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**Characterisation of source-separated, rigid plastic waste and evaluation of recycling initiatives:
Effects of product design and source-separation system**

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Abstract

Recycling of plastic from household waste (HHW) is crucial in the transition towards a circular plastic economy. Plastic from HHW consists of numerous immiscible polymers, product types and product designs (e.g. colour, polymer separability), which often lead to considerable physical losses during sorting, and low-quality recycled plastic. Consequently, recycling initiatives have been proposed to enhance the quantity and quality of plastic recycling from HHW. To quantify the potential effects of such initiatives, a detailed composition of plastic waste is necessary. The aim was to provide such detailed composition of Danish source-separated rigid plastic waste, including information regarding the polymer of the main product component, product type, polymer design and separability as well as colour. The potential effects on recycled quantity and quality from implementing selected recycling initiatives were quantified and recommendations provided. PET, PE and PP made up >90% of the source-separated plastic and both food- and non-food packaging existed in all three polymers. In total, 10-11% of the plastic was black, and around 44% consisted of multiple polymers, of which one-third was non-separable. Initiatives improving product design for recycling will likely result in increased quantity of recycled plastic. By effectively separating food from non-food packaging, e.g. by introducing two bins in the households or politically aligning polymers and product types (all food packaging in PET and PP, all non-food packaging in PE), 39-63% of the waste could potentially be recycled in a closed loop into food-grade quality packaging. The overall highest benefits were reached by combining initiatives.

1 Introduction

Recycling is often highlighted as a crucial measure in the transition towards a circular economy and closed material loops. Special focus has been placed on plastic, with a 55% recycling target for plastic packaging by 2030 (EU, 2018a) and a 60% recycling target for municipal solid waste, including plastic, by 2030 (EU, 2018b). Mixed plastic from municipal solid waste, particularly household waste (HHW), is a highly heterogeneous waste stream, as it includes a variety of different immiscible polymers, product types and designs. Moreover, plastic from HHW can contain both chemical and physical contamination from the production, use and waste management phases (Eriksen et al., 2018a; Eriksen et al., 2018b), and consequently it is a highly contaminated resource (Ragaert et al., 2017). As a result, recycling of plastic from HHW often includes considerable material losses (Van Eygen et al., 2018; Haupt et al., 2016) and leads to recycled plastic with poor material properties (Rigamonti et al., 2018). This limits the applicability of the recycled plastic and thereby plastic recycling systems' ability to close material loops (Eriksen et al., 2018a).

The heterogeneous and contaminated nature of plastic from HHW is a consequence of several issues. First, the use of several immiscible polymers in the production of plastic products makes it a prerequisite to separate plastic waste into individual polymer streams subsequent to collection and before reprocessing. During this process, some degree of material loss and contamination is inevitable, the degree depending on the performance and sorting efficiencies (Eriksen et al., 2018a). Second, the presence of numerous different product types, with different shapes, production methods, chemical content and legal requirements, is important. Especially mixing food packaging, which previously complied with strict chemical legislation, and non-food related products, not having to comply with the same strict legislation, is a challenge for the potential quality of recycled plastic (Hahladakis and Iacovidou, 2018), as mixing in many cases makes the recycled material unsuitable for food contact (Welle, 2011). In fact, 100% of a PE or PP waste stream and 95% of a PET waste stream, representing the input to the final recycling, have to have been approved previously for food contact, in order to be recycled into new food-grade secondary plastic (EC, 2008; EFSA, 2011), which is crucial for a recycling system's ability to close polymer loops (Eriksen et al., 2018a). Thus, a sorting systems ability to

mechanically separate food packaging from non-food plastic items, and thereby produce streams potentially suitable for recycling into food-grade material, is closely related to the distribution of food and non-food packaging within the different polymers in the plastic waste. Third, there are many different product designs, including different colours and an increasing complexity regarding polymer design. Black products cannot be sorted using NIR sorting technologies, which is the predominant spectroscopic technology for household plastic (Turner, 2018; Becker et al., 2017). Consequently, black products are lost in the sorting process and sent to incineration. Moreover, several challenges are related to complex polymer designs. If a product consists of several polymers that can be separated during sorting or recycling (e.g. a PET bottle with a PE cap), the non-targeted polymer (the PE cap) will be separated from the main waste stream intended for recycling and thereby often end up in the residual fraction sent to incineration (FCP, 2018). Moreover, products made of multiple non-separable polymers (e.g. a multilayer meat tray) contaminate the waste stream and will always introduce some degree of polymer cross-contamination (FCP, 2018; Hahladakis and Iacovidou, 2018). Third, all products made of multiple polymers have an increased risk of being sorted into the wrong polymer stream during mechanical sorting, as the NIR scanner may detect the polymer of the label or lid and sort it accordingly instead of sorting it according to the polymer of the main product component.

To mitigate these challenges, and thereby increase the quantity and quality of recycled plastic from HHW, initiatives related to changes in product design and configuration of the source-separation systems have been in focus. Recently, several organisations and stakeholders have launched guidelines to design new products suitable for recycling (Rethink Plastic, 2018; FCP, 2018; APR, 2018a). These guidelines include, for example, the stipulation that all components of a product should be of the same mono-polymer, or that they are fully disassembled during use (FCP, 2018). Moreover, Hahladakis and Iacovidou (2018) claim that not all plastic products are suitable for recycling; however, separately collecting the ones that are could improve closed-loop recycling and sustainable management. As an example, such an initiative is planned in Denmark in 2020, when the refund deposit system will be extended to include PET bottles for juice and lemonade, in addition to the current PET bottles for water and carbonated drinks (MEFD, 2018). However, detailed compositions of plastic waste, including information related to the polymer type of the main product component, product types, polymer design

and separability, as well as colour, are essential, in order to model and accurately evaluate the effects of such initiatives. Various studies have reported compositions of plastic waste from households (e.g. Edjabou et al., 2015; Enviros Consulting, 2009), some of them including the composition of several polymers and product types (Brouwer et al., 2017; Petersen et al., 2015). However, none of these studies includes specific information regarding polymer design and separability or the colour, and they rarely distinguish between food and non-food packing. Without such information, quantifying the effects of new recycling initiatives is not possible.

The aim of this study was to provide a detailed composition of Danish source-separated plastic waste and on this basis quantify the potential improvements in quantity and quality of recycled plastic associated with a range of new recycling initiatives reflecting both product design and configuration of the source-separation system. The following specific objectives were addressed: 1) Based on a sampling campaign, provide a detailed composition of source-separated plastic waste from the municipality of Copenhagen, Denmark, including information regarding the polymer type of the main product component, product type, polymer design and separability as well as colour, 2) define theoretical scenarios representing key types of recycling initiatives related to product design and configuration of the source-separation system, 3) quantify the potential quantity and quality of the recycled plastic in each scenario through material flow analysis and 4) evaluate the effects of the individual initiatives and provide recommendations supporting the highest increase in recycled quantities and qualities, thereby enhancing the overall circularity of HHW plastic recycling.

2 Methodology

2.1 Plastic waste characterisation

2.1.1 Study area

The waste sampling campaign covered source-separated plastic waste collected from households in the municipality of Copenhagen, the capital of Denmark. By January 2017, the municipality had a population of 591,481 (KK, 2016), distributed in 280,000 households (Mortensen, 2017). Since 2012, the households could source-separate rigid plastic, while the source-separation of soft plastic was

included in May 2017. The sorting scheme has since its beginning targeted both packaging and non-packaging items. The municipality assumes that 155 tonnes of source-separated plastic is collected per month (Mortensen, 2017), corresponding to a source-separated plastic generation rate of around 0.55 kg/household/month.

2.1.2 Waste sampling

The study included sampling of 3,700 kg of source-separated plastic waste from the municipality of Copenhagen from December 2017. This corresponded to the monthly amount of plastic waste collected from approximately 6,500 households. The sample was collected during four days with two or three days in between, one fourth of the total sample in each day. This assured that the total sample included plastic waste from both single- and multi-family houses, collected from several areas in Copenhagen. The collection was carried out following normal collection procedures in the area and with the same collection vehicles. The sample was characterised at a pilot-scale sorting facility owned by the municipality of Copenhagen (COWI, 2017), receiving source-separated plastic waste from the municipality.

Initially, the four subsamples were prepared individually, including removal of misplacements by manual sorting, a wind shifter, a magnet and an eddy-current separator, thereby totally removing 550 kg of non-plastic items (classified as ‘mis-sortings’) as well as 490 kg misplaced large plastic items that should have been delivered instead to recycling stations. Due to practical limitations, and since the soft plastic accounted for only 10% of the targeted fractions in the source-separated plastic, soft plastic was excluded from the sample before further characterisation. More details of the amounts received at the facility are provided in the Supplementary Material (SM), Table B1.

The remaining waste consisted of 2,400 kg rigid plastic items. At the sorting facility, all four subsamples were sorted further into the polymer types PET, PE, PP, PS and a residual fraction, by using a NIR scanner. During NIR sorting, one sample of each polymer fraction were taken from each subsample, resulting in a final sample of 460 kg, for further detailed characterisation.

2.1.3 Characterisation scheme

All waste products in the sample were characterised in a tiered approach (level I-IV) according to four aspects important for the recyclability of plastic products in HHW: I) polymer type of the main component, II) product type, III) polymer design and separability and IV) colour, an overview of which is presented in Table 1. These levels represent critical material properties potentially affecting the effectiveness of the sorting and/or reprocessing processes and thereby ultimately the overall recyclability of the plastic waste. A combination of all four levels gives 390 theoretical fractions; however, waste was only detected in 97 of these.

Previous studies have shown that plastic from households consist predominantly of the polymer types PET, PE, PP and PS (e.g. Edjabou et al., 2016; Petersen et al., 2015). As these polymer types are immiscible, they have to be separated from each other, before they can be recycled into new raw material (Ragaert et al., 2017). Consequently, as level I, the plastic was characterised into the polymer types PET, PE, PP, PS and a remaining “other polymers” fraction.

>Table 1<

The previous application of products in waste is important for the recyclability for several reasons. First, packaging approved for food contact has to comply with strict legislation, which non-food packaging does not. Second, chemical compounds from the previous content might have migrated into or bound to the plastic surface. Third, different product types, produced using different techniques (e.g. bottles produced from blow moulding and caps from injection moulding), can have different mechanical and chemical properties, even within the same polymer type, which can be a challenge in the recycling process (Cornell, 2016). Hence, as level II, the waste was characterised into 13 product types (Table 1). For simplicity and for comparison with other studies, the product types can be aggregated into broader categories, as presented in the SM, Table A1.

Several studies as well as the EU have stated that the design of plastic products is crucial for the recyclability (e.g. Hahladakis and Iacovidou, 2018; EC, 2018; Ragaert et al., 2017). To reflect key design

criteria potentially affecting recyclability, the waste products were characterised according to level III, including three types of polymer design and separability: 1) single-polymer products, 2) products made of multiple polymers that *can* be mechanically separated and 3) products made of multiple polymers that *cannot* be effectively separated mechanically. The three types of polymer design and separability are elaborated further below:

- **Single-polymer (SP):** Products that consist solely of one polymer and thus do not introduce a risk of polymer cross-contamination in subsequent recycling and are often relatively easy to recycle (Dahlbo et al., 2018). E.g. a disposable plastic plate.
- **Multiple polymers – separable (MP-S):** Products made of two or more polymers that *can* be separated mechanically during recycling, e.g. by shredding, followed by density separation or separation using NIR technology (APRb, 2018; PRE, 2014; Welle; 2011). MP-S products, however, still introduce potential risk of polymer cross-contamination during recycling. First, if a NIR scanner detects the label or lid instead of the body of the bottle, the product will be mis-sorted, i.e. put in the wrong stream. An example would be if a PE bottle with a PET label was sorted into the PET stream, instead of being correctly sorted into the PE stream. Second, only recycling systems designed to remove such polymer cross-contaminations may do this effectively.
- **Multiple polymers – *non*-separable (MP-NS):** Products made of two or more polymers that *cannot* be effectively separated from each other. This could for example be a multilayer PET tray for meat, which has been reported to contaminate the rest of the PET stream (Hahladakis and Iacovidou, 2018). *Non*-separable products will always introduce some degree of polymer cross-contamination and thereby complicate or deteriorate the recycling process and subsequent material quality (PRE, 2014; Hahladakis and Iacovidou, 2018).

Finally, since many plastic sorting facilities use NIR scanners that in most cases cannot detect dark or black plastic (Brunner et al., 2015), which is therefore lost in the residual fraction, the plastic waste was characterised into black plastic and plastic of other colours.

2.1.4 Characterisation procedure

The characterisation procedure included four main steps, as illustrated in Figure 1.

>Figure 1<

The first step involved characterising the mixed rigid plastic into polymer types, which was done using the NIR scanner at the pilot-scale facility. As there can be up to 25% mis-sortings in the polymer fractions produced at the pilot scale facility (COWI, 2017), the polymer type was further confirmed through visual inspection, when the product had a polymer identification label, or by using a handheld diamond ATR-FTIR scanner (4300 Agilent).

Classification into product types was done manually based on visual inspection of the product in general and the label describing the previous use. Trays, tubs and other rigid items, where the previous use could not be identified, were characterised as food packaging, if they were labelled with the European cup-fork symbol for materials approved for food contact (EC, 2008), and as non-food packaging if not so.

The polymer design and separability of each waste product was identified based either on visual inspection or by use of the handheld ATR-FTIR scanner. For products that clearly consisted of several parts (e.g. a bottle with a lid or a tray with foil attached) the polymer of both parts was identified using the FTIR. If the different parts were made up of different polymers, the products were classified as either “Multiple polymers – separable” or “Multiple polymers - non-separable,” based on how they were attached; otherwise, they were classified as “Single polymer.” Products that visually only consisted of one type of plastic (e.g. a disposable plate) were classified as “Single polymer” based on visual inspection, only. An exception was meat and dairy related packaging, as multilayer packaging is often applied here (Nicholson and Thaisen, 2017; WMW, 2015). In these cases, the polymer types of both the inside and outside were identified. If these were different, the product was classified as “Multiple polymers – *non*-separable,” otherwise as “Single polymer.”

In the final step, the products in each fraction were characterised manually into black items and items of other colours, based on visual inspection.

2.2 Modelling the effect of recycling enhancing initiatives

To evaluate the potential effect of different initiatives aimed at increasing the quantity and quality of plastic recycling, a simplified material flow analysis (MFA) model was set up, as illustrated in Figure 2. The MFA includes: 1) potential changes to the configuration of the existing source-separation system, 2) sorting of mixed plastic into polymers and 3) reprocessing of sorted waste streams into recycled plastic. As indicated in the figure, the overall source-separation efficiency in the household (i.e. the partitioning between residual waste and the source-separated fraction) is assumed fixed and not affected by the evaluated scenarios. While this assumption can be discussed, the needed data for the composition of the complementary plastic in the residual waste is currently not existing. As such, it is not possible to extend the system boundaries beyond the plastic waste currently source-separated. However, as the initiatives evaluated in this study targeted product design and the configuration of the source-separation system, the model is considered to provide relevant results for evaluation of potential effects from these initiatives.

Consequently, the input to the model represented the part of the rigid plastic waste that the households were currently able to source-separate, i.e. the currently source-separated plastic waste, having a detailed composition either identical to the composition obtained from the sampling campaign or estimated based on this composition. The output from the model was recycled plastic with a potential for use in production, as well as losses from the three processes. The potential quality of the recycled plastic was divided into either *high-quality* (potentially suitable for food contact applications) or *low-quality* (not suitable for food contact applications). This division was made based on knowledge about the previous application. Thus, if the recycled plastic sorted and send to final recycling originated from waste solely containing food packaging, it was assigned as *high-quality*. On the other hand, if it originated from waste containing a mixture of food and non-food packaging, it was assigned as *low-quality*.

>Figure 2<

2.2.1 Scenarios

Nine scenarios were defined, as presented in Table 2. The scenarios focused on potential changes in product design and source-separation system configuration, rather than changes in the technical aspects of sorting and reprocessing. However, as the technical performance of the plastic sorting has been shown to significantly influence the quantity of recycled plastic (Eriksen et al., 2018a; Faraca et al., 2019), all scenarios were modelled with an average as well as state-of-the-art sorting process. Where the average sorting process reflected average current conditions, the state-of-the-art sorting process represented a potential future situation. Extensive manual plastic sorting was not included as a sorting option in this study, as labour costs in Denmark are high and consequently, such a system would not be economically feasible.

The baseline scenario (*S0-baseline*) represented current Danish recycling conditions, where the ingoing composition of source-separable plastic waste was equal to the composition found via the sampling campaign, as presented in section 3.1. In this scenario, all plastic was targeted for source-separation as one fraction (mixing food and non-food packaging), in accordance with current practice in Copenhagen. As the waste composition, presented in section 3.1, exhibited a high degree of heterogeneity in each polymer with regards to product types, sorting the source-separated plastic into polymers before recycling, will not effectively separate food from non-food items and hence, only allows the production of *low-quality* recycled plastic.

The remaining scenarios were defined based on *S0-baseline* and represented changes to either the product design of individual products or from a system perspective, the configuration of the source-separation system or a combination thereof. A detailed description of all scenarios is provided in Table 2, and flow diagrams are presented in Figure 3.

Scenarios *S1-NoBlack* and *S2-OnePolymer* addressed changes to the product design of individual products, representing scenarios where no black or multi-polymer packaging plastics are produced, respectively. As such, the waste followed the same path as in *S0-Baseline*, where only *low-quality* secondary plastic was produced (Figure 3a). In scenarios *S3-TwoPlast* and *S4-TwoPlastExt*, the configuration of the source-separation system was changed and plastic was sorted into two bins in the household: Bin 1, solely containing food packaging with the potential for recycling into *high-quality*,

and bin 2, containing the remaining plastic waste, representing a mixture of food and non-food packaging recycled into *low-quality* (Figures 3b and d).

In *S3-TwoPlast*, bin 1 contained a simple mixture of PET beverage bottles for juice and lemonade, quite similar to those already included in the Danish refund deposit system for water and carbonated drinks. *S4-TwoPlastExt* represents an extension of *S3-TwoPlast*, as bin 1 contains a wider selection of food packaging (PET and PP bottles, trays and tubs for food, primarily consisting of a single polymer products). Thus, these scenarios represented changes to the configuration of the source-separation system.

>Table 2<

Scenario *S5-Alignment* addressed both product design from a system perspective and the source-separation system configuration. Here, the polymer of the main product component and the product type were aligned, so that all food packaging was produced in PET, PP or others, and all non-food packaging in PE or others, which facilitated the production of *high-quality* recycled PET and PP, despite source-separating all plastic into one bin (Figure 3c). However, only packaging plastic was allowed in this bin, as it is assumed unrealistic to regulate the use of polymers in all non-packaging products.

To model the effect of multiple initiatives, and to capture the largest potential increase in the quantity and quality of secondary plastic, three combination scenarios were defined: *S1.2-Combined*, *S1.2.4-Combined* and *S1.2.5-Combined*, where no black plastic or multiple-polymer products were combined and additionally combined with the sorting of two plastic fractions in the household or the alignment of the polymer and food/non-food packaging design.

>Figure 3<

2.2.2 Data inventory

The amount of waste entering the system was modelled equally in all scenarios, representing 100% of the currently source-separated plastic waste. The composition in scenarios *S0-baseline*, *S3-TwoPlast*

and *S4-TwoPlastExt* was equal to the composition found in the sampling campaign. For the remaining scenario, representing changes to the product design, this composition was altered to represent the effect of the specific product design initiative. All compositions are presented in SM, Table A3-A8, and a detailed description of the assumptions is presented in SM, Table A2.

The sorting efficiencies for single-polymer and multi-polymer, separable products were assumed identical to the average and high recovery efficiencies reported in Eriksen et al. (2018). Sorting efficiencies of black plastic and non-separable, multi-polymer products were assumed lower, at 5% and 35%, respectively, in all scenarios. The sorting efficiencies for the plastic in bin 1 in *S3-TwoPlast* and *S4-TwoPlastExt* were assumed elevated, as the plastic streams for this bin were more homogenous than the streams of entirely mixed plastic waste. All sorting efficiencies are provided in SM, Table A9, and the assumptions described in detail in SM, Appendix A.2.2. The reprocessing efficiencies were assumed equal for all scenarios and based on Faraca et al. (2019). Due to the removal of unwanted polymers in the waste stream for recycling during reprocessing (e.g. removal of PE caps from PET bottles), reprocessing efficiencies for multi-polymer products was assumed reduced compared to single-polymer products. Data are provided in SM, Table A10, and assumptions are described in detail in Appendix A.2.3. As the scope of this study was to evaluate potential improvements from recycling initiatives, contamination and misplacement during sorting was not included in the modelling.

3 Results and discussion

3.1 Rigid plastic composition

3.1.1 Polymers and product types

The composition of the rigid source-separated plastic waste, divided into polymers and product types, from the Municipality of Copenhagen, is presented in Table 3. Qualitative notes and pictures of the individual fractions are provided in SM, Appendix C.

Table 3 shows that more than 90% of the source-separated rigid plastic was PET, PE or PP, almost equally distributed among the three, with slightly more PP due to the presence of considerable amounts of non-packaging items. More than 95% of the packaging plastic was PET, PE and PP, with a majority

of PET around 37% and an equal amount of PE and PP around 29%. Thus, by targeting PET, PE and PP in the recycling process, it is theoretically possible to recover 92-95% of the collected plastic waste, depending on the source-separation system.

>Table 3<

Regarding product types, around half of the waste was food packaging that previously complied with strict legislation regarding chemical composition. Focussing solely on the packaging plastic, food packaging represented 63%, and most of it was PET and PP. The PET waste contained the highest share of food packaging (81%), however, the share of non-food items was still significantly higher than 5%. Consequently, mechanical sorting of the plastic waste into polymers, is not sufficient, in order to produce waste streams suitable for recycling into *high-quality* recycled plastic.

For both PET and PP, a large share of the food packaging was trays for meat and trays for other or unidentified food. Moreover, the PP food packaging fraction consisted of a considerable share of tubs for dairy products, whereas the PET fraction consisted of a large share of bottles, mainly for juice and smoothies, which consisted almost exclusively of clear plastic. Hence, this fraction closely resembled PET bottles for mineral water and carbonated drinks that are currently collected in many European countries through a deposit system (Simon, 2012), allowing for closed-loop bottle to bottle recycling (Welle, 2011).

Only 19% of the PE waste was food packaging and as much as 70% was non-food packaging. Common for the PE packaging was that it predominantly consisted of bottles, a small share for beverages, food and hazardous substances and a large share for cleaning and hygiene purposes (detergents, shampoo, cleaning products, etc.). This specific fraction represented 14% of all the rigid plastic waste and was relatively homogeneous, containing mainly white or translucent bottles (SM, Appendix C.3.4 and Table C2).

Thus, some tendencies appeared in relation to polymer and product types in the waste; for instance, PET plastic consisted predominantly of trays and bottles for food contact, while PE plastic consisted almost exclusively of bottles, the majority for non-food, soap-related purposes. PP was the most

heterogeneous polymer fraction, consisting of a large share of trays for food contact purposes, a smaller share of non-food bottles and a noticeable share of heterogeneous non-packaging items (toothbrushes, brooms, toys, etc., see SM, Appendix C.4.8). From Table 3, it is nevertheless clear that noticeable shares of the waste varied from these tendencies; for instance, even though the majority of bottles for cleaning and hygiene purposes were made of PE, smaller shares were also made of PP and PET. Sorting of the mixed source-separated plastic into PET, PE and PP will therefore lead to a mixture of food and non-food packaging, even with state-of-the-art sorting technology. This is detrimental for the potential quality of the recycled plastic, as it can only be recycled into *low-quality* material. Consequently, food packaging products representing half of the waste, cannot be recycled in a closed loop, with current recycling systems.

Some existing plastic sorting systems are able to sort out plastic streams suitable for *high-quality* recycling from mixed waste streams, e.g. PET beverage bottles. However, this requires strict sorting guidelines, limiting the type of plastic products source-separated for recycling, ultimately reducing the heterogeneity of the input to the sorting process (Enviros Consulting, 2009; Kosior and Churchward, 2004). Moreover, this is often combined with extensive manual sorting (Boulder County, 2011). As such, the composition of the plastic waste, as it enters the sorting process, is crucial for the further recyclability of the waste.

3.1.2 Polymer design and separability

>Figure 4<

The distribution of polymer designs and separability in all product types, as well as for all the waste, is presented in Figure 4. A detailed composition, divided into polymers, is provided in SM, Table B2. Slightly more than half of the rigid plastic waste consisted of single-polymer products, and hence slightly less than half consisted of products made of multiple polymers. Consequently, almost half of the waste could potentially introduce polymer cross-contamination into subsequent sorting and reprocessing processes. However, by having sorting and reprocessing processes designed to remove, for example,

lids and labels of other polymers from the main waste stream, polymer cross-contamination originating from separable, multi-polymer products can be avoided, which in turn will reduce the risk of contamination. That said, the remaining non-separable, multi-polymer products, corresponding to 15% of the total waste, will inevitably introduce some degree of contamination, despite processes designed to remove such contamination.

Observing Figure 4, several tendencies appears. First, all bottles were classified as either single-polymer products or multi-polymer separable products, with the latter representing the majority. Thus, the lid and label were different from the body on the majority of the bottles, especially for PET bottles (see Figure 5), which is in agreement with Welle (2011). For PE bottles, the majority were also made of multiple, separable polymers, due to a PP lid; however, a small share did consist of single-polymer products (most pronounced for food bottles, see SM, Appendix C.3.2). The same was observed for PP bottles, which indicates that it is possible to produce PE and PP bottles as single-polymer products, even though it is often not the case, whereas for PET bottles this may appear more challenging.

>Figure 5<

Second, trays and tubs were either single-polymer products, for instance simple items like a tray for fruit, or multiple-polymer, non-separable products, if the food required sealing, often using more or less removable multi-layer foil (e.g. meat trays, convenient salads, fresh pasta). Tubs and trays for meat had the largest share of multiple-polymer, non-separable products, and from Figure 5 it is clear that these were made of either PET or PP. In most cases, the trays were sealed with a foil that the citizens did not remove entirely, namely the share of non-separable, multiple polymers. However, the small share of PET and PP single polymer meat trays, representing trays where the sealing foil had been removed entirely, indicates that with the right design and source-separation guidelines, stating that all foil must be removed entirely, a considerable share of the meat trays might be turned into single-polymer products, thereby reducing the risk of subsequent contamination.

3.1.3 Black plastic

Out of all the source-separated rigid plastic, 10-11% was black (for details see SM, Table B3), which lies within the ranges of an earlier study reporting 10-15% black plastic in Copenhagen (PlasticZero, 2014). Figure 6 presents the distribution of the black plastic according to polymer and product type. Most of the black plastic, around 60%, was made of PP, followed by PET, making up around 20%. Two-thirds of all the black plastic was trays for food-related purposes (fruit and vegetables, meat, other and unidentified food), thereby representing plastic with a potential of recycling into *high-quality* plastic. Consequently, 7-8% of the PET food packaging and 18-23% of the PP food packaging would most likely be lost in the mechanical sorting process, as it was black and thereby non-detectable by NIR.

>Figure 6<

3.2 How can recycling initiatives affect the *quantity* of recycled plastic?

Figure 7 presents the percentage of source-separated plastic potentially recycled in each scenario for average and state-of-the-art plastic sorting, divided into polymers and qualities. It is clear that the potentially recycled quantities are considerably lower for the average sorting system (35-57% recycling) when compared to the state-of-the-art sorting system (51-72% recycling), which is in line with findings from several other studies (e.g. Eriksen et al., 2018; Faraca et al., 2018) and confirms that the performance of plastic sorting is crucial for the overall recycled quantities. Modelling data is presented in SM, Table B5 and Table B6.

All scenarios except for *S5-Alignment* resulted in the same or increased quantity of recycled plastic, when compared to *S0-Baseline*, for both sorting efficiencies. For the individual initiatives this was most pronounced for *S4-TwoPlastExt*, when the sorting system performed averagely. As the sorting efficiencies were higher for the more homogeneous plastic fraction 1, than the average sorting efficiencies used for the mixed heterogeneous plastic, the increase in recycled quantities was considerable for *S4-TwoPlastExt*. On the other hand, if the background sorting system was state-of-the-art, this difference was substantially reduced, and the benefits in regards to recycled quantities from *S4-TwoPlastExt* became minimal. The same was observed for scenario *S3-TwoPlast*. However, one version of *S3-TwoPlast* could be to include the remaining PET beverage bottles in the Danish refund deposit

system, as is planned in 2020 (MEFD, 2018). Such a solution might result in an increase in source-separation efficiency for the PET beverage bottles currently included in the source-separated plastic, as PET beverage bottles, included in refund deposit systems, are known to have high source-separation efficiencies between 80% and 87% (Haupt et al., 2018). As this aspect is not accounted for in this study, the increase in recycled quantities for *S3-TwoPlast*, might in reality be more pronounced, although still not expected to exceed those of *S4-TwoPlastExt*. Consequently, increases up to around 19% in recycled amounts can potentially be reached by source-separating the plastic into two bins in the household; however, the better the background plastic sorting system, the smaller the benefit. That said, the highest recycled amounts for both sorting efficiencies were found when *S4-TwoPlastExt* was combined with initiatives related to product design (*S1.2.4-Combined*).

The opposite trend was observed for scenarios *S1-NoBlack*, *S2-OnePolymer* and *S1.2-Combined*, representing changes to individual product design. The sorting efficiencies for black and non-separable, multi-polymer plastic were assumed to be lower than for the remaining plastic and to be unaffected by the default sorting performance, since no data suggesting otherwise currently exist. Thus, the higher the performance of the background sorting system, the larger the difference between the sorting efficiencies for black or multi-polymer products, compared to other products, and the greater the benefit by removing them from the waste. However, assumptions related especially to the sorting efficiencies of multi-polymer products were very uncertain, as no studies have directly investigated the influence of product design on sorting efficiencies. This highlights the need for data related to the sorting efficiencies of specific product types with different designs, if the effect of such initiatives needs to be quantified more accurately.

The only scenario representing a decrease in recycled amounts was *S5-alignment*, as the source-separation system included packaging plastic only and thereby excluded 31-32% of the PP waste, representing non-packaging items. However, combined with initiatives related to product design (*S1.2.5-Combined*), increases in recycled quantities, when compared to *S0-Baseline*, can still be reached. If, on the other hand, it was possible to align the polymer and product type for all plastic items, and not just packaging plastic, no decrease in recycled quantities would be expected.

In summary, the highest increase in potential recycled plastic quantities was reached by combining several initiatives related to both product design and the configuration of the source-separation system. It is, however, important to state that these potential increases were found, without taking the effect that the recycling initiatives may have on source-separation efficiencies into consideration. Consequently, the results may vary some, even though the main trends are assumed valid. This highlights the need for more comprehensive and detailed waste composition data, as such data represent the prerequisite for being able to evaluate the effects of recycling initiatives more accurately, including the effects on the entire recycling chain, including source-separation within households.

>Figure 7<

3.3 How can recycling initiatives affect the *quality* of recycled plastic?

Scenarios with a source-separation system included two plastic bins (*S3-TwoPlast*, *S4-TwoPlastExt* and *S1.2.4-Combined*), and scenarios where product types and polymers were aligned (*S5-Alignment* and *S1.2.5-Combined*), were the only scenarios producing *high-quality* recycled plastic. Whereas *S3-TwoPlast* only produced a small share of *high-quality* recycled PET (8-12%), *S4-TwoPlastExt* and *S5-Alignment* produced the largest shares of *high-quality* recycled plastic (39-63%). The share of non-food plastic items after the sorting process, in the outputs produced in the remaining scenarios, was between 18% and 82% and were therefore, as expected, unsuitable for recycling into *high-quality* material (details presented SM, Table B7 and B8).

For the average performing plastic sorting, *S4-TwoPlastExt* produced the largest amounts of *high-quality* plastic, especially when combined with product design initiatives (*S1.2.4-Combined*), thereby representing the scenario performing the overall best in terms of both the quality and the quantity of recycled plastic. Consequently, *S1.2.4-Combined* was the scenario with the highest circularity potential, when the sorting system was average. The circularity potential expresses the degree to which a recycling system is able to contribute to the closing of the individual polymer loops and is a function of the quantity and quality of the recycled plastic produced (a full definition is provided by Eriksen et al., 2018a). As

this scenario performed the best in both parameter, it represents the most circular recycling option, when having average plastic sorting.

On the other hand, *S5-Alignment* was the scenario producing most *high-quality* recycled plastic, especially when combined with product design initiatives (*S1.2.5-Combined*), when the sorting system was state-of-the-art. Moreover, the alignment scenarios (*S5-Alignment* and *S1.2.5-Combined*) were the only scenarios where all the recovered PET, PP and PE waste could potentially be recycled in a completely closed loop (*high-quality* for PET and PP, *low-quality* for PE). As a consequence, in the alignment scenarios, 100% of the food packaging recovered from sorting could – theoretically – be recycled into food-grade plastic through closed-loop recycling. For *S4-TwoPlastExt*, this was only the case for 78-83% of the recovered food packaging, and as a result 17-22% of the food packaging items had to be recycled to *low-quality* plastic. Consequently, even though scenario *S1.2.4-Combined* had the overall highest recycled quantities, scenario *S1.2.5-Combined* may have the highest circularity potential when implementing state-of-the-art plastic sorting.

3.4 Recommendations to enhance recycling

This study specifically addresses source-separated plastic waste from households in Copenhagen in 2017. The composition of plastic waste in other countries or cities might be different, and plastic waste compositions might change over time as the source-separation matures or changes, affecting the results. Consequently, the precise magnitude of the potential increases to quantity and quality demonstrated here is naturally limited to the temporal and geographical conditions for Copenhagen in 2017 or other places with comparable waste composition and conditions. Despite this, the main trends in the results are considered to be generic and more generally applicable. The following recommendations are provided based on the results, but considered generally useful for recycling systems managing source-separated plastic waste from households.

As the largest potential quantities and qualities of recycled plastic were found by combining initiatives related to product design and the source-separation system, it is recommended to focus on both aspects when working holistically with recycling of plastic from HHW. Specifically, to mitigate

the issues of contamination and loss related to the **product design of individual products**, it is recommended to:

- Regulate the design of PET, PE and PP packaging, so that no black or multi-polymer packaging products are allowed. In cases where packaging products cannot technically be produced with a single polymer, due to specific functionality requirements, the product should be produced in polymers other than PET, PE and PP, so that they will not end up in the recyclable PET, PE or PP stream and contaminate the plastic going to recycling. However, this should only be allowed when strictly necessary, so that the packaging producers do not just shift from PET, PE and PP to other polymers.
- Advise citizens to remove sealing foils entirely from trays (most relevant for meat trays), as this can eliminate a significant part of the risk related to contamination from multi-polymer, non-separable products. This option is also recommended by Rethink Plastic (2018) and requires that the sealing foil is designed for easy removal.
- Ensure that mechanical plastic sorting and recycling facilities are equipped and designed to effectively remove lids and labels of unintended polymers.

To reach the highest possible circularity potential (Eriksen et al., 2018), through **high-quality recycled plastic and closed-loop recycling**, initiatives related to product design should be combined with initiatives effectively separating food packaging from the remaining waste plastic products in the recycling chain. This could e.g. be achieved through one of the following solutions.

1. Food and non-food plastic should be source-separated into two separate bins in the household. This is a complex solution requiring the implementation of an extra collection route for plastic and extensive education of citizens regarding correct source-separation, potentially also specific labelling, to help the source-separation process.
2. Politically aligning polymers and packaging product types, so that food packaging will be produced in PET or PP and non-food packaging in PE (which follows the already existing pattern of the waste collected in this study). Combined with source-separation only targeting

packaging plastic, this allows for the theoretical potential of closed-loop recycling of all recovered PET, PE and PP packaging (*high-quality* for PET and PP), using existing infrastructure regarding plastic sorting.

Where the first solution is superior regarding both recycled quantities and qualities, if the background sorting system is average performing, the second solution will potentially produce the highest amounts of *high-quality* recycled plastic, if the background plastic sorting is state-of-the-art. Since there is considerable focus on increases in technological efficiencies in the transition towards a sustainable and circular economy (EC, 2018), the last solution might represent the better long-term solution.

4. Conclusion

Based on sampling and characterisation of source-separated plastic waste from Danish households, a composition of rigid source-separated plastic waste was provided, including detailed information about the polymer type of the main product component, product types (distinguishing between food and non-food packaging), polymer design and separability, as well as colour. The composition revealed that >90% of the plastic was PET, PE and PP, where most food packaging was produced from PET and PP and most non-food packaging, dominated by bottles for cleaning purposes, was made of PE. However, exceptions to this tendency were found within all polymers, and the sorting of rigid source-separated plastic waste into PET, PE and PP will therefore result in a mixture of food and non-food contact items, not suitable for recycling into food-grade recycled plastic. Regarding product design, around 44% of the waste consisted of multiple polymer products, where the polymers in one-third of these could not be mechanically separated. Moreover, 10-11% of the plastic waste was black and thereby potentially lost during sorting.

The detailed composition allowed for quantitative evaluation of potential effects from recycling initiatives. It was found that improving product design for recycling may potentially increase the amount of recycled plastic by 18-23%, compared to current conditions. Establishing recycling systems, where food packaging can be effectively separated from non-food items, may increase the share of *high-quality*

food-grade recycled plastic from 0% to 40-62%, by e.g. source-separating plastic into two bins in the household (one with food packaging and one with the remaining plastic), or politically aligning product types and polymers (so that all food packaging is made of PET and PP and all non-food packaging of PE). The largest increases in both recycled quantities and qualities are reached by a combination of initiatives. The study indicates that by implementing recycling initiatives, it is possible to reach a high level of closed-loop recycling for PET, PE and PP packaging. The study also demonstrates that initiatives addressing product design should be coordinated with the organisation of the source-separation system.

Finally, the study highlighted the need for more detailed waste composition data, like the data provided in this study, as well as recovery efficiencies for different types of products with different designs, in order to provide a more accurate quantification of the effects on the entire recycling chain, including influence from contamination.

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717 **Table 1:** Overview of the four characterisation levels.

Level I (i) Main Polymer	Level II (j) Product type	Level III (k) Polymer design and separability	Level IV (l) Colour
1 PET	<i>Food packaging:</i>	i.j.1 Single polymer (SP)	i.j.k.1 Other
2 PE	i.1 Bottles for beverages	i.j.2 Multiple polymers - Separable (MP-S)	i.j.k.2 Black
3 PP	i.2 Bottles for food		
4 PS	i.3 Tubs and trays for fruit and vegetable	i.j.3 Multiple polymers - <i>Non-separable</i> (MP-NS)	
5 Others	i.4 Tubs and trays for dairy products		
	i.5 Tubs and trays for meat		
	i.6 Tubs and trays for other/unidentified food		
	i.7 Other rigid food packaging		
	<i>Non-food packaging:</i>		
	i.8 Bottles for personal hygiene and cleaning		
	i.9 Bottles with hazardous labels		
	i.10 Other rigid non-food packaging		
	<i>Non-packaging:</i>		
	i.11 Toys		
	i.12 Others		
	i.13 Flower pots		

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721 **Table 2:** Overview of scenarios and what step in the plastic chain the initiative is influencing.

Scenario name	Description	Initiative influencing
S0-baseline	Representing current sorting practices in Copenhagen, where all source-separable rigid plastic was sorted as one fraction in the household, with a composition as presented in section 3.1.	
S1-NoBlack	Production of black packaging plastic is prohibited → Black products are assumed to be of other colours.	Product design of individual products
S2-OnePolymer	Only single-polymer products (either from regulation or change in citizens sorting behaviour) → Multi-polymer packaging products are assumed to be single polymers.	Product design of individual products
S3-TwoPlast	Source-separation of plastic in two bins: 1) PET beverage bottles and 2) the rest of the rigid plastic.	Source-separation system
S4-TwoPlastExt	Extended source-separation of plastic in two bins: 1) bottles, trays and tubs for food (PET and PP) and 2) the rest of the rigid plastic.	Source-separation system
S5-Alignment	Alignment of polymer and product design: all food-packaging of PET, PP or others and all non-food packaging of PE or others → all non-food packaging is assumed of PE and all bottles for beverage and food of PET. Source-separation of <i>packaging</i> plastic only.	Product design from system perspective + source-separation system
S1.2-Combined	Combination of S1 and S2 → Production of black plastic and multi-polymer products is prohibited. Black products are assumed to be of other colours, and multi-polymers to be single-polymer.	Product design of individual products
S1.2.4-Combined	Combination of S1, S2 and S4 → Black packaging products are assumed to be of other colours and multi-polymer packaging products of single polymers. Source-separation of two plastic fractions: 1) bottles, trays and tubs for food (PET and PP) and 2) the rest of the rigid plastic.	Product design of individual products + source-separation system
S1.2.5-Combined	Combination of S1, S2 and S5 → All non-food packaging is assumed of PE, all bottles for beverage and food of PET, black packaging products are assumed to be of other colours, and multi-polymer packaging products of single polymers. Source-separation of <i>packaging</i> plastic only.	Product design of individual products and from system perspective + source-separation system

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Table 3: Composition of the rigid part of the source-separated plastic waste from the Municipality of Copenhagen, December 2017, divided into polymers and product types.

Product type / polymer*	PET	PE	PP	PS	Others	Total
<i>Food packaging</i>	<i>25$\pm$1</i>	<i>5</i>	<i>20$\pm$1</i>	<i>2</i>	<i>0</i>	<i>52$\pm$1</i>
Bottles for beverages	6	2	0	0	0	8
Bottles for food	2	2	0	0	0	5
Trays and tubs for fruit and vegetable	2	0	1 $\pm$ 1	0 $\pm$ 1	0	3 $\pm$ 1
Trays and tubs for dairy	0	0	4 $\pm$ 1	0	0	5 $\pm$ 1
Trays and tubs for meat	4	0	6 $\pm$ 1	0	0	10 $\pm$ 1
Trays and tubs for other/unidentified food	9 $\pm$ 1	0	9 $\pm$ 1	1	0	18 $\pm$ 1
Other rigid food packaging	1	1	0	0	0	2
<i>Non-food packaging</i>	<i>6</i>	<i>19$\pm$1</i>	<i>3</i>	<i>1$\pm$1</i>	<i>0</i>	<i>30$\pm$1</i>
Bottles for hygiene and cleaning	4 $\pm$ 1	14	2	0	0	19 $\pm$ 1
Bottles with hazardous labelling	0	4 $\pm$ 1	0	0	0	4 $\pm$ 1
Other rigid non-food packaging	2	1	1	1	0	6 $\pm$ 1
<i>Non-packaging</i>	<i>0</i>	<i>2$\pm$1</i>	<i>11$\pm$1</i>	<i>0</i>	<i>5</i>	<i>18$\pm$1</i>
Toys	0	0	0	0	0	1
Flower pots	0	0	2	0	0	3
Others	0	2	9 $\pm$ 1	0	4 $\pm$ 1	15 $\pm$ 1
<i>Sum</i>	<i>31$\pm$1</i>	<i>27$\pm$1</i>	<i>34$\pm$2</i>	<i>3$\pm$1</i>	<i>5</i>	<i>100</i>

Figure 1: Overview of the characterisation procedure applied within the sampling campaign. All product types are presented in Table 1.

Figure 2: Conceptual model of the analysed system and the system boundaries. * only applies for scenarios *S3-TwoPlast*, *S4-TwoPlastExt*, *S5-Alignment*, *S1.2.4-Combined* and *S1.2.5-Combined*.

Figure 3: Flow diagram representing the sorting process associated with: a) *S0-baseline*, *S1-NoBlack*, *S2-OnePolymer* and *S1.2-Combined*, b) *S3-TwoPlast*, c) *S5-Alignment* and *S1.2.5-Combined* d) *S4-TwoPlastExt* and *S1.2.4-Combined*. The quality of the recycled plastic is indicated with colours: ■ = no recycling, ■ = low-quality, ■ = high-quality.

Figure 4: Distribution of the polymer design and separability [%] for the 13 product types as well as for all waste. Each product type's share of the total composition is given above the chart. The original data, on which the figure is based, including variation in data, is presented in Table B2, SM. B: Bottles, TT: Tubs and trays, OI: Other items.

Figure 5: Distribution of polymer type as well as polymer design and separability in three product categories. The original data, on which the figure is based, including variation in data, is presented in Table B2, SM. B: Bottles, TT: Tubs and trays.

Figure 6: Distribution of polymer types [%] in the black part of the plastic. Distributions are illustrated for product types, including more than 0.5% of the total black plastic, as well as for all products. The original data, on which the figure is based, including variation in data, is presented in Table B4, SM. B: Bottles, TT: Tubs and trays, OI: Other items.

High-quality: PET PP **Low-quality:** PET PP PE

Figure 7: Recycled plastic potentially produced in each scenario as a percentage of the ingoing currently source-separated plastic waste [%], divided into polymers and qualities for a) scenarios with average performing plastic sorting and b) state-of-the-art plastic sorting. A dashed line indicates the *S0-Baseline* level. The data, on which the figure is based, including variation in data, is presented in Table B5 and B6, SM.

Characterisation of source-separated, rigid plastic waste and evaluation of recycling initiatives: Effects of product design and source-separation system

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Appendix A Methodology

A.1 Aggregation of product categories

Table A1: Aggregation of product types (level III) into product and packaging categories.

Product type (level III)	Product category	Packaging category
i.1 Bottles for beverages	Bottles	Food packaging
i.2 Bottles for food		
i.3 Tubs and trays for fruit and vegetable	Trays and tubs	
i.4 Tubs and trays for dairy products		
i.5 Tubs and trays for meat		
i.6 Tubs and trays for other/unidentified food		
i.7 Other rigid food packaging	Other rigid items	
i.8 Bottles for personal hygiene and cleaning	Bottles	Non-food packaging
i.9 Bottles with hazardous labelling		
i.10 Other rigid non-food packaging	Other rigid items	Non-packaging
i.11 Toys		
i.12 Flower pots		
i.13 Others		

A.2 Scenario modelling

Table A2: Scenario overview including details on waste generation, source separation, mechanical sorting and reprocessing.

Scenario	Waste generation	Source-separation	Mechanical sorting	Reprocessing
No black plastic (S1-NoBlack)	Black products are assumed to be of other colours.	As in baseline scenario.	As in baseline scenario.	As in baseline scenario.
Only single polymer products (S2-OnePolymer)	Multi-polymer products are assumed to be single polymers.	As in baseline scenario.	As in baseline scenario.	As in baseline scenario. No loss from lids and labels.
Source separation of two plastic fractions - simple (S3-TwoPlast)	As in baseline scenario.	Source separation of two plastic fractions: 1) PET beverage bottles and 2) the rest of the rigid plastic.	Sorting efficiencies for plastic fraction 2 as in baseline scenario, higher for plastic fraction 1, as this fraction is more homogeneous.	Plastic fraction 1 is recycled into <i>high-quality</i> and plastic fraction 2 to <i>low-quality</i> . Lids and labels of other polymers are lost.
Source separation of two plastic fractions - extended (S4-TwoPlastExt)	As in baseline scenario.	Source separation of two plastic fractions: 1) bottles, trays and tubs for food (PET and PP), 2) the rest of the rigid plastic.	As in baseline scenario.	PET and PP are recycled into <i>high-quality</i> and PE to <i>low-quality</i> . Lids and labels of other polymers are lost.
Alignment of products and polymers (S5-Alignment)	All non-food packaging is assumed of PE. All bottles for beverage and food are assumed to be of PET.	Source separation of rigid <i>packaging</i> . Non-packaging goes to incineration.	As in baseline scenario.	As in baseline scenario. No loss from lids and labels.
Combination of S1 and S2 (S1.2 – combined)	Black products are assumed of other colours, multi-polymer products of single polymers.	As in baseline scenario.	As in baseline scenario.	As in baseline scenario. No loss from lids and labels.
Combination of S1, S2 and S4 (S1.2.4 – combined)	Black products are assumed of other colours, multi-polymer products of single polymers.	Source separation of two plastic fractions: 1) bottles, trays and tubs for food (PET and PP), 2) the rest of the rigid plastic.	Sorting efficiencies for plastic fraction 2 as in baseline scenario, higher for plastic fraction 1.	Plastic fraction 1 is recycled into <i>high-quality</i> and plastic fraction 2 to <i>low-quality</i> .
Combination of S1, S2 and S5 (S1.2.5 – combined)	All non-food packaging is assumed of PE, all bottles for beverage and food of PET, black products of other colours, and multi-polymer products of single polymers.	Source separation of rigid <i>packaging</i> . Non-packaging goes to incineration.	As in baseline scenario.	PET and PP are recycled into <i>high-quality</i> and PE to <i>low-quality</i> .

A.2.1 Compositions

Table A3: Simplified composition used in *scenario S0-Baseline, S3-TwoPlast, S4-TwoPlastExt*. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non separable

Other colors than black	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.2	5.7	0.0	0.0	1.6	0.0	0.0	0.1	0.0	0.0	0.0	0.0	7.7
Bottles and cans for food	0.1	1.9	0.0	1.7	0.3	0.0	0.4	0.0	0.0	0.0	0.0	0.0	4.5
Trays and tubs for fruit and vegetable	2.0	0.0	0.2	0.0	0.0	0.0	0.5	0.0	0.0	0.3	0.0	0.0	3.0
Trays and tubs for dairy	0.2	0.0	0.3	0.0	0.0	0.0	4.3	0.0	0.0	0.2	0.0	0.1	5.1
Trays and tubs for meat	0.7	0.0	2.4	0.0	0.0	0.0	0.5	0.0	3.6	0.0	0.0	0.0	7.3
Tray and tubs for other food	6.9	0.0	1.0	0.0	0.0	0.0	5.6	0.1	0.5	0.1	0.0	0.3	14.5
Other rigid food packaging	0.8	0.0	0.0	0.9	0.2	0.0	0.1	0.0	0.0	0.1	0.0	0.0	2.2
Non-food packaging	2.4	3.6	0.0	4.8	14.2	0.0	3.0	0.2	0.0	1.1	0.0	0.0	29.3
Non-packaging	0.1	0.0	0.0	1.9	0.0	0.0	6.7	1.3	1.1	3.4	0.5	0.5	15.5
Sum	13.6	11.2	3.8	9.3	16.4	0.0	21.1	1.7	5.3	5.2	0.6	1.0	89.2
Black plastic	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bottles and cans for food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for fruit and vegetable	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3
Trays and tubs for dairy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for meat	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.1	3.0
Tray and tubs for other food	1.1	0.0	0.1	0.0	0.0	0.0	2.0	0.0	0.2	0.1	0.0	0.3	3.9
Other rigid food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-food packaging	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.7
Non-packaging	0.0	0.0	0.0	0.5	0.0	0.0	1.2	0.4	0.2	0.7	0.0	0.0	2.9
Sum	1.5	0.0	0.6	0.5	0.3	0.0	3.2	0.4	2.6	1.3	0.0	0.4	10.8

Table A4: Assumed composition used in scenario *S1-NoBlack*. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non separable

Other colors than black	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.2	5.7	0.0	0.0	1.6	0.0	0.0	0.1	0.0	0.0	0.0	0.0	7.7
Bottles and cans for food	0.1	1.9	0.0	1.7	0.3	0.0	0.4	0.0	0.0	0.0	0.0	0.0	4.5
Trays and tubs for fruit and vegetable	2.1	0.0	0.2	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	3.3
Trays and tubs for dairy	0.2	0.0	0.3	0.0	0.0	0.0	4.3	0.0	0.0	0.2	0.0	0.1	5.1
Trays and tubs for meat	0.9	0.0	3.0	0.0	0.0	0.0	0.5	0.0	5.8	0.0	0.0	0.1	10.3
Tray and tubs for other food	8.1	0.0	1.0	0.0	0.0	0.0	7.6	0.1	0.8	0.2	0.0	0.6	18.4
Other rigid food packaging	0.8	0.0	0.0	0.9	0.2	0.0	0.1	0.0	0.0	0.1	0.0	0.1	2.3
Non-food packaging	2.5	3.6	0.0	4.8	14.5	0.0	3.0	0.2	0.0	1.4	0.0	0.0	30.0
Non-packaging	0.1	0.0	0.0	1.9	0.0	0.0	6.7	1.3	1.1	3.4	0.5	0.5	15.5
Sum	15.1	11.2	4.4	9.4	16.7	0.0	23.1	1.7	7.7	5.8	0.6	1.4	97.1
Black plastic	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bottles and cans for food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for fruit and vegetable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for dairy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for meat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tray and tubs for other food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other rigid food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-packaging	0.0	0.0	0.0	0.5	0.0	0.0	1.2	0.4	0.2	0.7	0.0	0.0	2.9
Sum	0.0	0.0	0.0	0.5	0.0	0.0	1.2	0.4	0.2	0.7	0.0	0.0	2.9

Table A5: Assumed composition used in scenario *S2-OnePolymer*. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non separable

Other colors than black	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	5.9	0.0	0.0	1.6	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	7.7
Bottles and cans for food	2.0	0.0	0.0	2.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	4.5
Trays and tubs for fruit and vegetable	2.2	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.3	0.0	0.0	3.0
Trays and tubs for dairy	0.4	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.4	0.0	0.0	5.1
Trays and tubs for meat	3.1	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.0	0.0	0.0	7.3
Tray and tubs for other food	7.9	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.3	0.0	0.0	14.5
Other rigid food packaging	0.8	0.0	0.0	1.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	2.2
Non-food packaging	6.0	0.0	0.0	19.0	0.0	0.0	3.2	0.0	0.0	1.2	0.0	0.0	29.3
Non-packaging	0.1	0.0	0.0	1.9	0.0	0.0	6.7	1.3	1.1	3.4	0.5	0.5	15.5
Sum	28.6	0.0	0.0	25.7	0.0	0.0	25.7	1.3	1.1	5.7	0.5	0.5	89.2
Black plastic	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bottles and cans for food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for fruit and vegetable	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3
Trays and tubs for dairy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for meat	0.8	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.1	0.0	0.0	3.0
Tray and tubs for other food	1.2	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.4	0.0	0.0	3.9
Other rigid food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-food packaging	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.7
Non-packaging	0.0	0.0	0.0	0.5	0.0	0.0	1.2	0.4	0.2	0.7	0.0	0.0	2.9
Sum	2.1	0.0	0.0	0.8	0.0	0.0	5.6	0.4	0.2	1.7	0.0	0.0	10.8

Table A6: Assumed composition used in scenario *S5-Alignment*. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non separable

Other colors than black	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.2	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7
Bottles and cans for food	2.2	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5
Trays and tubs for fruit and vegetable	2.0	0.0	0.2	0.0	0.0	0.0	0.5	0.0	0.0	0.3	0.0	0.0	3.0
Trays and tubs for dairy	0.2	0.0	0.3	0.0	0.0	0.0	4.3	0.0	0.0	0.2	0.0	0.1	5.1
Trays and tubs for meat	0.7	0.0	2.4	0.0	0.0	0.0	0.5	0.0	3.6	0.0	0.0	0.0	7.3
Tray and tubs for other food	6.9	0.0	1.0	0.0	0.0	0.0	5.6	0.1	0.5	0.1	0.0	0.3	14.5
Other rigid food packaging	1.7	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	2.2
Non-food packaging	0.0	0.0	0.0	11.3	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.3
Non-packaging	0.1	0.0	0.0	1.9	0.0	0.0	6.7	1.3	1.1	3.4	0.5	0.5	15.5
Sum	14.2	10.0	3.8	13.2	18.0	0.0	17.7	1.5	5.3	4.0	0.5	1.0	89.2
Black plastic	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bottles and cans for food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for fruit and vegetable	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3
Trays and tubs for dairy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for meat	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.1	3.0
Tray and tubs for other food	1.1	0.0	0.1	0.0	0.0	0.0	2.0	0.0	0.2	0.1	0.0	0.3	3.9
Other rigid food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-food packaging	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Non-packaging	0.0	0.0	0.0	0.5	0.0	0.0	1.2	0.4	0.2	0.7	0.0	0.0	2.9
Sum	1.5	0.0	0.6	0.9	0.3	0.0	3.2	0.4	2.6	1.0	0.0	0.4	10.8

Table A7: Assumed composition used in scenario *S1.2-combined*. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non separable

Other colors than black	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	5.9	0.0	0.0	1.6	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	7.7
Bottles and cans for food	2.0	0.0	0.0	2.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	4.5
Trays and tubs for fruit and vegetable	2.3	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	3.3
Trays and tubs for dairy	0.4	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.4	0.0	0.0	5.1
Trays and tubs for meat	3.9	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.1	0.0	0.0	10.3
Tray and tubs for other food	9.1	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.8	0.0	0.0	18.4
Other rigid food packaging	0.8	0.0	0.0	1.1	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	2.3
Non-food packaging	6.0	0.0	0.0	19.3	0.0	0.0	3.2	0.0	0.0	1.5	0.0	0.0	30.0
Non-packaging	0.1	0.0	0.0	2.4	0.0	0.0	7.8	1.7	1.3	4.1	0.5	0.5	18.4
Sum	30.7	0.0	0.0	26.5	0.0	0.0	31.3	1.7	1.3	7.4	0.5	0.5	100.0
Black plastic	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bottles and cans for food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for fruit and vegetable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for dairy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for meat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tray and tubs for other food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other rigid food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A8: Assumed composition used in scenario *S1.2.5-combined*. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non separable

Other colors than black	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	7.6	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	7.7
Bottles and cans for food	4.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	4.5
Trays and tubs for fruit and vegetable	2.3	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	3.3
Trays and tubs for dairy	0.4	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.4	0.0	0.0	5.1
Trays and tubs for meat	3.9	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.1	0.0	0.0	10.3
Tray and tubs for other food	9.1	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.8	0.0	0.0	18.4
Other rigid food packaging	1.9	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	2.3
Non-food packaging	0.0	0.0	0.0	28.5	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	30.0
Non-packaging	0.1	0.0	0.0	2.4	0.0	0.0	7.8	1.7	1.3	4.1	0.5	0.5	18.4
Sum	29.6	0.0	0.0	30.9	0.0	0.0	28.1	1.7	1.3	7.4	0.5	0.5	100.0
Black plastic	PET			PE			PP			Others			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
Bottles for beverages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bottles and cans for food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for fruit and vegetable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for dairy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trays and tubs for meat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tray and tubs for other food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other rigid food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-food packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A.2.2 *Sorting efficiencies*

The sorting efficiencies for ***SP and MP-S PET, PE and PP products*** (bottles and other products) to their intended outputs was based on the values for average and high performing material recovery facilities (MRFs), used in Eriksen et al. (2018). The values for the average performing MRF were calculated as the average between minimum and maximum values found in literature, whereas the values for the high performing MRF represented the highest reported literature values (Goodman, 2006; Shonfield, 2008; Dvorak et al., 2009; Enviros, 2009; Spendelow, 2011; Jansen et al., 2012; van Velzen et al., 2013; LRS consultancy, 2015; Cimpan et al., 2015; RRS, 2015).

Regarding ***MP-NS products***, several studies claim that it is more difficult to recycle multilayer packaging (Dahlbo et al., 2018; Hahladakis and Iacovidou, 2018) and that they should be routed to either mixed plastic or the residues (which in this study is assumed the same) (Raegert et al., 2017; Kaiser et al., 2017). However, Hahladakis and Iacovidou (2018) reported that it is a problem that multilayer PET trays for meat end in the PET bottle stream, contaminating the stream. Consequently, even though multilayer foils should ideally end in the mixed or residual fraction, this might in reality not always be the case. No studies have, to the knowledge of the authors, reported sorting efficiencies for multilayer plastic products from HHW, nor reported the potential reduction in sorting efficiency, compared to single polymer products. Thus, the sorting efficiency for MP-NS products was assumed, based on data from a study by Brouwer et al. (2017). In the study they reported that PE, PP and PET thermoforms contained several polymers. From the results of this study it was found that a large share of the trays (corresponding to thermoforms) represented MP-NS products. Thus, from Brouwer et al. (2017) sorting efficiencies for PE, PP and PET thermoforms to recyclable outputs was estimated and 35%, representing the average of these, was assumed to be the sorting efficiency for all MP-NS products in this study, both average and state of the art plastic sorting.

The waste stream from ***the simple plastic fraction 1*** (S3 and S1.2.3) will in reality contain almost exclusively PET bottles. Consequently, the separation efficiency of PET bottles from the simple refund deposit system to the PET output was assumed to be 95 % for both average and high performing plastic sorting, the highest reported in literature (Eriksen et al., 2018). The waste stream from ***the complex plastic fraction 1*** (S4, S1.2.4) is assumed to be more heterogeneous compared to that from the simple plastic fraction 1, but more homogeneous compared to the plastic stream from mixed plastic source-separation (S0, S1, S2, S5, S1.2.5). Hence, the sorting efficiency for PET and PP was assumed to be equal to the highest reported in literature for non-bottle PET and PP in the average performing scenarios (Eriksen et al., 2018). In the state of the art performing scenario the PET sorting efficiency for all PET products was assumed to be the highest reported for PET bottles, 95%, and 90% for PP.

It is well known within the field of plastic recycling that NIR scanners are not suitable for detection of **black plastic**, as black plastic exhibits very low reflectance of light in the spectra that NIR scanners can detect (Ragaert et al., 2017; Turner, 2018). However, specific NIR sorting efficiencies for the black products are not reported in literature. Instead the sorting efficiency of black products was based on expert judgement. Based on three sorting tests on Danish source-separated plastic waste from households, Malmgren-Hansen (2018) reported that at least 94% of the black plastic ended in the residual fraction. Hence, the sorting efficiency for all black products was assumed to be less than 6% and consequently, it was set to 5% in the MFA calculations.

A summary of all sorting efficiencies and in which scenarios they were used is presented in Table A9.

Table A9: Sorting efficiencies [-] for average and state of the art plastic sorting used in the MFA. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non-separable.

Sorting efficiencies	Value [-]	Scenarios					
		0	1	2	3 & 1.2.3	4 & 1.2.4	5 & 1.2.5
<i>Average sorting:</i>							
PET bottles to PET output	0.68	x	x	x	x	x	x
Other PET products to PET output	0.55	x	x	x	x	x	x
PE bottles to PE output	0.63	x	x	x	x	x	x
Other PE products to PE output	0.50	x	x	x	x	x	x
PP products to PP output	0.55	x	x	x	x	x	x
PET bottles from plastic fraction 1 (S3, S1.2.3) to PET	0.95				x		
PET products from plastic fraction 1 (S4, S1.2.4) to PET	0.90					x	
PP products from plastic fraction 1 (S4, S1.2.4) to PP	0.85					x	
Black plastic (SP, MP-S and MP-NS) to intended output	0.05	x		x	x	x	x
Sorting efficiency of all MP-NS products	0.35	x	x		x	x	x
<i>State of the art sorting</i>							
PET bottles to PET output	0.95	x	x	x	x	x	x
Other PET products to PET output	0.90	x	x	x	x	x	x
PE bottles to PE output	0.90	x	x	x	x	x	x
Other PE products to PE output	0.85	x	x	x	x	x	x
PP products to PP output	0.85	x	x	x	x	x	x
PET bottles from plastic fraction 1 (S3, S1.2.3) to PET	0.95				x		
PET products from plastic fraction 1 (S4, S1.2.4) to PET	0.95					x	
PP products from plastic fraction 1 (S4, S1.2.4) to PP	0.90					x	
Black plastic (SP, MP-S and MP-NS) to intended output	0.05	x		x	x	x	x
Sorting efficiency of all MP-NS products	0.35	x	x		x	x	x

A.2.3 Reprocessing efficiencies

The reprocessing efficiencies for *single polymer PET, PE and PP* waste products were assumed to be equal to those used in Faraca et al. (2018) for the advanced reprocessing, representing the median between the median and maximum reported sorting efficiency for the respective polymer in literature.

An additional loss was assumed for MP-S products as the lid and/or label were made of other polymer that needed to be separated from the body of the main product. According to Brouwer et al. (2017) PET beverage bottles consist of between 78-92% PET (the rest is other polymers for caps, label, etc.). In average this means that only 87% of the *MP-S PET* waste products are going to extrusion, assuming that all non-PET plastics will be removed during reprocessing, which is multiplied with the reprocessing efficiency for single polymer PET. Similarly, it was assumed that *MP-S PE* products and *MP-S PP* products contained 10 % and 6 % other polymers, respectively (Brouwer et al., 2017), that was assumed removed during reprocessing.

The reprocessing efficiencies for *MP-NS PET, PE and PP* waste products were assumed to be equal to those used in Faraca et al. (2018) for the simple reprocessing, representing the median between the minimum and median reported sorting efficiency for the respective polymer in literature. The lower reprocessing efficiencies were assumed as multilayer plastic products complicates recycling and lowers the quality of the recycled material, potentially producing greater loss during reprocessing.

All reprocessing efficiencies are presented in Table A10 as well as in which scenarios they are used.

Table A10: Reprocessing efficiencies [-] used in the MFA. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non-separable.

Parameter	Value [-]	Scenarios					
		0	1	2	3 & 1.2.3	4 & 1.2.4	5 & 1.2.5
<i>Reprocessing efficiencies</i>							
Single polymer PP products to recycled PP	0.86	x	x	x	x	x	x
Single polymer PE products to recycled PE	0.91	x	x	x	x	x	x
Single polymer PET products to recycled PET	0.88	x	x	x	x	x	x
MP-S PP products to recycled PP	0.81	x	x		x	x	x
MP-S PE products to recycled PE	0.82	x	x		x	x	x
MP-S PET products to recycled PET	0.77	x	x		x	x	x
MP-NS PP products to recycled PP	0.69	x	x		x	x	x
MP-NS PE products to recycled PE	0.76	x	x		x	x	x
MP-NS PET products to recycled PET	0.76	x	x		x	x	x

Appendix B Detailed results

B.1 All incoming source-separated waste

Table B1: Composition [kg] of the total sample from the municipality of Copenhagen, 2017.

Role in sorting scheme	Material fraction	Sub-fraction	Amount [kg]
Targeted fractions	Rigid plastic	PET	612
		PE	531
		PP	731
		PS	134
		Other/residual plastic	348
	Soft plastic	PE	254
		PP	20
Misplacements	Big rigid plastic	PE	61
		PP	76
		Other polymers	245
	Big soft plastic	PE	110
	Metals	Ferrous	73
		Non-ferrous	35
	Non-plastic for combustion		441
Total			3,671

B.2 Composition of rigid plastic waste - polymer, product type and product design

Table B2: Detailed composition of source separated rigid plastic waste from the municipality of Copenhagen, 2017, divided into product types, polymer groups and product purity. TT: Trays and tubs, SP: Single polymer, MP-S: Multi polymer – separable, MP-NS: Multi polymer – *non*-separable.

Polymer Product design	PET			PE			PP			Other polymers			Sum
	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	SP	MP-S	MP-NS	
<i>Food packaging</i>	<i>12-13</i>	<i>7-8</i>	<i>4-5</i>	<i>3</i>	<i>2</i>	<i>0</i>	<i>12-15</i>	<i>0</i>	<i>6-7</i>	<i>1-2</i>	<i>0</i>	<i>1</i>	<i>51-52</i>
Bottles for beverages	0	5-6	0	0	2	0	0	0	0	0	0	0	7-8
Bottles and cans for food	0	2	0	2	0	0	0	0	0	0	0	0	4-5
TT-fruit and vegetable	2	0	0	0	0	0	0-1	0	0	0-1	0	0	3-4
TT-dairy	0	0	0	0	0	0	4-5	0	0	0-1	0	0	5
TT-meat	1	0	3	0	0	0	0-1	0	6	0	0	0	10-11
TT-other/unidentified food	8-9	0	1	0	0	0	7-8	0	1	0	0	1	18-19
Other rigid food packaging	1	0	0	1	0	0	0	0	0	0	0	0	2
<i>Non-food packaging</i>	<i>2-3</i>	<i>3-4</i>	<i>0</i>	<i>4-5</i>	<i>14-15</i>	<i>0</i>	<i>3</i>	<i>0</i>	<i>0</i>	<i>1-3</i>	<i>0</i>	<i>0</i>	<i>29-31</i>
Bottles for hygiene and cleaning	0	3-4	0	2	11-12	0	1-2	0	0	0	0	0	19-20
Bottles with hazardous labelling	0	0	0	3-2	2	0	0	0	0	0	0	0	4-5
Other rigid non-food packaging	2	0	0	1	0	0	1	0	0	1-3	0	0	5-7
<i>Non-packaging</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>2-3</i>	<i>0</i>	<i>0</i>	<i>7-8</i>	<i>1-2</i>	<i>0-1</i>	<i>4-5</i>	<i>0-1</i>	<i>0-1</i>	<i>18-19</i>
Toys	0	0	0	0	0	0	0	0	0	0	0	0	1
Flower pots	0	0	0	0	0	0	2	0	0	0	0	0	2-3
Others	0	0	0	2	0	0	5-6	1-2	1	3-4	0	0-1	14-16
<i>Sum</i>	<i>15</i>	<i>10-12</i>	<i>4-5</i>	<i>9-10</i>	<i>16-17</i>	<i>0</i>	<i>22-26</i>	<i>1-3</i>	<i>8</i>	<i>6-8</i>	<i>1</i>	<i>1-2</i>	<i>100</i>

B.3 Composition of rigid plastic waste - Colour

Table B3: Share [%] of black plastic in the different polymers and product types.

Product type / polymer	PET	PE	PP	PS	Others	Total
<i>Food packaging</i>	<i>7-8</i>	<i>0</i>	<i>18-23</i>	<i>38-46</i>	<i>0</i>	<i>12-15</i>
Bottles for beverages	0	0	0	0	0	0
Bottles for food	0	0	0	0	0	0
Trays and tubs for fruit and vegetable	4	0	0	44-52	0	9-11
Trays and tubs for dairy	0	0	0	0	0	0
Trays and tubs for meat	18-20	0	27-37	56-64	0	24-31
Trays and tubs for other/unidentified food	8-15	0	22-28	56-64	0	17-22
Other rigid food packaging	0	0	0	24-30	0	2
<i>Non-food packaging</i>	<i>1</i>	<i>2</i>	<i>1-2</i>	<i>22-28</i>	<i>0</i>	<i>2-3</i>
Bottles for hygiene and cleaning	0	2-3	1	0	0	2
Bottles with hazardous labelling	0-36	0	0	0	0	0
Other rigid non-food packaging	2-3	1	2-3	24-30	0	6-8
<i>Non-packaging</i>	<i>0</i>	<i>19-24</i>	<i>15-20</i>	<i>0</i>	<i>13-18</i>	<i>15-19</i>
Toys	0	0	0	0	0	0
Flower pots	0	29-36	19-27	0	0	20-28
Others	0	20-25	14-18	0	15-19	15-19
<i>All polymers</i>	<i>6-7</i>	<i>3-4</i>	<i>17-18</i>	<i>28-35</i>	<i>13-17</i>	<i>10-11</i>

Table B4: Distribution of all the black plastic [%].

Product type / polymer	PET	PE	PP	Others	Sum
<i>Food packaging</i>	<i>15-20</i>	<i>0</i>	<i>35-42</i>	<i>6-9</i>	<i>58-69</i>
Bottles for beverages	0	0	0	0	0
Bottles for food	0	0	0	0	0
Trays and tubs for fruit and vegetable	1	0	0	2-3	3
Trays and tubs for dairy	0	0	0	0	0
Trays and tubs for meat	7	0	17-21	0-1	25-28
Trays and tubs for other/unidentified food	7-12	0	18-21	4-5	30-37
Other rigid food packaging	0	0	0	0	0
<i>Non-food packaging</i>	<i>1</i>	<i>3-4</i>	<i>0</i>	<i>3-4</i>	<i>6-8</i>
Bottles for hygiene and cleaning	0	3-4	0	0	3-4
Bottles with hazardous labelling	0	0	0	0	0
Other rigid non-food packaging	0-1	0	0	3-4	3-5
<i>Non-packaging</i>	<i>0</i>	<i>4-6</i>	<i>15-19</i>	<i>6-8</i>	<i>25-33</i>
Toys	0	0	0	0	0
Flower pots	0	1	4-5	0	5-7
Others	0	3-5	11-14	6-8	20-26
<i>Sum</i>	<i>15-21</i>	<i>7-9</i>	<i>55-58</i>	<i>15-20</i>	<i>100</i>

B.4 Modelling results

Table B5: Detailed modelling results, when the plastic sorting system is **average** performing. High-Q: Potential for *high-quality*, Low-Q: *Low-quality*

Scenario	Recycled plastic [%]						Total loss [%]	Change in recycled material [% ¹]	High quality [%]
	PET		PE	PP		Total			
	High-Q	Low-Q	Low-Q	High-Q	Low-Q				
S0 - Baseline	-	13-14	13-14	-	10-12	36-39	61-64	-	0
S1 - Black	-	14	13-14	-	12-14	38-41	59-62	5-7	0
S2 - OnePolymer	-	14-15	13-14	-	12-13	40-43	58-60	9-10	0
S3 - TwoPlast	4	10	13-14	-	10-12	37-40	60-63	3	11-12
S4 - TwoPlastExt	13	4	13-14	8-9	4-6	43-46	54-57	18-19	48-52
S5 - Alignment	13-14	-	15-16	6-7	-	35-36	64-65	-9-(-2)	55-57
S1.2 - combined	-	15-16	14-15	-	15-17	45-47	53-55	19-27	0
S1.2.4 - combined	15-16	5-6	14-15	13-15	6-7	55-57	43-45	45-54	52
S1.2.5 - combined	15-18	-	16-17	9-10	-	40-42	58-60	7-13	60-61

¹⁾ Mass-based change compared to *S0-Baseline*

Table B6: Detailed modelling results, when the plastic sorting system is **state of the art**. High-Q: Potential for *high-quality*, Low-Q: *Low-quality*

Scenario	Recycled plastic [%]						Total loss [%]	Change in recycled material [% ¹]	High quality [%]
	PET		PE	PP		Total			
	High-Q	Low-Q	Low-Q	High-Q	Low-Q				
S0 - Baseline	-	19-21	18-20	-	15-18	53-58	42-47	-	0
S1 - Black	-	21-22	19-20	-	16-20	56-61	39-44	5-6	0
S2 - OnePolymer	-	22-24	20-21	-	16-20	59-64	36-41	12-13	0
S3 - TwoPlast	4	15-16	18-20	-	15-18	53-58	42-47	0	8
S4 - TwoPlastExt	13-14	6-7	18-20	9-10	6-9	54-58	42-46	1-2	39-44
S5 - Alignment	19-20	-	22-23	9-10	-	51-52	48-49	-11-(-4)	55-57
S1.2 - combined	-	24-25	21-22	-	23-26	69-71	29-31	23-31	0
S1.2.4 - combined	16-17	9	21-22	14-16	10-11	70-72	28-30	25-34	43-44
S1.2.5 - combined	23-24	-	23-24	14-16	-	60-62	38-40	8-15	62-63

¹⁾ Mass-based change compared to *S0-Baseline*

Table B7: Concentration [%] on non-food packaging or non-packaging items in each modelled output, when the sorting system is *average*.

Polymer Quality	PET		PE Low	PP	
	High	Low		High	Low
S0 - Baseline	-	20-21	80-81	-	33-45
S1 - Black	-	19-20	80-82	-	30-40
S2 - OnePolymer	-	19-20	80-81	-	31-43
S3 - TwoPlast	0	26-29	80-81	-	33-45
S4 - TwoPlastExt	0	62-64	80-81	0	88-92
S5 - Alignment	0	-	100	0	-
S1.2 - combined	-	18-19	82	-	39-41
S1.2.4 - combined	0	52-55	82	0	92-93
S1.2.5 - combined	0	-	100	0	-

Table B8: Concentration [%] on non-food packaging or non-packaging items in each modelled output, when the sorting system is *state of the art*.

Polymer Quality	PET		PE Low	PP	
	High	Low		High	Low
S0 - Baseline	-	21-23	80-81	-	38-46
S1 - Black	-	21-22	80-81	-	34-42
S2 - OnePolymer	-	20-21	80-81	-	33-42
S3 - TwoPlast	0	27-31	80-81	-	38-46
S4 - TwoPlastExt	0	67-69	80-81	0	89-91
S5 - Alignment	0	-	100	0	-
S1.2 - combined	-	19-20	82	-	38-40
S1.2.4 - combined	0	52-55	82	0	92-93
S1.2.5 - combined	0	-	100	0	-

Appendix C Supplementary qualitative information - Picture and notes

In this section all qualitative observations made during recycling is summaries for all fractions in Table C1-C3 and pictures of most fractions are presented.

C.1 Summary notes for all polymers, product types and product designs

Table C1: Notes on food packaging product categories, divided into polymer types (PET, PE and PP) and product design. Square indicate dominating colours, where: : clear, : white, : mixture of colours, : black. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non-separable.

Product category	PET			PE		PP		
	SP	MP-S	MP-NS	SP	MP-S	SP	MP-S	MP-NS
Bottles for beverages	Smoothies, juice, etc. <i>without</i> caps	Smoothies, juice, etc. with caps	-	-	Juice and drink-yoghurt. Sleeve and/or cap in different polymer.	-	Various bottles with lid and/or label in other polymer	-
Bottles for food	Toppings, <i>without</i> caps	Cooking fat, spices, toppings.	-	Mainly vinegar, where cap is PE.	Various food bottles with PP lid.	Topping with PP lids.	-	-
T&T fruit and veggies	Various fruit and veggies	-	Various fruit. multilayer foil attached.	-	-	Mainly tubs for tomatoes.	-	-
T&T dairy	Lids or bot-toms for cheese and butter	-	Cheese with multilayer foil attached.	-	-	Various tubs for skyr, greek yoghurt, etc. with print. Lids for butter	-	-
T&T meat	Raw meat and cold cuts, where foil has been <i>manually removed</i>	-	Raw meat and cold cuts, where foil is still <i>attached</i>	-	-	Various tubs for meat and fish for bread.	-	Trays in green or black (meat) or dark blue (fish). Multilayer foil still attached
T&T Other food	Cup/fork symbol, where use couldn't be identified. Most assumed to be for fruit.	-	Fresh pasta or cup/fork symbol, where the use couldn't be identified	-	-	Various trays. The use of black trays was unidentified and assumed to be for fruit and veggies.	Miscellaneous	Miscellaneous
Other rigid food packaging	Egg trays	-	-	Pill glasses or dietary supplement	Miscellaneous	Miscellaneous	-	-

Table C2: Notes on non-food packaging and non-packaging product categories, divided into polymer types (PET, PE and PP) and product design. Square indicate dominating colours, where: : clear, : white, : mixture of colours, : black. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non-separable.

Product	PET			PE		PP		
	Pure	Mix+	Mix-	Pure	Mix+	Pure	Mix+	Mix-
B&C personal hygiene and cleaning	Mainly bottles for cleaning <i>without</i> lids	Various personal hygiene and cleaning	-	Personal hygiene and cleaning. <i>Without</i> lids.	Mainly products for cleaning with PP lids and/or PET label.	Various bottles. Mainly small for personal hygiene.	Various personal hygiene products.	-
Cans hazardous	-	-	-	Dark green bottles with yellow lid (PE) for technical purposes or clear cans.	Various large cans.	-	-	-
T&T for non-food	Miscellaneous	-	-	-	-	Miscellaneous	-	-
Other rigid non-food packaging	Miscellaneous	-	-	Lids.	Various bottles for unidentified use with cap and /or label in other polymer	Various lids in different colours and white paint buckets.	Lids	-
Toys	-	-	-	Various toys.	-	-	-	-
Electronics	-	-	-	-	-	-	-	-
Others	Miscellaneous	-	-	Miscellaneous	-	Miscellaneous	DVDs, computer games, etc.	Toothbrushes, dish washing brushes, etc.
Flower pots	-	-	-		-		-	-

Table C3: Notes on all product categories, divided into polymer types (PS and others) and product design. Square indicate dominating colours, where: : clear : white, : mixture of colours, : black. SP: Single polymer, MP-S: Multiple polymers – separable, MP-NS: Multiple polymers – non-separable.

Product	PS			Others		
	Pure	Mix+	Mix-	Pure	Mix+	Mix-
Bottles for beverages	-	-	-	-	Miscellaneous.	-
Bottles for food	-	-	-	-	-	-
T&T fruit and veggies	Various trays for fruit and veggies. The clear are for mushrooms.	-	-	-	-	-
T&T dairy	Mostly tubs for crème fraise with blue print.	-	Tub for butter with coated with PET on the inside, covered with cardboard.	-	-	-
T&T meat	-	-	Meat trays with multilayer foil attached	-	-	-
T&T Other food	Various trays with cup/fork symbol where use could not be identified.	-	Various trays with cup/fork symbol where use could not be identified.	Miscellaneous	-	Miscellaneous
Other rigid food packaging	One time plates, cups and cutlery	Sprinkles for backing	Various packaging with cup/fork symbol where use could not be identified.	-	-	Miscellaneous
B&C personal hygiene and cleaning	-	Miscellaneous. Personal hygiene.	-	-	-	-
Cans hazardous	-	-	-	-	-	-
T&T for non-food	Various unidentified trays without cup/fork symbol	-	-	Very rigid packaging for products like electronics.	-	-
Other rigid non-food packaging	Packaging for products, possibly electronics.	-	-	-	Various packaging.	-
Toys	Various toys.	Various toys.	Various toys.	Various toys.	Various toys.	Various toys.
Electronics	-	-	-	Various electronics.	-	Various electronics.
Others	Miscellaneous. Mainly hangers <i>without</i> metal hook.	Hangers <i>with</i> metal hook.	-	Miscellaneous. Lots of heavy plastic assumed to include high share of fillers	Miscellaneous.	Miscellaneous. Many CDs.

C.2 PET

C.2.1 *Bottles for beverages*

Multiple polymers – separable

Lids are made of different polymers (PE or PP)

Mainly clear plastic with coloured labels

Bottles for juice, squash, etc.

Single polymer

Lids of different polymers have been removed by the citizens sorting the item.

Mainly clear plastic

Bottles for juice, squash, etc.

C.2.2 Bottles for food

Multiple polymers – separable

Lids are made of different polymers (PE or PP)

Mixed colours. The main component is predominantly clear but the sleeve or label is coloured.

Bottles for liquid margarine, spices, ketchup, etc.

Single polymer

Lids of different polymers have been removed by the citizens sorting the item.

Mixed colours

Bottles for liquid margarine, spices, ketchup, etc.

C.2.3 *Trays and tubs for fruit and vegetable*

Single polymer

Mainly clear plastic

Small paper label

**Multiple polymers
– non-separable**

Clear PET trays with multilayer foil attached.

Mainly clear plastic with coloured print

C.2.4 *Tubs and trays for dairy products*

**Multiple polymers
– non-separable**

PET tray for slices for cheese, with attached multilayer foil.

Mainly clear plastic with coloured printing

Single polymer

Lids or bottoms for slices of cheese or butter.

Mixed colours

C.2.5 *Trays and tubs for meat*

**Multiple polymers
– non-separable**

Trays for cold cut meat slices,
where the citizens with attached
multilayer foil.

Mixed colours, much black.

Single polymer

Trays for cold cut meat slices,
where the citizens have completely
removed the attached multilayer
foil.

Clear and black plastic.

C.2.6 *Trays and tubs for other/unidentified food*

Single polymer

Clean trays with cup/fork symbol for food contact approval

No or very small labels

Mainly clear or black plastic

**Multiple polymers
- non-separable**

Many clear trays for fresh pasta with attached multilayer foil.

Some unidentified food-contact trays with attached multilayer foil

Mainly clear and black.

C.2.7 Bottles for hygiene and cleaning purposes

Multiple polymers – separable

Lids are made of different polymers (PET or PP)

Mixed colours

Mixture of cleaning products, shampoo/conditioner containers, etc.

C.2.8 Other/unidentified rigid non-food packaging

Single polymer

Packaging with few or no labels for other or unidentified non-food purposes.

Black and clear

C.3 PE

C.3.1 *Bottles for beverages*

Multiple polymers – separable

Lids (labels are made of different polymers (e.g. PP))

Mainly opaque and white with coloured labels

Bottles for juice, drinkable yoghurt.

C.3.2 *Bottles for food*

Multiple polymers – separable

Lids are made of different polymers (PET or PP)

Mixed colours

Mixed products for food

Single polymer

Lids of same polymer as body (PE)

Mainly opaque

Bottles for vinegar, etc.

C.3.3 Other rigid food packaging

Single polymer

Mainly white

Packaging for medicine or dietary supplement

C.3.4 Bottles for hygiene and cleaning purposes

Multiple polymers – separable

Lids and/or labels are made of different polymers (PET or PP)

Mainly white

Mostly large bottles/cans for cleaning purposes (e.g. detergents)

Single polymer

Lids have been removed by the citizens prior to source separation

Mainly light colours

Mostly large bottles/cans for cleaning purposes (e.g. detergents)

C.3.5 Bottles with hazardous labelling

Multiple polymers – separable

Lids and/or labels are made of different polymers (PET or PP)

Mixed colours – lots of loud colours

Mostly large bottles/cans

Single polymer

Lids are PE or have been removed by the citizens prior to source separation

Mainly dark-green products

C.3.6 Other/unidentified rigid non-food packaging

Multiple polymers – separable

Mainly bottles or cans of unidentified non-food purposes, without label.

Lids and/or labels are made of different polymers (PET or PP)

C.3.7 Others

Single polymer

Miscellaneous products

Mainly black

C.4 PP

C.4.1 *Bottles for food*

Single polymer

Lids and bottle of PP

Mixture of colours

Bottles for various toppings

C.4.2 *Trays and tubs for fruit and vegetable*

Single polymer

Mainly clear plastic

Small paper label

Tubs for tomatoes

C.4.3 Tubs and trays for dairy products

Single polymer

Mainly large tubs for dairy Greek yoghurt, skyr, etc.

Some lids and tubs for butter

Mainly white with colourful printing

C.4.4 Trays and tubs for meat

Multiple polymers – non-separable

Trays for raw meat (pork, beef, chicken, fish), with multilayer foil attached on top partially removed by the citizens.

Mixed colours, much black.

Single polymer

Various tubs for meat and fish

Mixture of colours

C.4.5 Trays and tubs for other/unidentified food

Single polymer

Clean trays with cup/fork symbol for food contact approval

No or very small labels

Mixed colours with a lot of black

Various type of products

C.4.6 *Bottles for hygiene and cleaning purposes*

Single polymer

Mainly small products for personal hygiene purposes, with PP lid.

Mixture of colours

C.4.7 *Flower pots*

Single polymer

Mixture of colours with lots of black

C.4.8 Others

Single polymer

Mixture of products and colours
with some black

**Multiple polymers
– non-separable**

Various different products
containing several parts glued or
melted together.

Mixture of colours

C.5 PS

C.5.1 *Trays and tubs for fruit and vegetable*

Single polymer

Clean, mainly clear or black, plastic

Small paper label

Clear plastic is trays for mushrooms of a specific brand.

C.5.2 *Tubs and trays for dairy products*

Single polymer

Tubs for crème fraise

White plastic with bright blue printing

Multiple polymers – non-separable

Tubs for butter, coated with PET on the inside and with cardboard glued on the outside.

White plastic with coloured cardboard

C.5.3 Trays and tubs for meat

**Multiple polymers
– non-separable**

Trays for raw meat with multilayer foil attached on top partially removed by the citizens.

Mixed colours, much black.

C.5.4 Trays and tubs for other/unidentified food

Single polymer

Clean trays with cup/fork symbol for food contact approval

No or very small labels

Mixed colours with a lot of black

C.5.5 Other rigid food packaging

Single polymer

Lots of single use tableware

Mixture of colours with lots of white

C.5.6 *Other rigid non-food packaging*

Single polymer

Various unidentified trays without cup/fork symbol

Mixture of colours

Many of few types of specific products

C.6 Others

C.6.1 Others

Single polymer

Various products in various colours

Some black plastic

Multiple polymers – non-separable

Various different products
containing several parts glued or
melted together.

Mixture of colours

Appendix D

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