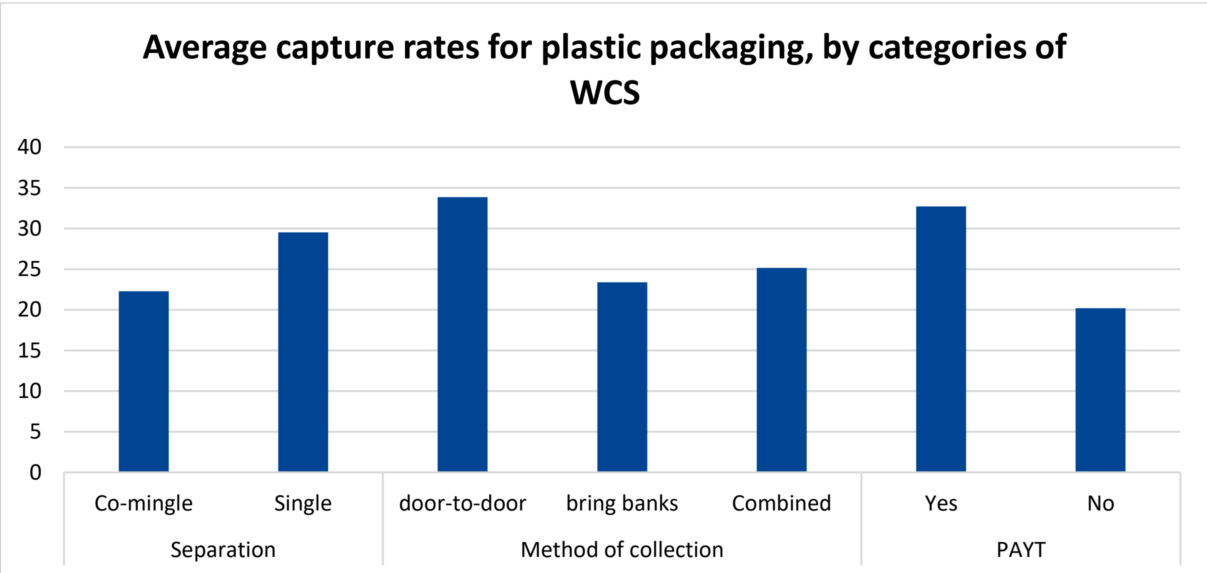

Figure 46: Average capture rates for plastic packaging, by categories of WCS

Overall, the same observations can be made than with glass packaging and paper and cardboard, with smaller differences between source separation and co-mingled systems.

5.3 PPW impurities and destination

Data were collected on the outcomes of sorted materials, both source-separated and co-mingled. The collected data focused on the impurity rates, the output of sorting centres used in case of co-mingled collection, and the destination of sorted materials.

However, very few data were actually collected:

- Data on impurities could be retrieved for about one third of the documented WCS (39 WCS);
- The output of sorting centres for co-mingled fractions were documented for 19 WCS, representing only 15% of the total number;
- Data on the subsequent destination of sorted waste is given for about 60 WCS, with various degree of precision.

5.3.1 Impurity rates

Data were collected on the impurity rates for several PPW fractions, including co-mingled PPW. A summary of these data is presented in the figure below:

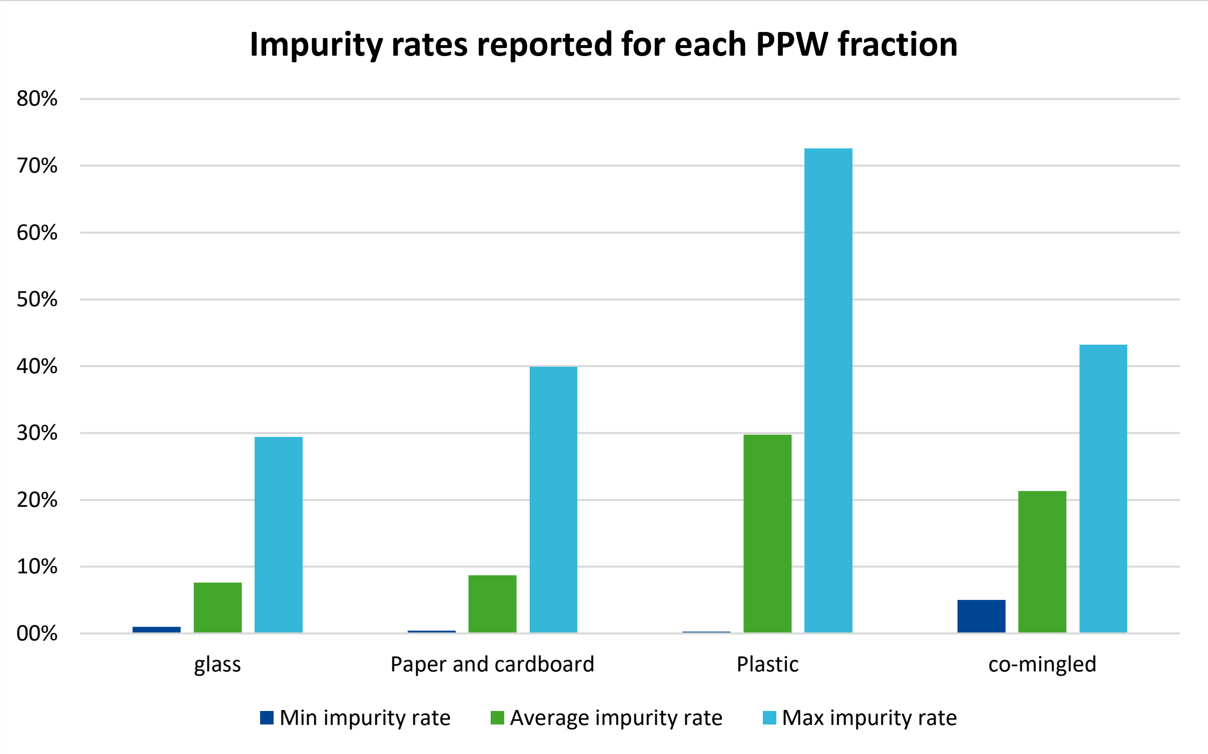

Figure 47: Impurity rates reported for each PPW fraction

For (source-separated) glass and paper/cardboard, the average impurity rates are rather low (respectively 8 and 9%), while they are more significant for source-separated plastics and co-mingled PPW (respectively about 30% and 20%). However, it should be noted that the impurity rates for plastics are only available for a very limited number of systems (7). Another observation is the relatively important heterogeneity of values observed for the different waste fraction.

The average impurities rates are presented on the figure below, for each waste fraction for which data are available:

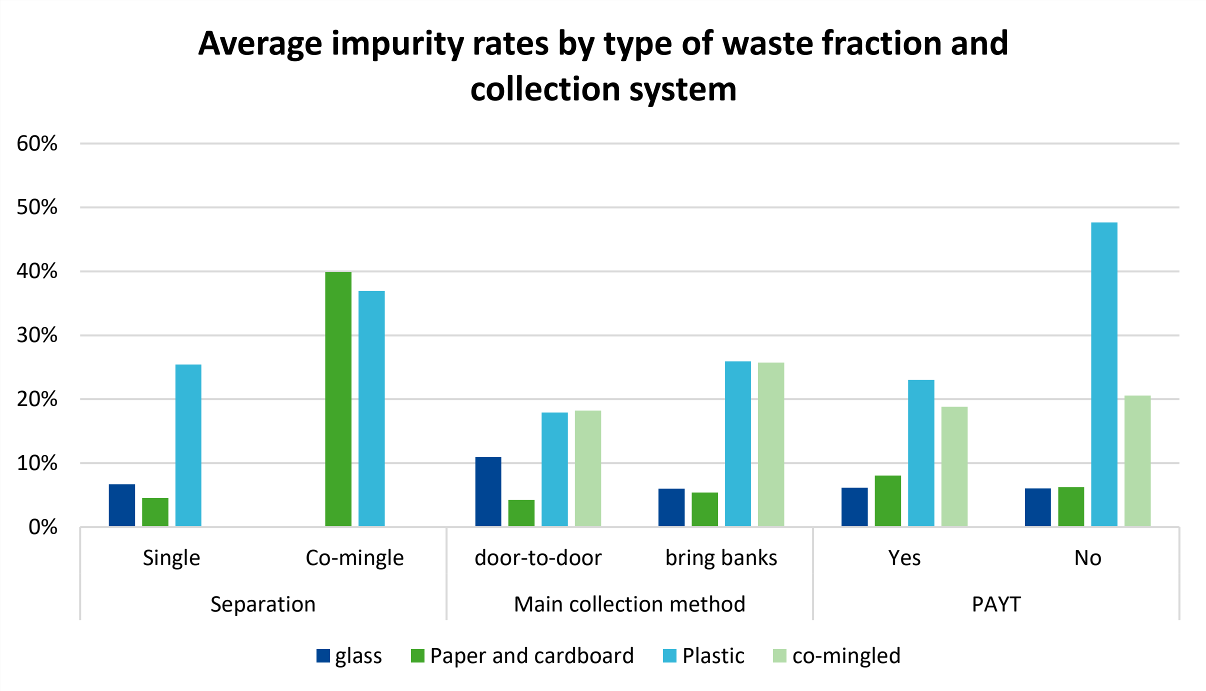

Figure 48: Average impurity rates by type of waste fraction and collection system

Source-separation tends to give lower impurity rates than co-mingled streams; collection systems has an unclear impact: door-to-door seems to be associated with lower impurity rates for plastics and co-mingled fractions than bring bank systems, similar ones for paper and cardboard, and higher ones for glass packaging. PAYT does not seem to have a link with impurity rates.

Regarding co-mingled fractions, potential links between the content of co-mingled fractions and the impurity rate were investigated. Sufficient data are only available for two types of co-mingled streams: PMC, and paper/cardboard mixed with PMC. In average, the impurity rates are similar: 20% for both fractions.

The total losses for all PPW were also calculated, and average values were calculated for the different types of separation systems, as presented in the figure below:

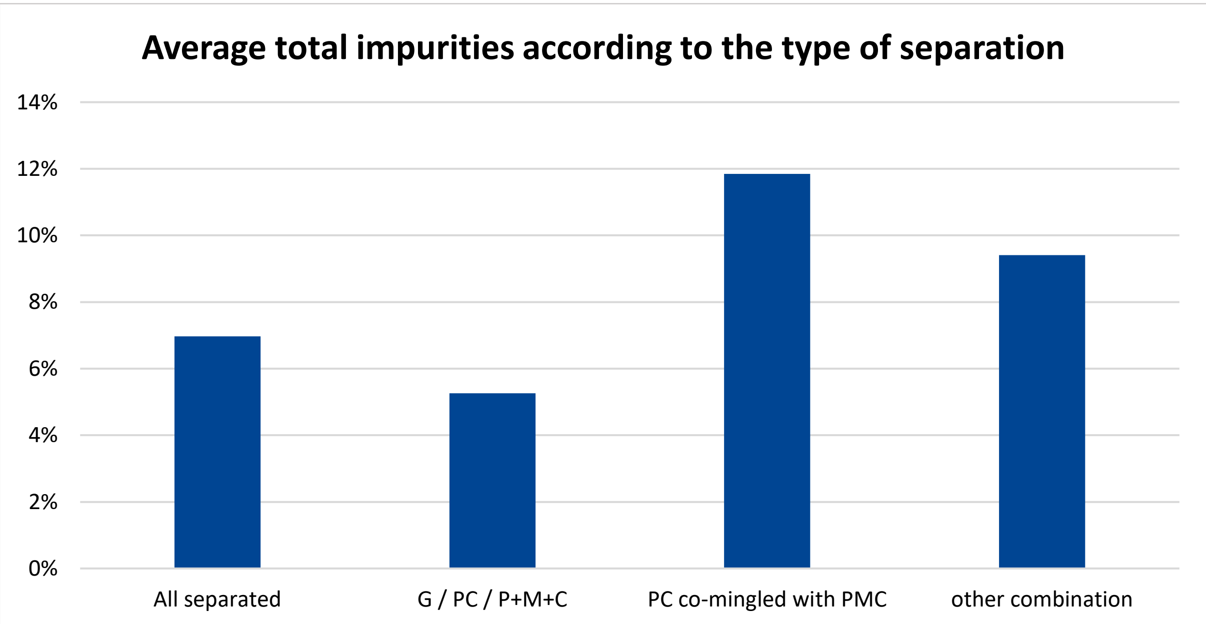

Figure 49: Average total impurities according to the type of separation

The collected data tend to show that systems using the co-mingling of paper and cardboard with other packaging waste seems to present more losses than systems separating all fractions at the source or co-mingling PMC.

5.3.2 Destination

Information were collected on the outcomes of collected PPW. Most information was collected for glass, paper and cardboard, and co-mingled fractions. The level of details is very heterogeneous, but it is unclear whether this is due to the fact that the local authorities did not have access to this information or if the data were not communicated to the consortium.

When data are available, the first destination is generally documented (transfer station, sorting centre, pre-treatment unit where impurities are removed…). However, the final outcome is less well reported. In some cases, the final recycling plant is indicated (especially when located in the same region). In other cases, it seems to be unknown, either because it is managed by the PRO or the waste company handling the sorted waste, or because several recycling plants can receive the sorted material.

5.4 PPW sorting rates

As explained previously, data were collected on the outcomes of sorted fraction, e.g. the sorted fractions extracted from co-mingled streams in mechanical sorting centres. Data on total sorted fractions (i.e. source-separated streams and output of sorting centres) could be identified for 50 waste collection systems:

- The detailed output of centres sorting co-mingled fractions were available for about 19 waste collection systems;
- 18 WCS resort to source-separation for all the PPW fractions;
- Two WCS resorting to sorting of residual waste prior to incineration provide data on the output of this pre-sorting stage;
- Several WCS provided the data on sorted quantities instead of the collected fractions.

Comparing sorted quantities is interesting, especially considering that impurity rates in co-mingled fractions can make it difficult to obtain sound comparisons with collected quantities. Sorted quantities offer a first idea on how much local authorities contribute to material recycling, even though there are some uncertainties on the outcomes of the sorted materials (e.g. whether plastic undergoes further sorting stages where part of it will be recovered as RDF, or regarding the differences with quality requirements).

5.4.1 Outputs of sorting centres for co-mingled streams

The following graph shows the output of the sorting centres processing co-mingled streams, ranked according to the rate of impurities:

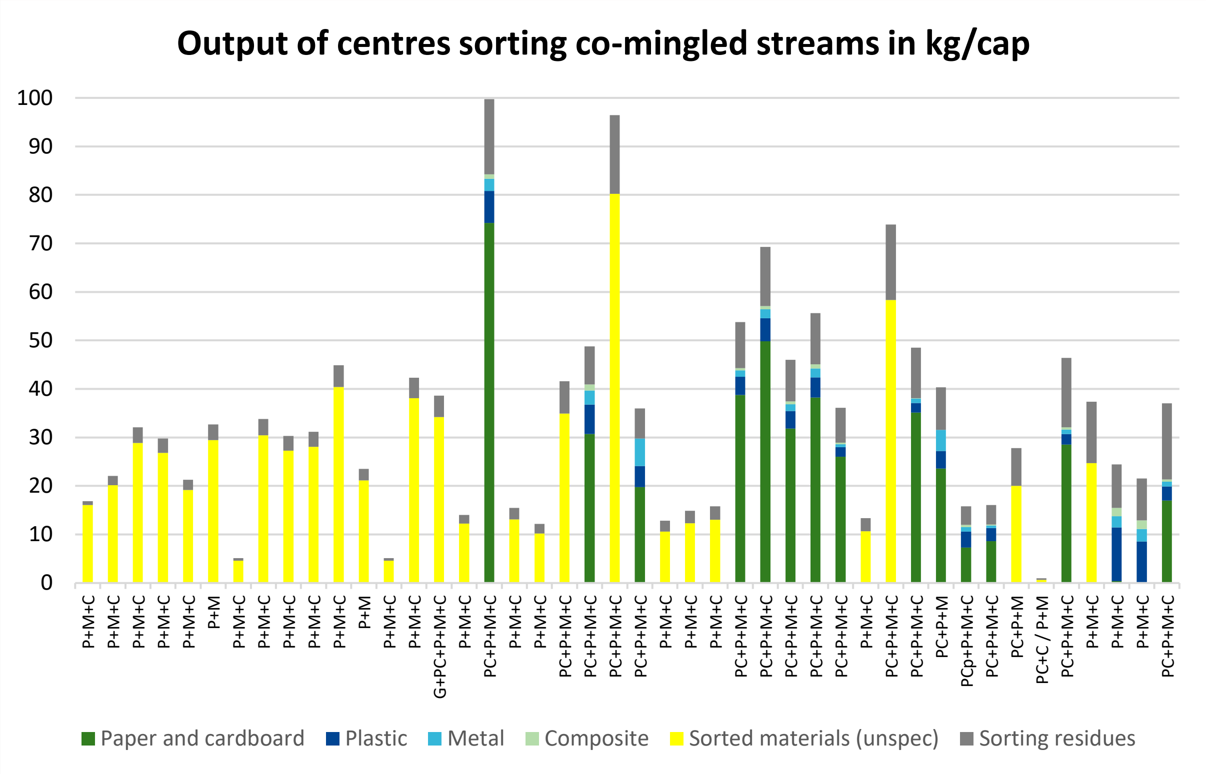

Figure 50: Output of centres sorting co-mingled streams in kg/cap

As highlighted in the previous part, systems co-mingling paper and cardboard with other materials tend to present higher impurity rates, even if some systems doing so seem to achieve relatively lower impurity rates, while some "PMC" systems have comparably high ones. There seems to be little correlation with the mode of collection and sorting residues, since WCS using bring banks can be found in both PMC systems with low impurity rates and PMC systems with significant ones.

The composition of sorted quantities are quite heterogenous among the documented WCS, even though the most significant fractions are similar, as shown in the following graph:

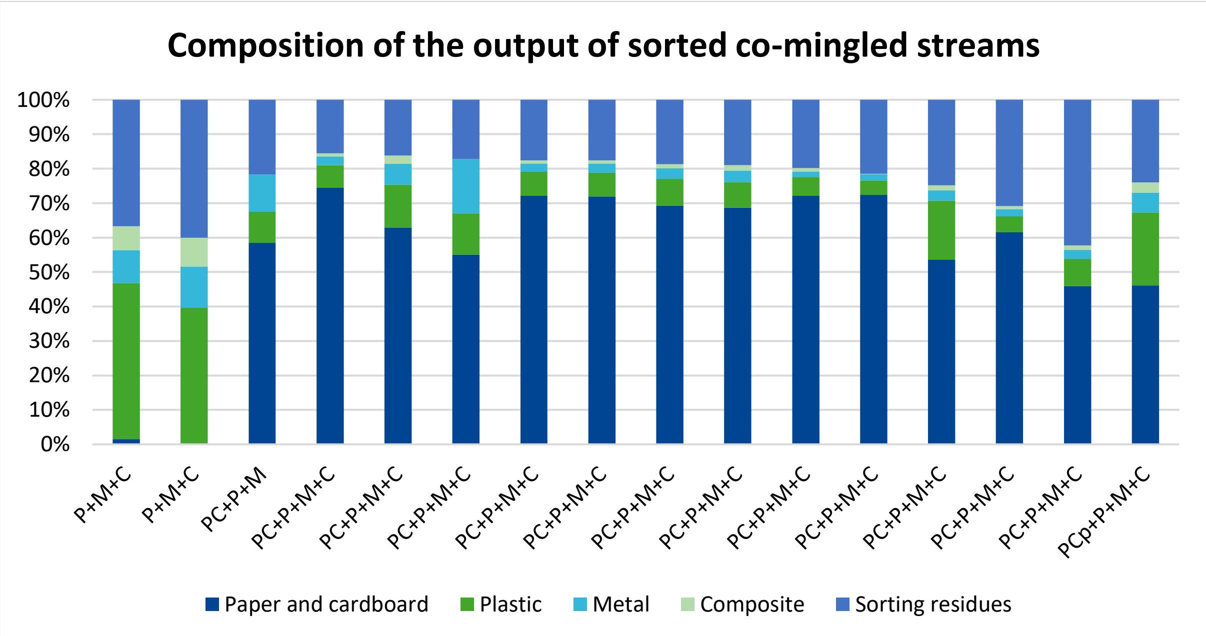

Figure 51: Composition of the output of sorted co-mingled streams

Paper and cardboard waste is the main sorted fraction for WCS co-mingling it with the other packaging waste, representing in average 80% of the sorted fraction. Then plastic packaging is the second most important one, representing about 2/3 of the sorted fraction for PMC systems, and a bit more of 10% for the systems co-mingling paper and cardboard with PMC.

5.4.2 Sorting rates

The global sorting rate for PPW is available for 74 waste collection system, and the average in this panel is 49%. The comparison of average sorting rates according to the characteristics of the collection schemes provides the same observation than for capture rate:

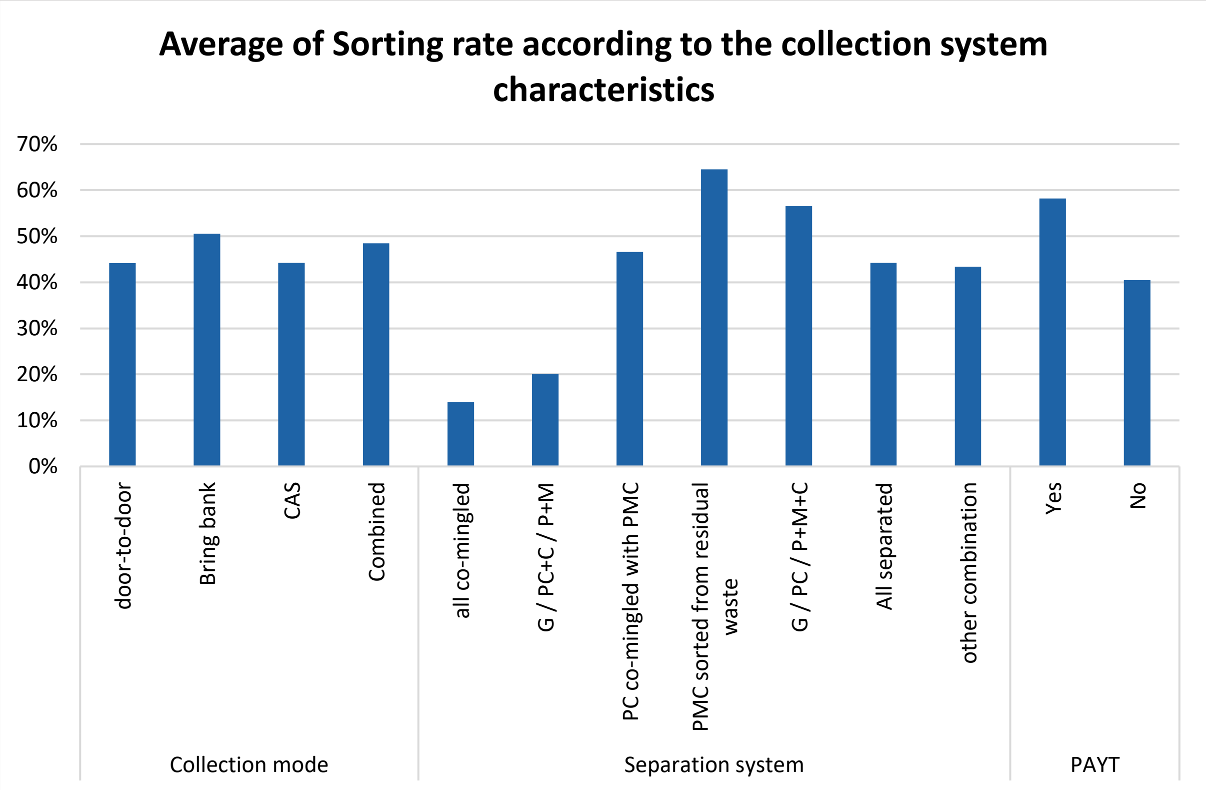

Figure 52: Average of Sorting rate according to the collection system characteristics

The observations that can be made are quite close to the one made when comparing the capture rates with these factors.

There is no clear correlation between the main collection mode and the sorting rate. Separation systems presenting the highest sorting rates are the “PMC” systems as well as the systems sorting PMC out of the residual waste and before treatment, while systems co-mingling all PPW fractions present the lowest performances. There is also a clear distinction between the average sorting rates of waste collection systems using PAYT and systems not using it.

Likewise, the comparisons of territories according to their contexts leads to the same observations as for capture rates: Territories with low GDP presents lower sorting rates, as do waste collection systems with very high density. Tourism does not seem to impact the sorting performances.

Finally, it must be noted that the little data available on the outcomes of sorted materials do not allow to compare their quality and their contribution to circular economy. Further investigation would be required to identified trends on this aspect.

6. Similarities among WCS with high and low performances

The previous observations tend to show that few instruments can be highlighted as necessary and/or sufficient to provide high performances for PPW. There seems to be systems that provide overall better results, e.g.:

- Systems resorting to PAYT generally present higher performances and lower production of residual waste;
- Systems source separating glass, and paper and cardboard tend to have higher capture/sorting rates than systems co-mingling them.

On the other hand, it seems that high performances can be reached either with door-to-door or with bring bank system. Besides, using both PAYT and source separation of paper and cardboard do not guarantee high capture rates. It is important to remind here than the keys to success seem to be a combination of instruments, and adaptation of the collection systems to the typology of housing. It is also important to note that the categories described here might encompass different realities, and that some instruments could not be properly categorised (e.g. communication activities, availability of bring banks, whether containers are located on the public space or not, or whether they are shared among inhabitants of vertical housings…). The pre-collection systems might also play a role in the success of the WCS, and little information is available on this element.

However, it can be relevant to identify and cross-analyse the waste collection systems that provides the best performances, as well as the ones presenting the lowest ones, in order to identify common trends, and thus successful combinations that could be highlighted as good practices.

6.1 Common trends and similarities of the best performing systems

The best performing territories were identified as the top 15 WCS regarding capture rates for PPW, and the top 15 WCS regarding sorting rates for PPW. Nine WCS are found in both top 15 lists, meaning that the list of top performing cities consists in 21 WCS.

As indicated before, data on capture rates and on sorting rates are only available for respectively 111 and 74 WCS, and the panel of WCS documented by COLLECTORS is not exhaustive, meaning that it is possible that some of the best performing territories in Europe might not be included in this panel.

However, the number of WCS documented by COLLECTORS is quite significant, so it is safe to assume that the similarities found in these territories are relevant and that some general conclusions on high performing WCS can be drawn from this analysis.

6.1.1 Local context in top-performing WCS

Almost all the top performing WCS are located in Western Europe, with only two of them being in Southern Europe. 12 of them are in the Netherlands, 4 in Belgium, 3 in Austria, and 2 in Italy. This might reflect the fact that these WCS benefit from a national or regional framework (regulation, EPR system) which promotes high recycling performances. For instance, both Austria and Belgium set very high landfill taxes.

When it comes to the typology of territory (inland, mountains, remoteness…), it is interesting to note that the panel is quite diverse, mixing inland, not remote territories, coastal areas, mountain areas, islands, and inland, remote areas.

12 WCS out of the identified 21 are rather small territories, with less than 40,000 inhabitants, and only 3 are above 500,000 inhabitants. Only one territory belongs to the "high density" category (with a density of 2,600 inhabitants per km²), while the other are mostly average and low-density territories. Most territories (15) have an average GDP, while the remaining WCS are equally distributed between the high-GDP and low-GDP categories. Regarding tourism, low and very low tourism areas represents more than half of the panel, yet it also includes four WCS with very high tourism activity and two with "extremely high" tourism (i.e. cities with significant overnight stays compared to the resident population).

6.1.2 Organisation of waste collection in top-performing WCS

The distribution of the sorting systems among the top-performing WCS is presented in the graph below:

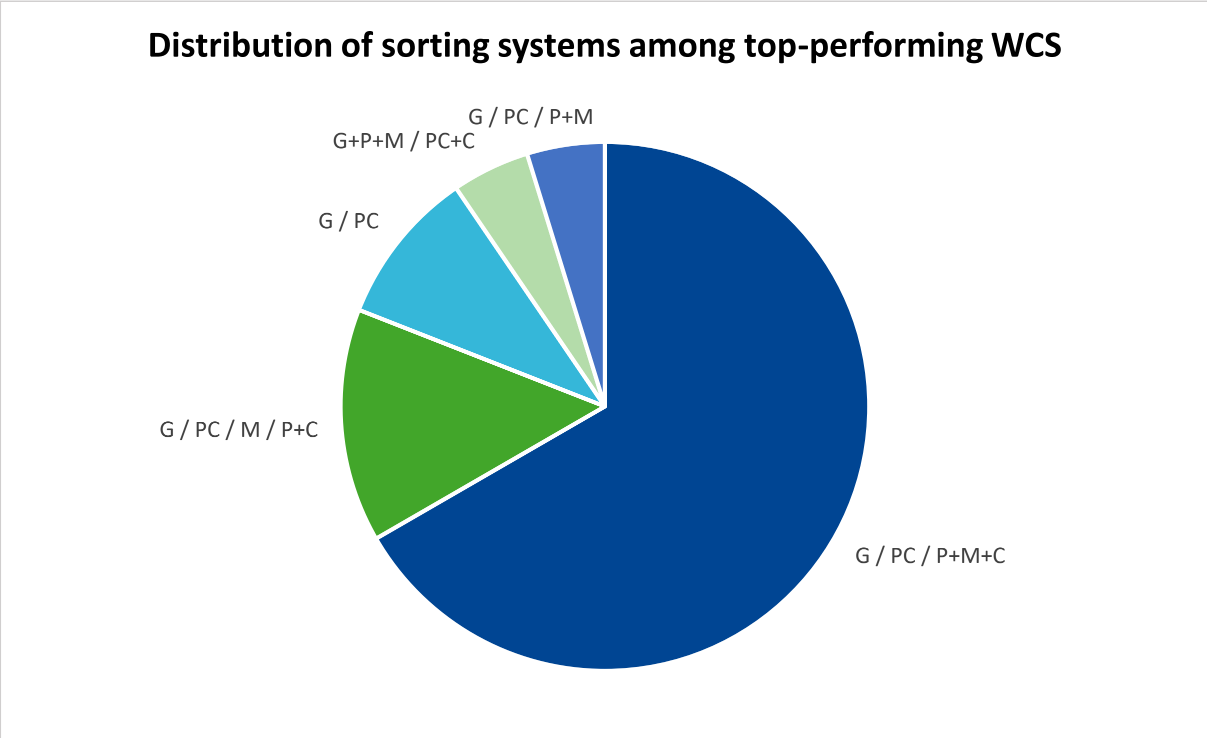

Figure 53: Distribution of sorting systems among top-performing WCS

The most represented system is the "traditional PMC system". The other systems almost all rely on source-separation for glass and paper/cardboard, but one system that comingles glass with plastic and metal, and paper/cardboard with composite packaging. The sorting system for PMC is a bit more heterogeneous. Two of the systems sort PMC from residual waste prior to incineration.

When it comes to collection modes, it is interesting to note that 13 WCS mostly use bring banks for all the different fractions. For the others, the situations are more diverse. Glass collection is mostly resorting to bring banks in all territories, and door-to-door collection is applied to the other fractions (paper and cardboard, and PMC).

Finally, all WCS but two have a PAYT system. Both systems not using PAYT are the ones that extract PMC from residual waste prior to incineration, which might be the reason why PAYT is not implemented.

6.1.3 Top-performing WCS using bring bank systems

While bring bank systems might be associated with lower performances and higher impurities due to the fact that it can appear as less convenient to users, and more complicated to control, it is interesting to note that many WCS among the top-performing ones identified by COLLECTORS mostly use bring banks. Most of them are located in the Netherlands, and are mostly small to average territories in terms of number of inhabitants and population density. All of them source-separate glass and paper/cardboard and co-mingle part or all of the PMC fractions. The density of container is also generally higher than the average, especially for the PMC (co-mingled or source separated).

There are not many differences between top-performing systems using door-to-door or bring banks, except that door-to-door systems tend to be more densely populated and with a higher GDP.

6.1.4 Performances of top-performing WCS

Regardless of the separation system, the most significant quantities come from paper and cardboard, as shown in the following graph:

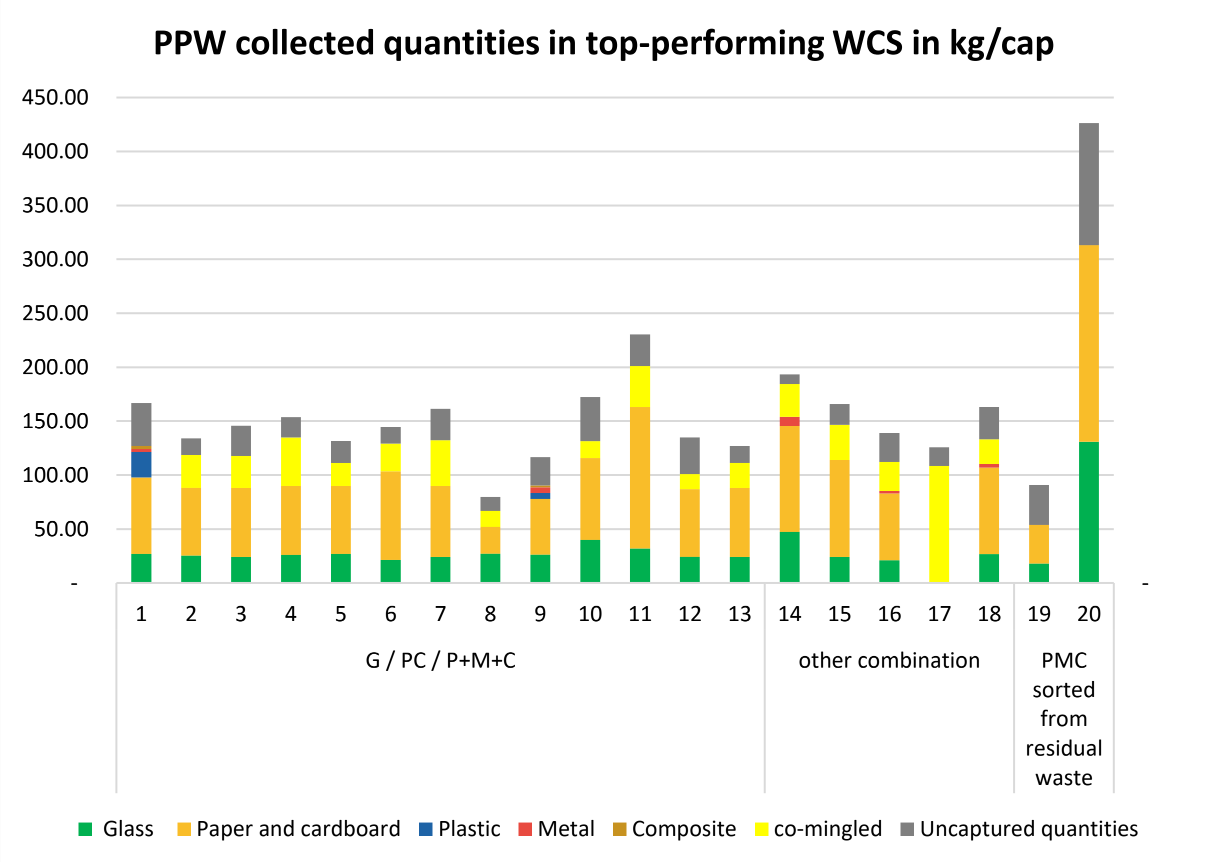

Figure 54: PPW collected quantities in top-performing WCS, kg/cap

The impurity rates are available for some of the WCS. They range from 3% to 8%. The total sorted quantities are available for one of the WCS sorting PMC out of residual waste, which shows an increase of sorted quantities by +17%.

Detailed data on collected quantities according to the collection modes are only available for 7 of the top-performing WCS. They are presented in the graph below:

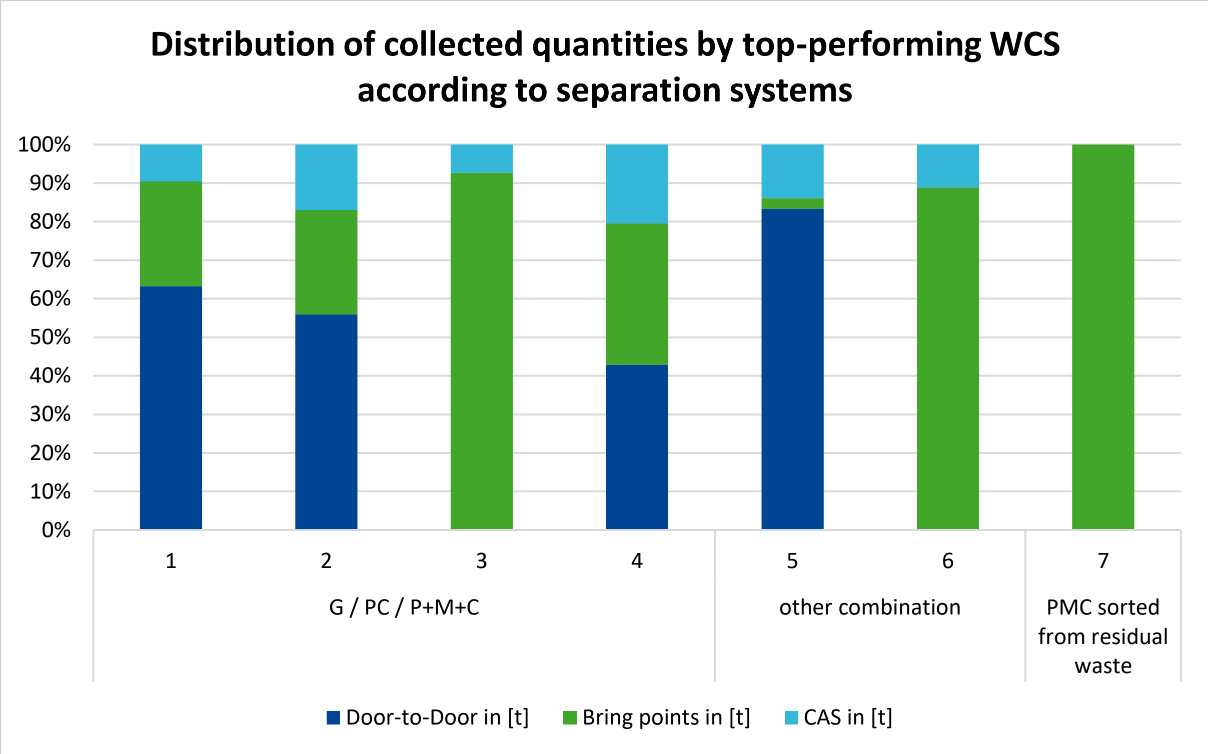

Figure 55: Distribution of collected quantities by top-performing WCS according to separation systems

The graph reflects the diversity of collection methods used by top-performing WCS, ranging from all bring system to systems mostly relying on door-to-door collection.

6.2 Common trends and similarities of the lowest performing systems

The same approach was used for low-performing waste collection systems: the 15 lowest-performing territories regarding capture and sorting rates were identified and combined in one list of 18 low-performing territories.

6.2.1 Local context in low-performing WCS

There is an over-representation of central and eastern Europe territories (almost half of the panel); the rest of the panel is composed of territories all over Europe: five from western Europe, four from southern Europe, and one from northern Europe. There are 11 Member States covered by this panel (Bulgaria, Croatia, Cyprus, France, Greece, Hungary, Italy, Lithuania, Malta, Slovenia, and the UK). When it comes to typology of territories, there is an over-representation of coastal areas and islands.

The territories covered by this panel is more diverse than the one of the top-performing territories, with population ranging between 8,000 and 1,750,000 inhabitants. There is also a more diverse distribution of density of population, with the presence of high-density and very high-density, as well as of very low-density areas. Low and very low-GDP areas represent half of the territories in the panel, yet two of the WCS have a high GDP. The panel include mostly areas with low tourism intensity, yet three WCS have very to extremely high tourism activities.

6.2.2 Organisation of waste collection in low-performing WCS

The distribution of sorting systems among the low-performing WCS is presented in the graph below:

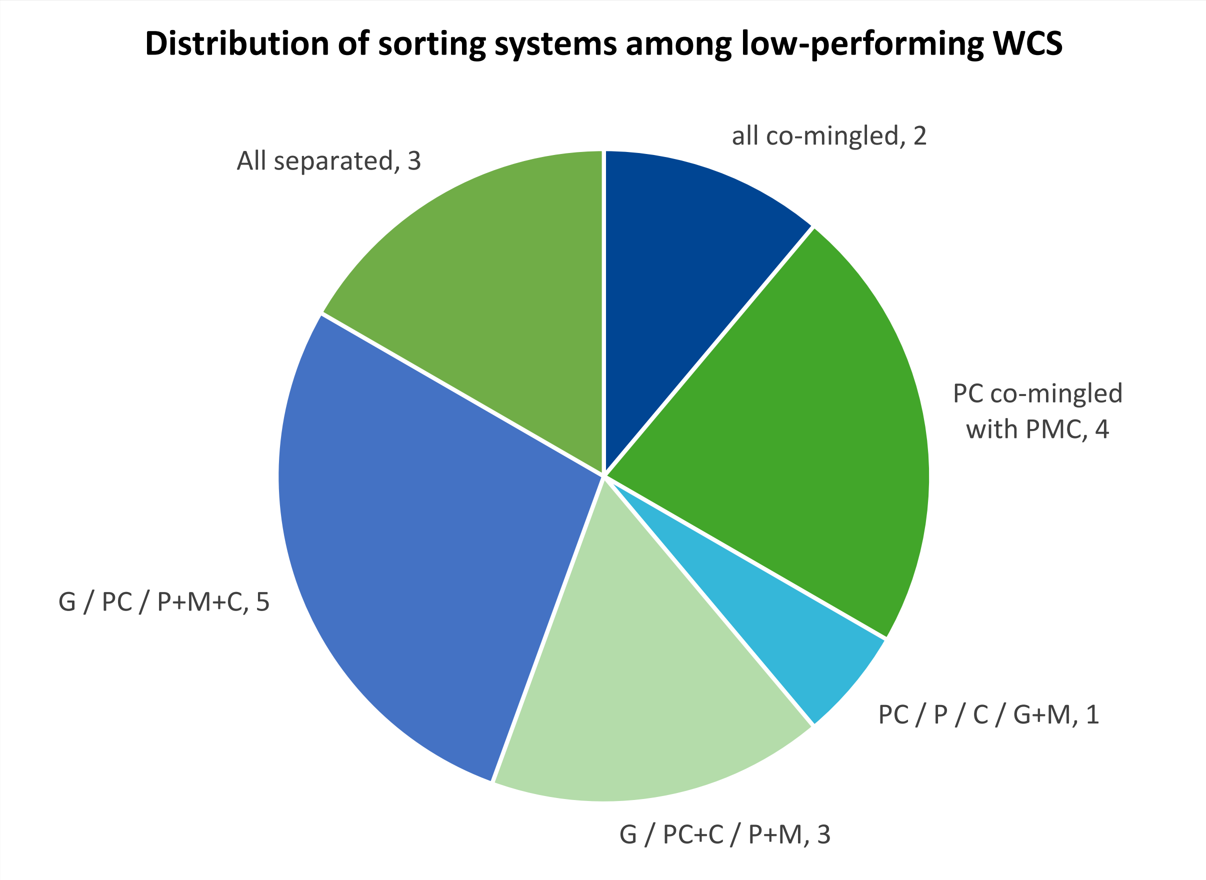

Figure 56: Distribution of sorting systems among low-performing WCS

It is interesting to note that the diversity of sorting system is more important here than with the top-performing system. Co-mingling of paper and cardboard (either with composite, or with all PMC) is more represented than with the top-performing WCS, but there is also a large number of "PMC" systems and systems source-separating all the different fractions.

When it comes to collection modes, bring bank systems represent more than half of the panel, the rest being door-to-door systems (5), and combined systems (1) and civic amenity sites-based system (1). However, the WCS labelled "door-to-door" encompass a diversity of systems when looking at the collection modes for each waste fractions: some of them rely on door-to-door collection for all packaging waste fractions, while other mix door to door and bring banks depending on the waste fractions. The density of bring points in the bring bank-based systems are generally lower than the average for most waste fractions, which might partly explain the low performances.

PAYT systems are under-represented among the low-performing territories, with only 5 WCS using them.

6.2.3 Performances of low-performing WCS

The collected quantities of the different PPW fractions are presented in the graph below:

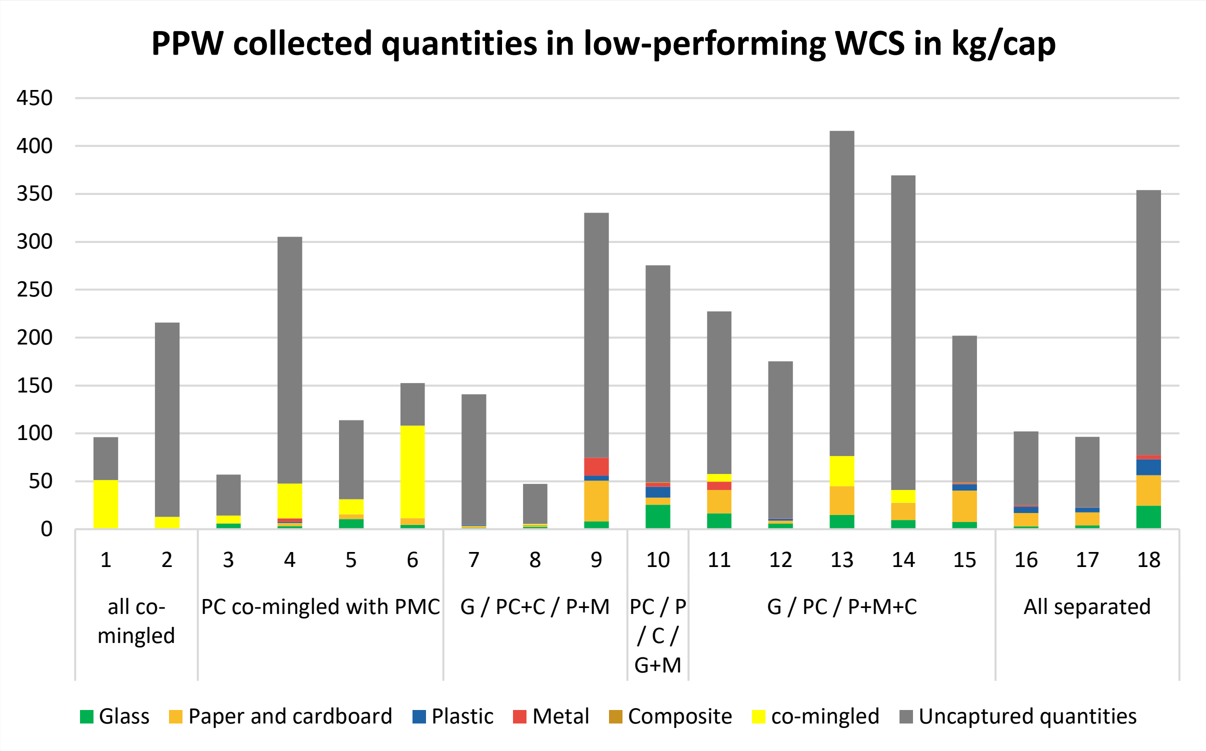

Figure 57: PPW collected quantities in low-performing WCS in kg/cap

There is no clear pattern when it comes to the collected quantities. One interesting element is the fact that some WCS have a rather high capture rate, but the very high impurity rates make the sorting rate drop to low level (below 25%). Few data are available on impurity rates, but the ones available range from 10% to 70%, with the higher rates being observed for systems relying mostly on co-mingling.

6.3 Waste performances in specific contexts

The analyses showed that several specific contexts significantly impacted the generation and management of PPW:

- Densely populated areas tend to have lower performances, possibly due to the lack of space limiting the possibilities of source-separation, and due to the importance share of vertical housing which prove more difficult to involve;
- Low-income areas appeared to be less well performing, possibly due to the lack of resources to implement source separation;
- Highly touristic areas generate more PPW per inhabitants, that can make waste management challenging.

6.3.1 Densely populated areas

The 10 densest territories were selected for the analysis, with density of population ranging from 5,000 to 21,300 inh/km². The collection systems in this panel are quite different, with an equal distribution among door-to-door and bring bank systems. Only two of these dense territories use PAYT.

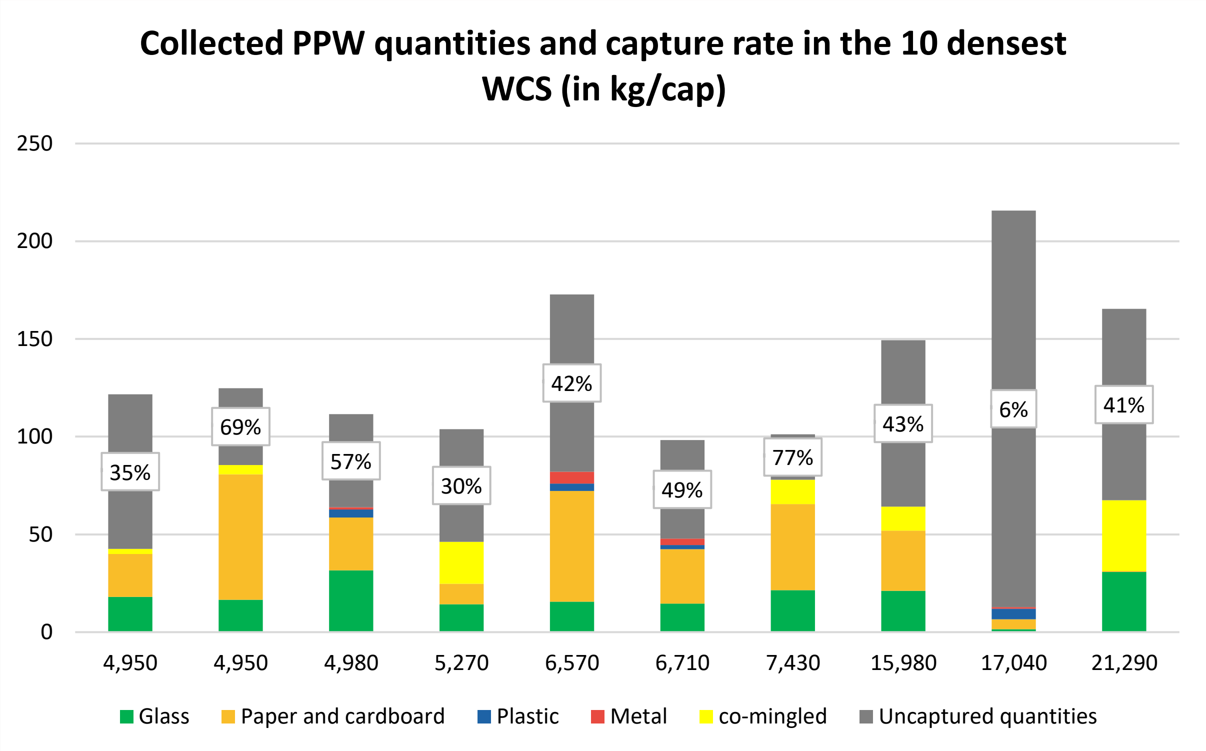

Figure 58: Collected PPW quantities and capture rate in the 10 densest WCS (in kg/cap), ranged by density of population (shown in inh/km² at the bottom of each graph)

Only three WCS have a capture rate above 50%, and two of them have a relatively "low" density compared to the rest of the panel. There are not clear differences between the well- and the low-performing WCS: most of the WCS source-separate both glass and paper and cardboard. The better performing systems tend to use more door-to-door collection modes for paper/cardboard and PMC.

The data available on capture rates for the different waste fractions shows that the best performing territories have quite good performances for glass and paper, and average to low performances for PMC, while the low-performing ones fail to reach good capture rates for either glass, or paper/cardboard, or both. For glass, the data on the density of containers do not explain the difference in performances; for paper and cardboard, most of the best performing WCS use a combination of door-to-door collection and source separation, while the low-performing ones either use bring banks or co-mingle it with PMC. The low-performance systems using mostly bring banks generally have lower densities of containers compared to the others. The low-performing systems resorting to door-to-door also present rather high collection frequencies for residual waste, which might partly explain the performances.

The absence of clear explanation behind the difference leads to think that the reasons should be found in elements that were not covered by the data collection, such as communication activities, or pre-collection systems, which are quite important in vertical housing.

6.3.2 High tourism activities

To analyse the performances of highly touristic cities, the eight WCS belonging to the "extremely high tourism activity category" (i.e. with overnight stays per inhabitant over 50) were listed. These territories are mostly islands or mountain areas, with a very low density. The collected quantities of PPW and capture rates are presented in the graph below:

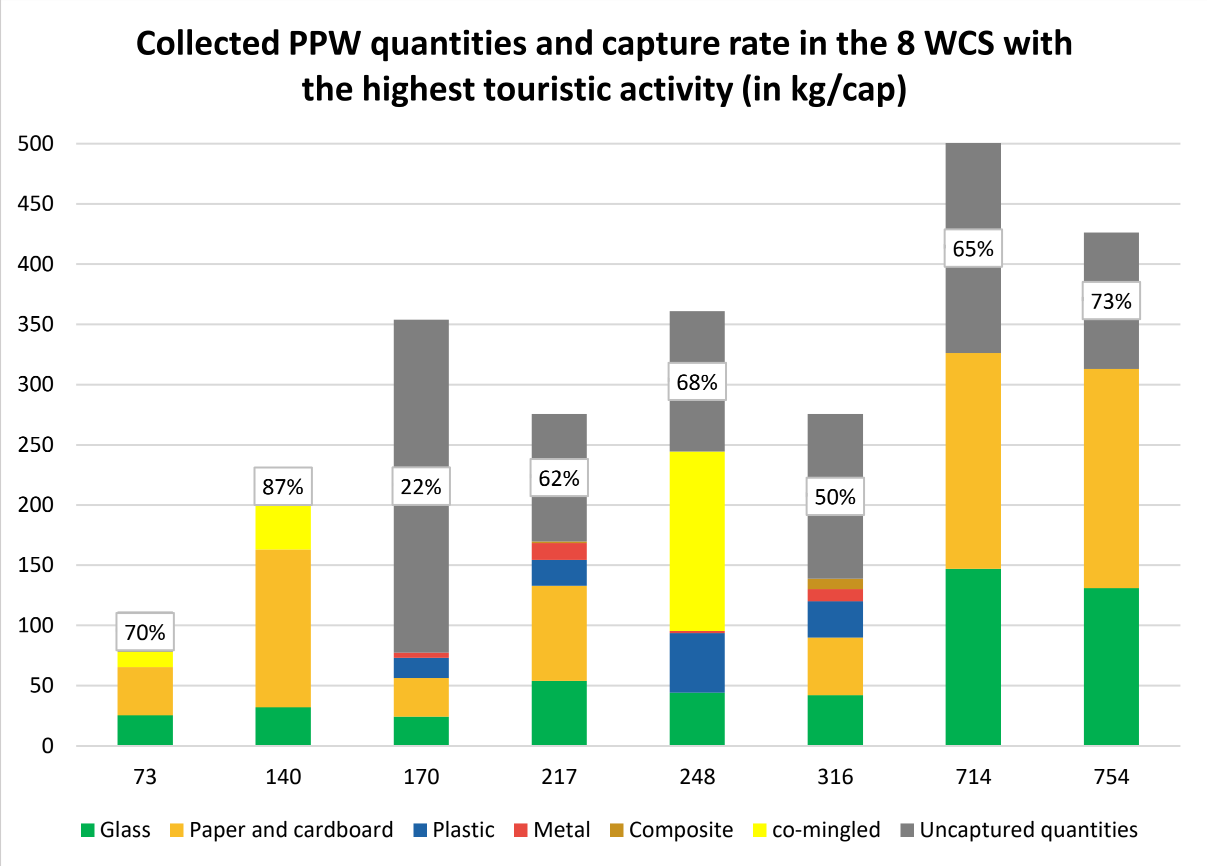

Figure 59: Collected PPW quantities and capture rate in the 8 WCS with the highest touristic activity (in kg/cap), ranked by touristic activity (overnight stays per inh. at the bottom of each bar)

The graph shows the impact of tourism on PPW generation, with increasing produced quantities in more touristic areas. It also shows that the performances among the panel are rather high.

The waste management systems are quite different among this panel, and there are no real similarities among the top-performing WCS, besides the fact that glass and paper/cardboard are source-separated. Three WCS are collection PMC with the residual waste and extract them before incineration; two of them are among the best performing territories. Otherwise, the systems resort either to door-to-door, bring bank, or civic amenity sites based-systems.

The three best WCS among the panel have especially good capture rate for glass, which is collected in bring banks. PAYT systems are in use in two of the three best performing systems, the other one using mechanical sorting on residual waste.

6.3.3 Low-GDP territories

The 10 WCS with the lowest GDP were identified. All of them are located in central or eastern Europe, but one located in Southern Europe.

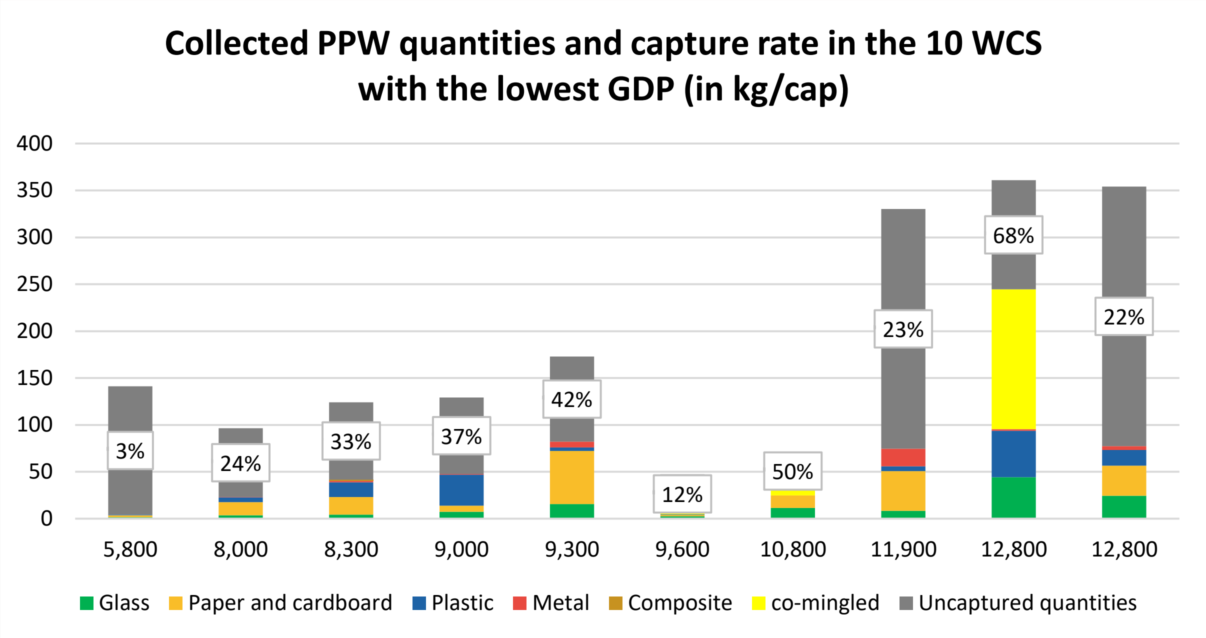

Figure 60: Collected PPW quantities and capture rate in the 10 WCS with the lowest GDP (in kg/cap). The GDP per inh. is indicated at the bottom of each bar (in €/cap)

The low-GDP WCS present rather low performances; only two of them have a capture rate higher than 50%. However, there is no clear explanation behind these higher performances. Both of them mostly use bring banks for all waste fractions, with different separation systems. There does not seem to be a correlation between the density of containers and the performances within this panel; some of them even have figures that are comparable or above to the average of all WCS.

6.4 The influence of PAYT

One of the main parameters that explains differences among the performances of WCS is the use of PAYT systems. The data collection does not allow to have details on the type of PAYT systems. The overall impact of PAYT on the performances of the documented WCS is presented in the graph below:

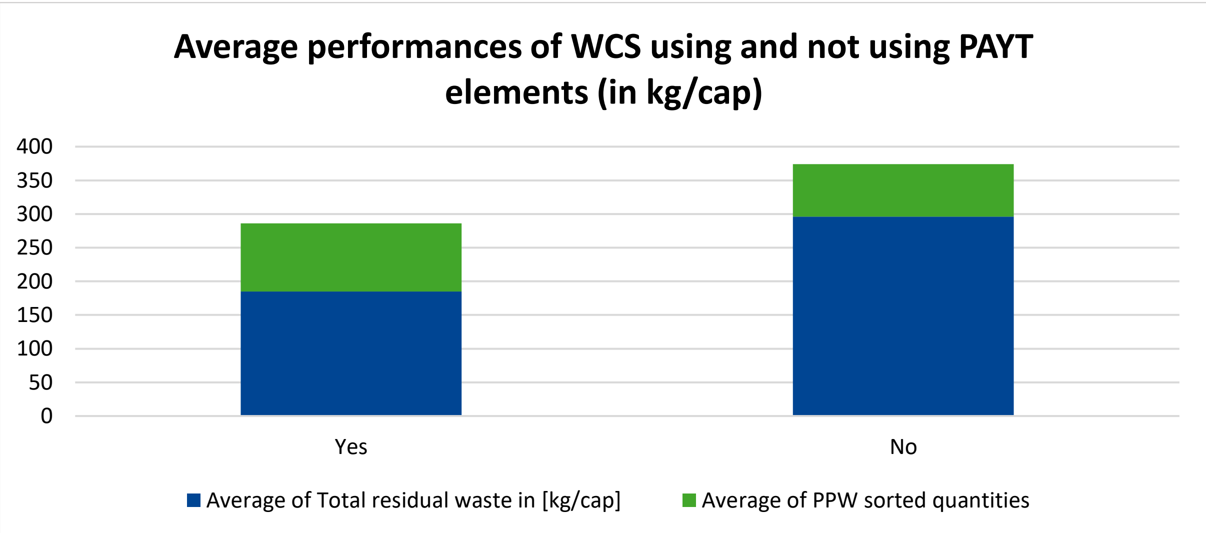

Figure 61: Average performances of WCS using and not using PAYT elements (in kg/cap)

The graph shows the significant impact of PAYT on both the collected quantities of PPW and the residual waste generation. This is also highlighted in the following graph:

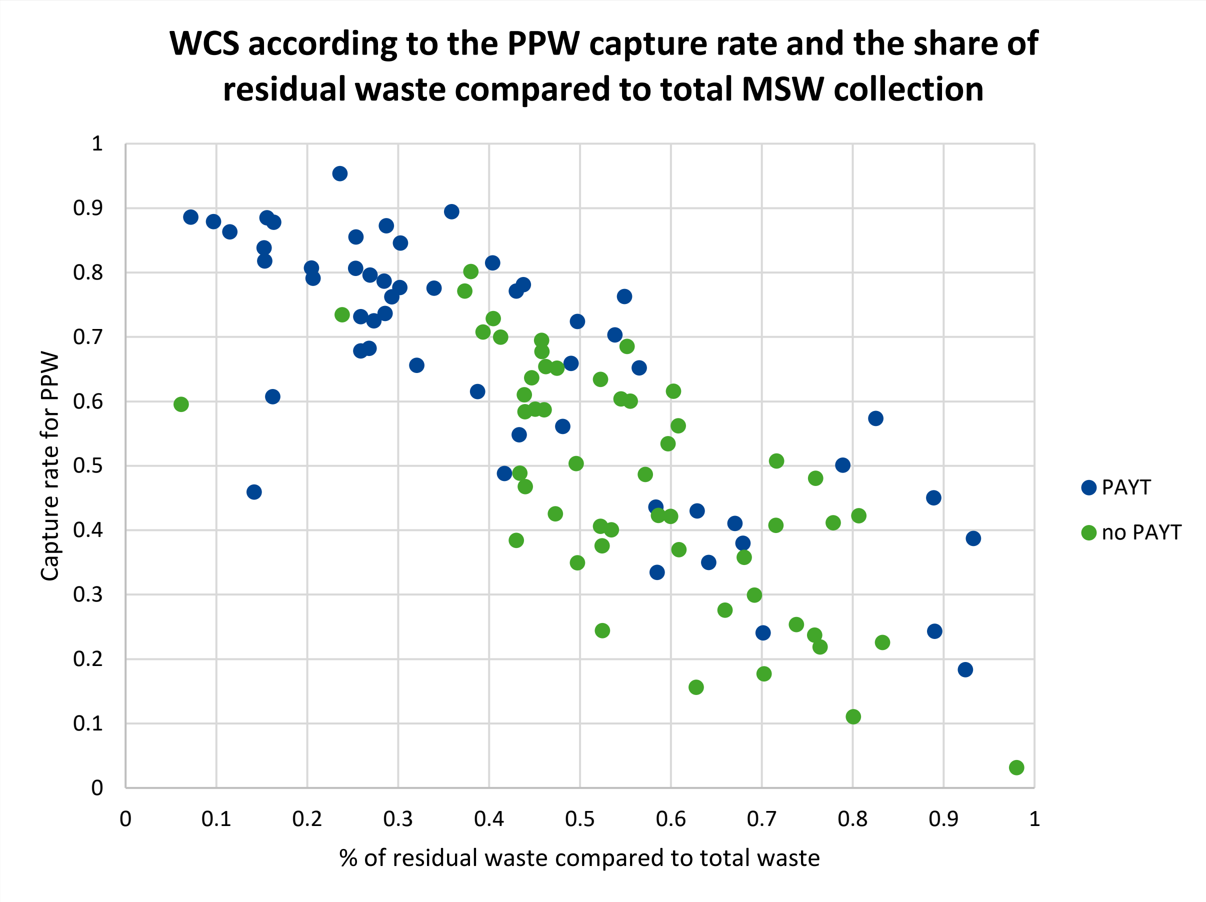

Figure 62: WCS according to the PPW capture rate and the share of residual waste compared to total MSW collection

This show that there are mostly PAYT systems (in blue) among the high performing WCS (in the upper left of the graph), while there are mostly non-PAYT systems (in yellow) among the low-performing ones (in the bottom right). However, some exception can be observed, meaning that PAYT systems do not guarantee high performances, and that some WCS managed to reach high performances without it.

It also shows that very few WCS reach a PPW capture rate higher than 80%, or a generation of residual waste below 25% of the total municipal waste, without having a PAYT system.

7. Conclusion

The COLLECTORS project allowed the collection of a significant database representing 12% of the EU population, whose analysis both confirms some observations made by previous report by the Observatory, and highlights some new elements regarding paper and packaging waste collection in Europe. The panel of documented WCS represents about 12% of the European population and covers 24 Member States, with quite different typologies and contexts. Even if it might not be completely representative of how municipal waste is organised and the average European performance, it provides an interesting overview of the different types of organisation, levels of performances, and allows drawing conclusions on effective instruments.

The overview highlights the great diversity of collection systems across Europe, with many different sorting systems and combination of collection modes. However, there are some common trends: the use of bring system for glass packaging is quite widespread, and the "PMC" system (source-separating glass and paper/cardboard, and co-mingling the other packaging) is the most widespread across the different Member States.

The significant number of documented WCS also allows to establish correlation between the context, paper and packaging generation, and performances. While waste generation is the result of many different drivers, several parameters seem to strongly impact local PPW generation: very high tourism activities can be associated with very significant PPW production, while territories with higher GDP tend to have higher generation rates for paper and cardboard. Two external parameters can be associated with lower performances: territories with very high population and areas with very low GDP generally present lower recycling performances.

When it comes to successful waste strategies, the analyses tend to show that the key to success seems to lie in the combination of various instruments:

- Source separation: system source-separating glass and paper/cardboard tend to present better performances, while the source-separation of PMC does not seem to be correlated with higher performances;
- Collection mode: interestingly, "door-to-door" systems and "bring bank" systems present on average comparable performances, and it seems that both types of collection enable very high performances. It does not necessarily mean that both collection modes would give the same performances in one given territory;
- For bring bank systems, a higher density of containers (i.e. the number of containers per km^2) tends to lead to higher capture rates, while there is no correlation between the number of containers per inhabitant. It reflects the fact that the proximity is a key factor of success;
- PAYT: systems using PAYT present higher capture rates and lower generation of residual waste. It seems unlikely to reach the highest capture rates without using it.

However, the available data do not allow to obtain a complete understanding of success factors. Some crucial elements could not be documented, such as communication or pre-collection, among other. Besides, little is known on the outcome of sorted fraction after the final sorting stage. Data on impurity rates and actual use of sorted materials are generally not available, which limits the possibilities of understanding the contribution of well-performing system to the circular economy.

The COLLECTORS project will address both these points by conducting in-depth analysis of well-performing systems to better understand their environmental and economic impact. These findings will contribute to improve the knowledge of the Observatory.

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