Issue paper: Recycling of different waste streams

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Contents

1 Introduction 4

2 The current waste management system and general issues 5

2.1 General introduction to the Dutch waste management system 5
2.2 Theoretical framework of recycling 6
2.3 Discarding behaviour 7
2.4 Quantity and quality of collected waste, recycled material and compost 7

3 Focus on recycling of different waste streams and their issues 10

3.1 Lightweight packaging (LWP) 10
3.2 Organic waste (kitchen and garden waste) 12
3.3 Paper and board 13
3.4 Glass 14
3.5 Metal packaging 15

4 Conclusion and next steps 16

4.1 Issues in the waste management system 16
4.2 A real circular and sustainable future 17
4.3 Next steps in the project 17
Literature 21

1 Introduction

The Netherlands strives to attain a more circular economy that will simultaneously result in less municipal solid waste and more secondary resources [Website VANG, 2021]. A more circular economy could lead to lower environmental impacts, create employments and reduce our dependency from primary resources. This implies that both the wastes of companies and civilians need to be reduced as much as possible and the unavoidable share needs to be converted into secondary resources. Although substantial progress has been made in the last years, there is also a growing list of issues and dilemmas that hamper further progress. This issue paper will highlight issues in the current (and near future) waste management system.

This paper has been written in the context of the project "Increase circularity by the use of biobased and/or industrially compostable materials" financed by TKI BBE (Topconsortium for Knowledge- and Innovation Biobased Economy). The aim of this project is to explore to what extent biobased and/or industrially compostable materials can contribute to a more circular economy by providing an alternative solution for products that currently cause issues in the waste management system. We will identify products that are problematic in the current waste management system and list different alternatives. In the next phase of the project we will – for one or more specific products – perform an in-depth circularity and feasibility analysis to compare the various alternative solutions.

There are many definitions of the term "circular economy". In this issue paper, we define the circular economy along the lines of the "new plastic economy" as presented by the Ellen MacArthur Foundation in 2016 [Ellen MacArthur Foundation, 2016]. This implies that in our economy we need to strive towards the use of only secondary and renewable resources and hence no longer fossil-based (depletable) resources, that we should not waste materials anymore, but instead recycle them towards secondary resources and that we should avoid the leakage of materials into nature.

The scope of this issue paper is limited to waste flows that originate from Dutch households, also referred to as post-consumer wastes and municipal solid wastes. Since most of the products and materials that are used and discarded by civilians are fast moving consumer goods (FMCG), these are addressed in this issue paper. We focus on post-consumer wastes in which there are clear issues and exclude the deposit refund system for PET bottles and reusable glass beer bottles.

2 The current waste management system and general issues

2.1 General introduction to the Dutch waste management system

The Netherlands has an elaborate system for the collection of municipal solid waste. Bottom line of the waste treatment policy is the waste hierarchy according to the "Ladder of Lansink" [Website recycling.nl, 2021]. This means that prevention of waste generation and reuse of products do have the highest priority, and then – in order or priority - recycling, energy recovery, incineration and land fill. The landfilling of 35 types of waste is formally forbidden in the Netherlands. Additionally there is a high landfill tax, consequently just 2% of the overall Dutch waste volume is landfilled. It is the responsibility of each municipality to organise the separate collection of materials within its borders, as is described in our national waste management plan (LAP-3). This boils down into an obligation to separately collect mixed municipal solid waste (MSW), organic waste, paper & board, packaging glass, packaging plastics, metals, textile waste, Waste from Electrical and Electronic Equipment (WEEE) and hazardous wastes. Only metals and plastics are exempted from the obligation to implement a separate collection scheme and can also be recovered from mixed MSW. The municipalities have the freedom to implement the collection methods and systems of their choice within their borders, so they can opt for kerbside collection, drop-off collection, the use of wheelie bins, containers or bags. Furthermore, they can decide on the collection frequency and the service level. The choice for the specific collection system for different waste streams depends on a combination of factors: technical factors like the quality of the collected waste, but also local policies, economic and socio-cultural factors play a role.

Although municipalities were obliged to operate all these collection schemes, some urban centres stopped with the separate collection of organic waste, since the amounts were deemed too low and the contamination levels were too high. Furthermore, several urban municipalities also chose to mechanically recover plastic packages and beverage cartons from MSW, either since they did not want to implement separate collection systems or because the results were disappointing. Consequently, the waste collection methods and systems are fragmented over the Netherlands. In general we observe separate collection schemes for all waste types (organic, lightweight packaging, paper & board, glass, textiles) in the rural East and South of the Netherlands. Whereas in the urban centres in the western part we observe a few separate collection systems for glass, paper & board and textiles which is supplemented with the mechanical recovery of plastic packages and beverage cartons.

In the last decade, the national government has encouraged municipalities to minimise the amount of mixed MSW per capita per year and to reduce this amount to 100 kg/cap.a in 2014. The municipalities in the predominantly rural areas responded by introducing "Pay as you throw systems" and "reversed collection systems". The latter implies that most of the recyclable wastes are separately collected with a kerbside collection system and that the mixed MSW is collected with drop-off containers. This gave varying results. In some municipalities indeed the amount of mixed MSW dropped to levels of 30-50 kg/cap.a, the amounts of recyclable materials grew enormously and the qualities were still acceptable. However, in other municipalities the qualities of the separately collected wastes were too much polluted with non-targeted contributions and had to be incinerated. This resulted in a lively debate in the Netherlands on how to reduce the amounts of mixed MSW without impairing the transition towards a more circular economy.

An important aspect in this transition is that *a change in one of the single waste streams can cause quality issues in another stream. However, often waste streams are approached as individual streams without looking to the consequences on other streams.* This is one of the challenges in the waste management system.

2.2 Theoretical framework of recycling

The theoretical perspective on collection and recycling value chains is that these systems typically consist of three steps: collection, sorting and recycling, see Figure 1. In a few value chains, an additional pre-sorting is executed, while in other value chains multiple collection pathways are used. The official definition of recycling is: "*Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations*" [EU, 2008]. In the recycling value chains materials flow from households and industries to various manufacturers that procure the secondary resources. At each step materials can be added and removed. Manufacturers typically have purchase specifications to which their feedstocks have to comply. These specifications often list allowed ingredients and forbidden ingredients. Alternatively they list properties that need to be attained and that can only achieved by the presence of desired materials and the absence of undesired materials. These undesired materials are named contaminants or impurities.

Most contaminants and impurities enter the value chain during collection either as non-targeted contributions or as non-targeted components of targeted product. Non-targeted contributions are misplaced materials or products that end up in the wrong waste stream (plastics in organic waste, food waste in paper & board). Non-targeted components of targeted products are for example labels, lidding or caps that are made from a different material than the main material and will not be removed in the recycling processes. This is common in recycling chains where packages and products are present that are not designed for recycling.

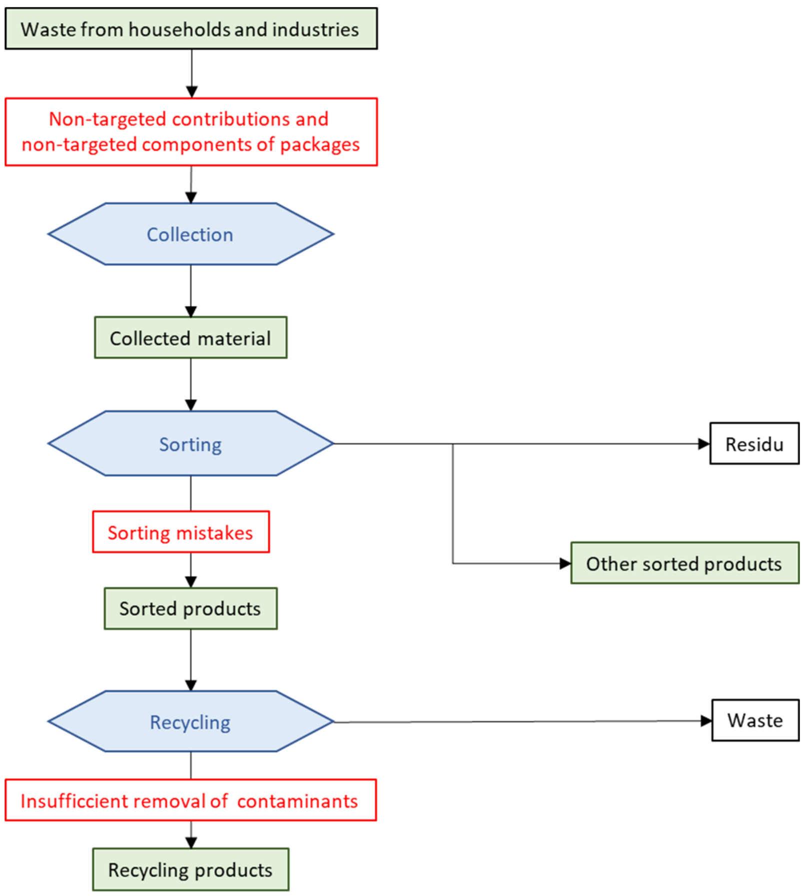

Figure 1[1]: The three common steps in a recycling chain at which contaminants are added and others are removed.

[1] Not all of the "blocks" in Figure 1 can be quantified. For example the sorting residue is not explicitly registered, but included in the company waste of the sorting facility.

In the subsequent steps of the recycling value chain contaminants can be removed. Many techniques to remove contaminants from solid waste streams are not very selective (magnets are the exception). Therefore, the quality of the recycled product is a result of the initial amount of contaminants and impurities in the collected materials and the separation efficiencies of pre-sorting, sorting and recycling. The recycled material has to fulfil requirements for the concentration of the non-targeted and targeted components. All these parameters in the recycling chain are different for the various materials and will be discussed in the next chapter.

2.3 Discarding behaviour

Hundreds of articles have been written on what motivates civilians to participate with separate collection schemes and what they experience as barriers [Sewak et al., 2021; Minelgaitė and Liobikienė, 2019; McDonald and Oates, 2003; Woodard et al., 2006; Geiger et al., 2019; Knickmeyer, 2020]. Scientists agree that it is a multifaceted phenomenon of which multiple elements are, yet, not completely understood, let alone the interrelations between the elements. First, civilians have to be persuaded to participate, then they need to be motivated to show the desired behaviour continuously which effectively implies a behavioural change. Important elements to illicit participation with civilians are:

- Knowledge and education (they understand the necessity),
- Facilities (they need to have sufficient room in the house to keep waste fractions separate),
- High service level (it should be easy).

Furthermore, large biospheric values (these reflect how important individuals find it to benefit nature and the environment), norms and social pressure [Thomas and Sharp, 2013; Geiger, 2020] can further leverage participation. Financial incentives (such as Pay as you throw (PAYT) schemes) can also encourage more civilians to participate.
But there is also an order in the likeliness that civilians will participate in keeping certain materials separate. So materials that are relatively easy to keep separate such as paper & board and glass will have in general higher participation rates than organic waste and Light Weight Packaging (LWP), which might smell or take up large volumes. Moreover clear communication/guidance and habits play a role in consumer behaviour.

Besides positive behaviour also undesired behaviour is witnessed in separate collection. Some civilians do not only discard the targeted materials in the separate collection bags or wheelie bins, but also non-targeted contributions. This can be due to for example:

- Lack of knowledge; for example silicon adhesive tubes need to be discarded in the mixed MSW and not in the LWP.
- Confusing products; for example people don’t recognize that some types of paper products have a plastic coating.
- Ease; plant pots are discarded in the organic waste, if the plants are fixed in the pots. Or products are discarded in the wrong bin when the other bins are full.
- Abuse; to reduce cost, products are discarded in the bin where no additional payment is required (such as PAYT schemes).

This undesired behaviour is studied hardly at all by scientists, but is registered by EPR organisers, collection agencies and municipalities that suffer from material rejections and want to limit their losses.

2.4 Quantity and quality of collected waste, recycled material and compost

In Table 1 the most important parameters are listed that relate to the quantity and quality of separately collected materials in Dutch municipalities. These parameters are: the amounts of municipal waste types in 2019, the shares of recyclable fractions in mixed municipal solid waste (MSW), the contamination levels of the separately collected materials, the approximated collection rates and the known quality / acceptance limits.

Table 1 ***The quantity and quality of municipal solid waste fractions in the Netherlands, based on the most important parameters.***

Parameters	Mixed MSW	Organic waste (incl. food waste)	Paper & board packages	Pack. Glass	LWP
Collected amount NL (+), 2019, [kton/a]	2830	1553	838	357	333
Collected amount NL (+), 2019, [kg/cap.a]	163	90	48	21	19
Share in MSW (++), [%]	n.a.	31%	5.9%	4.6%	8.4% (Plastic) 2.4% (Metal) 1.7% (Beverage cartons)
Average contamination level, [%]	n.a.	3.9% (O)	2.1% (P)	0.5% (G)	~15% (L)
Approximated collection rate, [%]	n.a.	63%	83%	73%	44%
Quality limits collected materials, [%]	n.a.	(2%)*	1.5%	?	15%

+ Collected amounts: CBS-statline website, visited Aug 26th 2021.

++ shares in MSW: RWS 2019, when applicable only relating to packages

O: https://www.verenigingafvalbedrijven.nl/nieuws/betere-gft-kwaliteit-vereist-ketensamenwerking;
https://www.verenigingafvalbedrijven.nl/nieuws/steeds-meer-vervuiling-tussen-het-gft ;
https://www.gemeente.nu/ruimte-milieu/afval/kwaliteit-ingezameld-gft-holt-achteruit/

P: Omrin rapportage: productvreemde vervuiling in huishoudelijk papier 2019

G: Nedvang onderzoek 2014

L: large variation between samples, RWS 2018.

*: formally there is no acceptation limit, however 2% has been proposed by VA.

This overview clearly shows that currently large fractions of potentially recyclable materials end up in the mixed municipal solid waste fraction and are lost for recycling. So, the potential for improvement is substantial. Simultaneously, most waste fractions contain too much non-targeted contributions that need to be removed. Therefore, to progress towards a more circular economy, both a quantitative impulse and a quality impulse are required. Two types of municipal solid waste stand out; the organic and the LWP waste. Too little is separately collected and both types of waste contain too much non-targeted contributions. For organic waste a partial explanation is the fact that several urban centres in the western part of the Netherlands do not operate a separate collection scheme at the moment. The collection rate for food waste (around 25%) is even much lower than the rate for organic waste (63%).

For LWP, also a growing group of municipalities do not operate a separate collection scheme, but instead let the waste management company mechanically recover the LWP from the mixed MSW. The average overall collection rate of 44% for LWP includes materials that are removed during sorting and mechanical recycling, hence the recycling rate is lower. Rejected LWP and the rejects from recycling are officially registered as company waste.

A fraction of the organic waste that is present in MSW is recovered. This recovered fraction is named "organic wet fraction" and is anaerobically digested to bio-methane. The digestate is too polluted with stones, plastics, metals and may not be landfilled or used as fertiliser. It needs to be dewatered mechanically and is subsequently incinerated. Although this is to be preferred over direct incineration, still the nutrients present in the organic waste are lost. The recovery rate of organic waste still present in Dutch MSW is currently unknown. Please note this concerns the organic waste still present in MSW, not the separately collected organic waste (which is discussed in section 3.2).

Most policy targets are focusing on the quantity of separate waste streams. The Dutch VANG policy stipulates that the amount of MSW should be below 100 kg/cap.a and a separation rate (the amount of waste that is separated) of 75% needs to be reached.
The national recycling targets for the different materials are indicated in Table 2, as well as the estimated recycling rate in 2017, according to the new EU calculation method. Please note that the exact calculation method for different materials can vary, and it is therefore difficult to compare the numbers. For more details on the new EU calculation method for different materials, we refer to earlier publications [Thoden van Velzen et al., 2019; Brouwer et al., 2019; Thoden van Velzen et al., 2020]. The table shows that for glass and plastic packages the recycling rates in 2017 are still too low compared to the targeted values, whereas recycling rates for paper & board and metal packages are already above the actual target. The numbers are for 2017 so recent changes are not visible in the numbers.

Table 2 ***Actual recycling targets and the estimated recycling percentage in 2017 in the Netherlands for different materials.***

Material	Estimated recycling percentage in 2017, based on new EU calculation method	Recycling target 2019 (unless stated otherwise) [Afvalfonds, 2020]
Glass packages	71-76% (possibly 82% when taking glass-rejects into account as well). [Thoden van Velzen et al., 2019]	90%
Paper & board packages	87% [Thoden van Velzen et al., 2019]	75%
Plastic packages	35-39% [Brouwer et al., 2019]	50% in 2025 and 55% in 2030
Metal packages	90-94% [Thoden van Velzen et al., 2020]	85%

The application of recycled materials in products is an even bigger challenge. For example for plastic products (in all sectors) only approximately 10% of the amount that was put on the Dutch market in 2018 was recycled and actually applied in new products [Plastics Europe, 2020]. Besides quantity, the quality of different streams is crucial to make sure that the recycled material can be properly applied; however, this is more difficult to catch in policy targets. Quality is depending on the recycling value chain of the stream itself, as indicated in Figure 1, but also on cross-contamination between different streams. An important issue is that often waste streams are treated as individual streams, whereas a change (improvement) in one of the streams may have a negative effect on the quality of another waste stream. Stakeholders often focus on a specific stream and side-effects on other materials are not always taken into account.

3 Focus on recycling of different waste streams and their issues

In this section we will describe specific issues for the recycling of different waste streams: the two retrieval schemes for lightweight packaging (LWP): separate collection of LWP and LWP from residual municipal solid waste, organic waste, paper/board, glass and metal packaging.

3.1 Lightweight packaging (LWP)

Lightweight packaging waste is retrieved via separate collection schemes and is also mechanically recovered from mixed MSW. The issues for both retrieval methods run mostly parallel. LWP contains both non-targeted contributions (in average 15%, but outliers to 40% have been reported [LCKVA, 2017; LCKVA, 2018]) and substantial amounts of non-targeted components of targeted products. Since in the (pre-)sorting phase only non-targeted contributions can be rejected these are in the focus of the quality assessments at the cross-docking facility or the entrance of the sorting facility. The policies and interventions of the cross-docking and sorting facilities vary. Some cross-docking facilities have a pre-sorting crew that removes the visible non-targeted contributions, others simply reject the complete heap of collected material in case non-targeted contributions are clearly visible.

Lightweight packaging waste that is accepted for sorting will be automatically sorted on object level by a complex array of separation machines. The Netherlands has four sorting facilities that process the lion's share of this feedstock. All sorting facilities differ in details but have a fairly similar set-up: first bag-opening and loosening of the materials, then sieving in roughly three size fractions (roughly: < 5 cm, between 5 and 25 cm and > 25 cm), de-metallisation with magnets and Eddy current separators, wind-sifters and/ or ballistic separators, followed by a cascade of NIR sorting machines and manual sorting crews for each sorted product (on object level) and then bunkers and bale presses.

The sorting facilities in the Netherlands typically produce 9 sorted products from the LWP, see Table 3

Table 3 The nine sorted products that are produced from Dutch LWP and traded with recycling companies.

Sorted product	DKR[2] Specification	Most common objects
PET bottles	328-1	PET bottles
PET trays	328-5	PET trays, cups, etc.
PE	329	HDPE bottles
PP	324	PP trays, tubs
Film	310	PE flexible packages
MIX	350	PP flexible packages
Beverage cartons	510	Beverage cartons
Tinplate / Steel	412	Tinplate Cans
Aluminium	420	Cans & aerosol cans

These sorted products (still objects) are traded to recycling facilities. The plastic sorted products are often traded in bales and these are first loosened, demetallised, milled, washed, elutriated (sink-float separated), dried, extruded and melt filtered. This is a fairly standard recycling process, but other more elaborate recycling processes are also operated.

[2] DKR specifications are standards for quality and purity of sorting products, as established by DKR. https://www.gruener-punkt.de/de/downloads.html

During sorting and recycling not all the non-targeted contributions and components can be removed, since these processes have mediocre separation efficiencies. This results in recycled plastics which are in fact often a blend of polymers and also do contain some other materials (paper fibres, wood fibres, metal flakes) albeit in low concentrations. This complex composition causes the recycled plastics often to have mediocre properties.

The general issues for the LWP recycling value chain are manifold and only the most eminent are discussed:

- Each sorting or recycling process has a maximum efficiency, which is never 100%. This efficiency is a combination of different parameters, like tuning of the sorting machines, the composition of the products, design for sorting and recycling, processing speed, technology limits, etc. Small rigid objects (with one dimension of less than 5 cm) end up in the sorting residues and are incinerated. Also flexible packages with a surface area less than 25 cm^2 predominantly end up in the sorting residue, so a substantial amount of the plastic and metal packages ends up in the sorting residue. For plastic packages this is roughly 30%, including loose components (such as caps, closure rings, tear strips), but also small bottles, pouches, coffee capsules, etc. Flexible packages with a surface area between 5x5 cm (25 cm^2) and one A4 (625 cm^2) predominantly end up in the mixed plastics and not in the film sorted product.
- NIR sorting takes place on object level. The majority of the plastic packages is not designed for recycling and for example contain non-targeted components, or possess too large labels, or are coloured black (a colour that is not recognised by most NIR sorting machines) which hamper the recognition of the main polymer and hence the sorting process [Brouwer et al., 2021].
- Flexible packages are separated from LWP or MSW by ballistic separation and wind-sifting. This first concentrate contains predominantly PE films, but also PP films, laminated films, paper & board and textiles. This heterogeneous mixture can be agglomerated to a relative impure and invaluable recycled material. Alternatively, the flexible concentrate can be sorted with NIR machines, but this is less common, since the losses are relatively large. NIR sorting results in a small amount of fairly pure recycled PE film and mixed plastic side products. The recycled LDPE can be used to blow new films (dark grey garbage bags).
- There is currently no large scale recycling process for laminated flexible packages. For PET trays the recycling process is still under development. The process needs to be optimised and the trays need to be designed for recycling. Furthermore, there is an imbalance between the supply and demand for some of the currently available rPET products.
- Packages that contain product residues are either too heavy to be sorted or the presence of residues hampers the recognition of the material and they end-up in the wrong sorted product. In case they do end-up in sorted products, they generate solid waste and/or pollution of the washing water.
- Agglomerates (multiple different packages that have been compressed into one lump) can lower the sorting efficiency since the separation machines are unable to break them up. These agglomerates are either formed as a result of undesired discarding behaviour of civilians (stuffing one larger package full with smaller items and discarding the stuffed object) or by distortions of the packages themselves due to applied forces in the collection process (for instance the PET tray that is folded over a flexible film).
- There are plastic articles (targeted and non-targeted) that hamper the operation of sorting and recycling machines. For example, plastic nets are well-known to clog over the teeth of mills and video tapes have the unpleasant habit of unrolling during the sorting process, lowering the performance of all sorting machines.
- The current collection & recycling system targets the recycling of the three main polymers: PE (rigids and film), PP (rigids) and PET (rigids). It is in the nature of all collection & recycling systems to focus on the most abundant materials. PS is sorted to the mixed plastics, since attempts to produce a PS sorted product from Dutch LWP resulted in impure, unsaleable sorted products. Likewise, attempts to produce a second sorted product from the flexible concentrate (PP flexibles) was unsuccessful. PVC is deliberately sent to the sorting residues and other polymers (PC, PMMA, PUR, biopolymers) are hardly present and when present distributed over the sorting residues and the mixed plastics.

- The political desire to accomplish high recycling rates in combination with a small share of well-recyclable plastic packages causes the production of large amounts of mixed plastics, which are only suitable for less demanding applications [Picuno et al., 2021].
- Most recycled plastics made from LWP are unsuited for the production of food-grade recycled plastics, whereas the largest market demand for recycled plastics is food-grade [Brouwer et al., 2020]. Currently only recycled PET and some small-scale closed loop systems for other plastics have food contact approval.
- Recycled plastic based on post-consumer waste is always a combination of different polymers (the only exception is recycled bottle PET). This makes multiple mechanical recycling loops challenging, resulting in a continuous high demand for virgin materials. In 2017 average polymer purity was for PET more than 98%, for PE and PP rigids around 92% and for PE film around 82% [Brouwer, 2019a].

3.2 Organic waste (kitchen and garden waste)

Separate collection of kitchen and garden waste (municipal organic solid waste) has several advantages over incineration with the mixed municipal solid waste. It contains a lot of wet material which, if incinerated with mixed municipal waste, is energy inefficient. Furthermore, it contains nutrients which may be recovered through composting or anaerobic digestion, but are lost when incinerated. Therefore organic waste is separately collected. Organic waste is collected, pretreated, for example by grinding and/or sieving and subsequently composted (i.e. in the presence of oxygen) and/or anaerobically digested (i.e. in the absence of oxygen). These biological processes result in a significant mass reduction of the waste due to removal of moisture, and conversion of readily biodegradable matter into CO_2 and water. Composting yields compost, a complex organic residue which can be used as soil improver in agriculture and landscaping. Anaerobic digestion yields biogas and a sludge which needs to be further treated through composting to be able to be utilized. The 1.5 Mton organic waste processed annually in the Netherlands results in approx. 675 kton of compost. There are no formal quality criteria for the resulting compost. But because there is only demand for compost with true soil improving properties, the sector has set-up a certification program 'KEURcompost' [Website Keurcompost] including quality criteria for different compost classes including requirements regarding biological activity (maturity) and composition (organic matter content, salts, heavy metals, and solid contaminants such as glass, stones, and plastic residues). Currently, there are 20 companies active in the processing and recycling of organic waste in the Netherlands. They vary significantly in size (annual amounts of waste processed) and type of installation. About half of them (processing approx. one third of the separately collected organic waste) have an anaerobic digestion installation preceding the composting process. Each facility has its own unique processing scheme which can vary with regard to the type of pretreatment (shredding, sieving), average residence time of the waste in the composting phase, post-composting treatments (sieving, magnets, wind sifting, ballistic solids separation) and recirculation of sieving fractions.

The most eminent general issues for the organic waste recycling value chain are discussed below:

- In the last decade, the concentration of non-targeted contributions in separately collected organic waste has risen [Website VA; Website gemeente.nu]. The techniques capable of removing contaminants from organic waste are either selective and have a limited effectivity (magnets, ECS) or are insufficiently effective (sieving, wind-sifting). As a consequence, an increasing amount of collected organic waste is being rejected and either incinerated or separately digested and then incinerated.
- The biggest issues with reaching the quality criteria for compost are with glass and plastics. In 2018, contamination of GFT-compost with glass (2-20 mm) was found to be 0.07%, and other contaminants >2mm (mainly plastics) were found to be 0.04% (weight-% based on dry matter) [Van der Zee & Molenveld, 2020]. When glass ends up on the agricultural fields with the application of compost, there is a risk of glass fragments contaminating harvested food products. This is dangerous and as a consequence the limits for glass in compost are strict. According to the 'Uitvoeringsbesluit Meststoffenwet [website Overheid.nl, 2021] compost cannot contain more than 0.5% by weight of foreign non-biodegradable parts. To fulfill the criteria for 'Keurcompost' the limits for glass (2-20mm) are resp. <0.05% for class A and 0.10% for class B [Website

Keurcompost, 2021]. Currently, only visible plastic residues in compost are generally seen as a problem by the composting sector because farmers (and citizens) do not like the looks of plastics in the agricultural field. Quality criteria are confined to limits for visible particles (2-20 mm). However, concern about the smaller invisible plastic particles in compost is growing with the general apprehension of the impact of micro- and nano-plastics on the environment and human health [SAPEA, 2019]. European policy is moving to take action to reduce the release of microplastics into the environment.

- There is a lack of clarity at households for what waste should be discarded in the biowaste-bin. The guidelines for what is considered organic waste can vary per municipality – depending on which waste treatment facility is contracted to process the waste. Although attempts to harmonize this on a national level are ongoing, this has not yet penetrated to the individual households.
- A European standard EN 13432 [NEN, 2000] for compostable packaging has been developed and adopted, specifying the requirements for a product to be suitable/compatible to be processed/recycled together with organic waste to compost. However, in the Netherlands, there is a debate on whether this standard is suitable to select products that can be accepted in the organic waste stream. In this debate it is brought forward that it is still unclear whether the disintegration rate of compostable products (i.e. certified according to this standard) would be sufficient to be compatible with the current organic waste treatment practice in the Netherlands. This is questioned because the current practice has focused more and more on high throughput of organic waste and corresponding short composting cycles (low residence times). In 2020 WFBR finalized a study into the fate of a series of EN 13432 certified products in a Dutch industrial waste treatment facility operating with composting cycles of 11 days. It was concluded that certified compostable products are not likely to contaminate the final compost with visible plastic residues, nor are they expected to end up in the residue of the composting process which is being discarded (incinerated) [Van der Zee & Molenveld, 2020].
- The incentives for separate organic waste collection are mainly quantitative (amount of processed organic waste) instead of qualitative (quality of the organic waste to produce high quality compost).

3.3 Paper and board

Paper & board is collected and either sorted or directly traded to paper mills. There are roughly a dozen paper mills in the Netherlands that process our paper & board and there are a small number of dedicated sorting facilities. In the Netherlands and most European countries the collection infrastructure for used paper and board is good and collection and recycling rates are high. The high recycling rate of paper is (partly) depending on the way this number is defined. The recycling rate is based on the amount of paper that is processed by the paper recycling company, rather than the amount of paper that is actually incorporated into new (recycled) paper and board.
Opposed to other materials discussed in this issue paper, used paper and board collected for recycling is not considered waste. Paper and board recovered from MSW is not accepted and collection guides state that only dry and clean paper and board is allowed in the collection system (no food residues, no sanitary paper and no combinations of paper and plastic). Still, due to lack of awareness, poor recognition and an increasing amount of complex packaging products, the level of non-targeted contributions in collected paper & board is gradually rising over the years [Omrin, 2019].
Depending on supply and demand, collected paper & board that contains too much non-targeted contributions is first sorted. The sorting technologies to remove contaminants (magnets, sieves, wind sifters, optical sorters with NIR) are fairly successful, but their costs need to be justified. Paper mills are apprehensive about the quality of collected paper & board, since a line-breakage or the rejection of whole paper rolls due to the presence of impurities named "stickies" is very costly for these companies.

The general issues for the paper and board recycling value chain are manifold and only the most eminent are discussed:

- Paper recycling companies do not accept paper that is defined as a waste stream although technically it would be possible to recycle these materials. Formally, only dry and clean paper and board is allowed in the collection system and the increasing amount of paper-based food packaging contaminates the paper recycling system with food residues, liners and chemicals to make the paper packages water-resistant. This actually reduces the amount of packaging that is recycled.

- Recycled paper contains multiple chemicals that originate from printing inks residues, glues, etc. Therefore, it can in most cases not be used as food packaging. For application in food contact packaging almost exclusively virgin fibre pulps are used. Some food can still be packed in recycled paper boxes, e.g. eggs.
- In the Netherlands beverage cartons and coffee cups are deemed to be used as raw material for the production of hygiene paper, tubes and cores. Dutch beverage cartons contain fairly large quantities of yoghurt like product residues. In the Netherlands there is one small facility to recycle beverage cartons that are collected in the LWP system, and there are two larger facilities in Germany that might accept Dutch beverage cartons, depending on the market situation. Paper and board recycling is strongly dependent on this market situation. Prior to the national sword policy of China, beverage cartons were recycled. From 2018 the European market flooded with collected paper & board and no paper mill was interested in Dutch beverage cartons. Hence, significant amounts had to be incinerated. In 2020 the demand for board grew faster than the European collection could offer, and beverage cartons were recycled again.
- Recyclability of paper & board products is often defined by the maximum amount (in percentage) of foreign materials (such as plastics) these products may be composed of. Allowed percentages range from 1.5 to 5%. There is no scientific basis setting these limits so they are not clearly related to the recyclability of paper & board products or the quality of recycled paper.
- At the moment there is no generally accepted standard test for recyclability of paper products. This is partly due to the fact that different disintegrators from different paper producing companies will give different results, and that there is no standard pulping time used. Some paper products can be recycled but will reduce process yield and result in costly waste streams.
- The consumer acceptance of paper-based packaging combined with the need to redesign non-recyclable (flexible) packaging is a motive for many companies to move to paper & board-based packaging. Still these products are not recyclable neither accepted in paper and board collection systems when they contain food residues.
- Within the SUP (Single Use Plastics) regulation plastic coated paper is defined as a plastic and therefore not allowed. This leads to an increased use of waxes, PFAS, silicon oils and other substances which are required to make the paper water and grease resistant. These substances can be harmful for food safety, the environment or the recycling process. A European wide survey on PFAS uses in disposable food packaging and tableware by a consortium of NGO’s indicates that at least 30% of the products contained intentionally added PFAS (32 in a total of 99 samples). Moreover, the study indicates that recycled paper contains PFAS [Tegengif, 2021].

3.4 Glass

Glass bottles and jars are separately collected with predominantly drop-off containers. This separately collected packaging glass contains roughly 0.5% non-targeted contributions (of which stones, pebbles, china and thermal glass are the most challenging) and roughly 1% packaging components of other materials (such as metal lids, paper labels, corks, etc.). The glass ovens have very strict acceptance limits for contaminants in sorted glass cullets (below 20 grams in 1000 kg) and hence the sorting facilities have to remove large amounts of metals, stones and other types of glass. Furthermore the cullets have to be sorted on colour. The glass recycling companies succeed to sort the glass to the colour and contaminant specifications with a whole cascade of sieves, tumblers, optical sorters, laser sorters and XRF sorters. In order to obtain the products that fulfil the specification also substantial amounts of side products have to be produced, which varies from construction materials to glass powder for blasting applications.

Issues with glass recycling are discussed below:

- Most issues are with spirit producers that want to use exotic bottles made from stoneware, dyed glass bottles or glued seals and large plastic labels that are difficult to remove.

- Another issue is the higher recycling target in comparison to the collection rates. Since almost all packaging glass is collected with drop-off systems, the participation rates tend to be mediocre in the urban centres, which hampers the accomplishment of higher collection rates.

3.5 Metal packaging

Metal packaging products can be collected and recovered via different waste streams: LWP, recovery of LWP from MSW, and recovery from bottom ashes during the incineration process of residual waste. Most metal packages are composed of multiple materials. For instance a tinplate can is composed of sheet steel with thin-layer of tin, an epoxy-based or plastic coating, a paper label, etc. Most aluminium packages are made from dedicated alloys, coatings, prints, etc. The separation technologies to sort ferrous metals and non-ferrous metals from waste streams (Magnets and Eddy Current separators) are very selective. Additionally, the Magnetic Density Separation (MDS) and X-ray fluorescence (XRF) sorting technologies to separate the non-Ferrous metals are also very selective. This implies that during the recycling chain most non-targeted components are lost and are therefore not critical for the properties of the recovered metal. The tin layer, however, mixes into the steel during melting, and forms an alloy with reduced mechanical properties as compared to normal steel. Furthermore copper-based non-targeted contributions (wires, electronics) introduce copper into steel which even has a more detrimental effect than tin on the mechanical properties.
Recycled aluminium picks up small amounts of iron and silicon during the recycling chain. This changes the metallurgic properties, making it more suited for casting applications.
Most metal objects are recovered in high yields from mixed MSW and LWP. However, small aluminium objects are recovered in relatively low mass yields. These small aluminium objects are either thin-walled and/or composed of multiple materials of which aluminium is a minority material and therefore high oxidation losses occur in the mixed MSW recycling system Examples are: coffee capsules, pet food-pouches, Caprisun-pouches, drug blisters, laminated flexible films with an aluminium layer. Improvements of the recovery yield of thin-walled aluminium objects is welcomed.

The issues are threefold:

- First of all, most metal packages are not recycled circularly; aluminium packaging becomes casting aluminium and packaging steel becomes mostly construction steel.
- Secondly, smaller aluminium objects (coffee capsules, pet food pouches, etc.) suffer from relatively high oxidation and recovery losses in the predominant mixed MSW recycling pathway.
- Thirdly some objects are composed of multiple materials and potentially include organic waste, hampering their recovery (coffee capsules, small metal portion packs for processed cheese and meat products), introducing metal contaminants in steel (electronic boards connected to steel objects).

4 Conclusion and next steps

4.1 Issues in the waste management system

In this paper, we described the current Dutch waste management system: collection, sorting and recycling of different waste streams. We highlighted some general issues in the system and also some issues that are specific for a particular waste stream. Below, we summarize the main issues, divided into three categories: collection, quality and systemic issues. We note them separately, however the issues can be interrelated as well. These issues are fairly generic and applicable to multiple European countries.

- **Collection issues**.
    - Undesired discarding behaviour by civilians
    - Not all municipalities operate separate collection schemes for all materials,
        - Organic waste is not separately collected everywhere,
        - Separate collection of LWP failed in the urban centres in the western part of the Netherlands; the collection rates were too small and the collected material contained too much non-targeted contributions.
    - Collection systems interact with each other,
        - Policies to reduce the amount of collected MSW can raise the level of in non-targeted contributions in most separately collected materials.
- **Quality issues.**
    - All separately collected and recovered materials face various quality issues,
        - Plastics: most targeted objects are not designed for recycling and collected LWP often contains too much non-targeted contributions,
        - Organic waste: contamination with glass, plastics, etc.,
        - Paper & board: composed packages with plastic/paper combinations, contamination with printing inks, etc.
        - Glass: issues with stoneware, thermal glass, pebbles,
        - Metal packages: issues with composed objects.
- **Systemic issues.**
    - Most recycled materials are not suited for circular recycling of food packages, there are only a few exemptions: glass, mono-collected PET bottles and mono-collected aluminium cans.
    - High recycling targets are difficult to accomplish,
        - Plastics: the combination of a small amount of well-recyclable packages and high recycling targets results in the production of much mixed recycled plastic,
        - Glass: the drop-off collection system makes it hard to attain high collection rates in the urban centres,
    - Not all products fit into the current recycling system.
        - The size of items can be an issue,
        - A combination of different materials that can’t be separated in the recycling process,
        - For some products there is not yet a recycling technology in place
    - Waste streams are approached as individual streams. Optimizations in one stream are made without looking to the consequences on other streams.
    - There is a lot of unclarity and mis-information on the topic of recycling and circularity.

Even if there are many issues, in general in the Netherlands the waste management system is well arranged compared to other countries. However there are still a lot of open questions. There is no easy fix for everything; the route to more circularity includes a combination of many partial solutions for various issues that need involvement and increased awareness of many different stakeholders including consumers and government.

4.2 A real circular and sustainable future

Looking to the future, the question arises how a real circular and sustainable system would look like. We take plastics as example, because of the current societal focus on issues with the plastics system. The technical limit of the current Dutch plastic packaging recycling system is estimated at 72%, when all stakeholders take concerted actions [Brouwer et al, 2020]. Even if this limit would be reached, the system is not intrinsically sustainable: plastics are still mainly fossil-based, litter is still accumulating in nature, a food packaging is not recycled back into a food packaging, etc. A new fossil-free based system should be developed over the years. A transition towards the use of renewable carbon feedstocks has to take place from one of the three possible sources: recycling, biomass or CO_2 capturing. This transition will take many years and needs involvement and awareness of all of us.

4.3 Next steps in the project

This issue paper has been written in the context of the project "Increase circularity by the use of biobased and/or industrially compostable materials". This document can be seen as a starting point; a description of the current waste management system and its issues. With the project we would like make a next step towards a solution for some of the issues in the current waste management system. The main research question is: *can we identify products where potentially biobased and/or industrially compostable products could increase real circularity?*

We can think of specific products that do not properly fit in the current waste management system due to one or more of the issues described in this paper. We would like to explore if biobased and/or industrially compostable products could solve some of the issues for specific products and increase circularity. When considering alternative solutions we will explicitly consider a wide range of potential alternatives, where biobased and/or industrially compostable is one of the options. Moreover the alternative solutions should not have a negative effect on other waste streams.
Examples of products that cause issues in the current waste management system and could potentially benefit from such a solution are tea bags and coffee pads, meat trays and coffee capsules. Please note these cases <u>only serve as examples</u>. The final selection of the cases will be made in a later stage, and the cases will be studied in detail during the project.

<u>Example 1: Tea bags and coffee pads</u>
Current situation: according to the actual waste guidelines, tea bags and coffee pads should be discarded in the mixed municipal solid waste. However 60% of the consumers discard them in the organic waste bin or on the compost heap. Tea bags and coffee pads contain microplastics and are too small to be removed during the composting process, and causes invisible plastic contamination of the compost and leakage of microplastics into the environment. When tea bags and coffee pads are discarded with the mixed MSW they are incinerated. In that case organic waste is removed from the biosphere and incineration of wet material is inefficient.

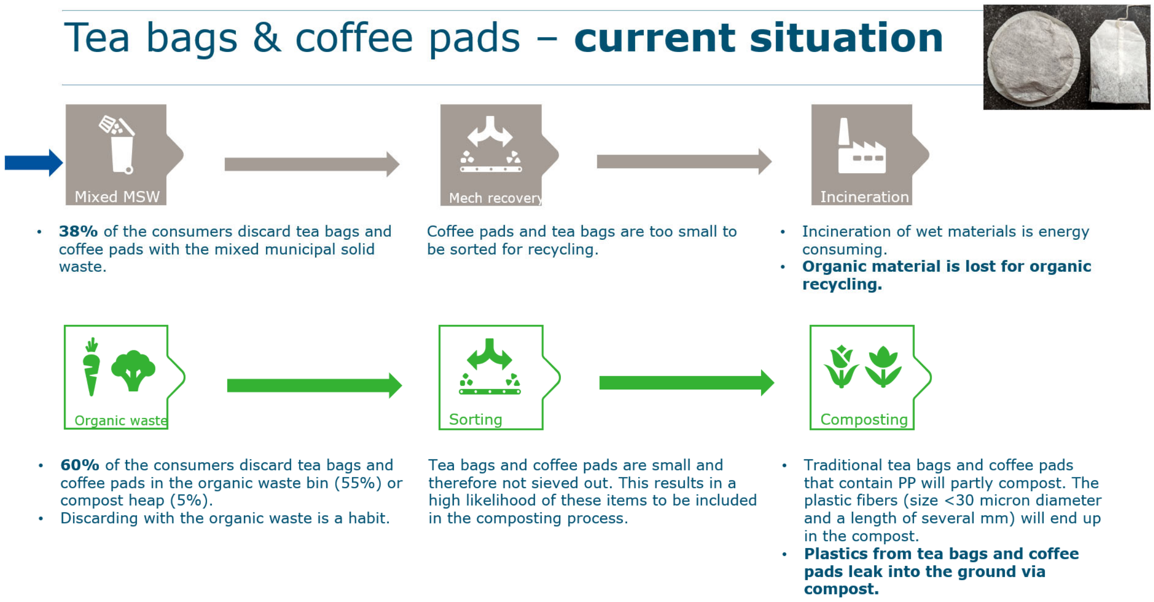

Figure 2 ***Current situation for tea bags and coffee pads.***

During the project we could consider potential alternatives (like a campaign to change the discarding behaviour of consumers, a re-usable solution like a tea egg and compostable tea bags and coffee pads) and compare them from a sustainability and feasibility point of view.
Note: for tea bags and coffee pads it is already agreed in a Dutch Green Deal that once at least 75% of the tea bags and coffee pads on the market is compostable, these products will be admitted in the organic waste.

Example 2: Meat trays
Current situation: most meat trays are made from PET, but contain components of other materials: a sealing medium, a top film and an inlay. Meat trays are mostly discarded with the LWP and can be well sorted via NIR technology and manual sorting. Recycling is a challenge due to the different packaging components. Until late 2020 there was no recycling technology in place for PET trays. A recycling process is now in place, but still needs further development. Issues occur due to the presence of paper (inlays, labels), top films and PE sealings; meat trays are not yet designed for recycling. The recycled PET is not transparent enough to create new transparent trays. In case PET trays end up in the mixed MSW they are incinerated, as well as when they are discarded with the organic waste (except when the trays are processed in the composting facility, where they will cause microplastics contamination).

Even when assuming the challenges in PET tray recycling would be solved and PET tray recycling would be on the same level as for example PET bottle recycling, the current meat trays cannot be considered as an intrinsically sustainable and circular packaging. This is for example due to the technical limits of the current plastic recycling system [Brouwer et al, 2020], the fact that the material is fossil-based and the fact that when trays end up in nature as litter they do not degrade and accumulate in nature. A transition will be required to move to a real sustainable and long term solution. This is the case for a lot of packaging types, but we could use meat trays as example case.

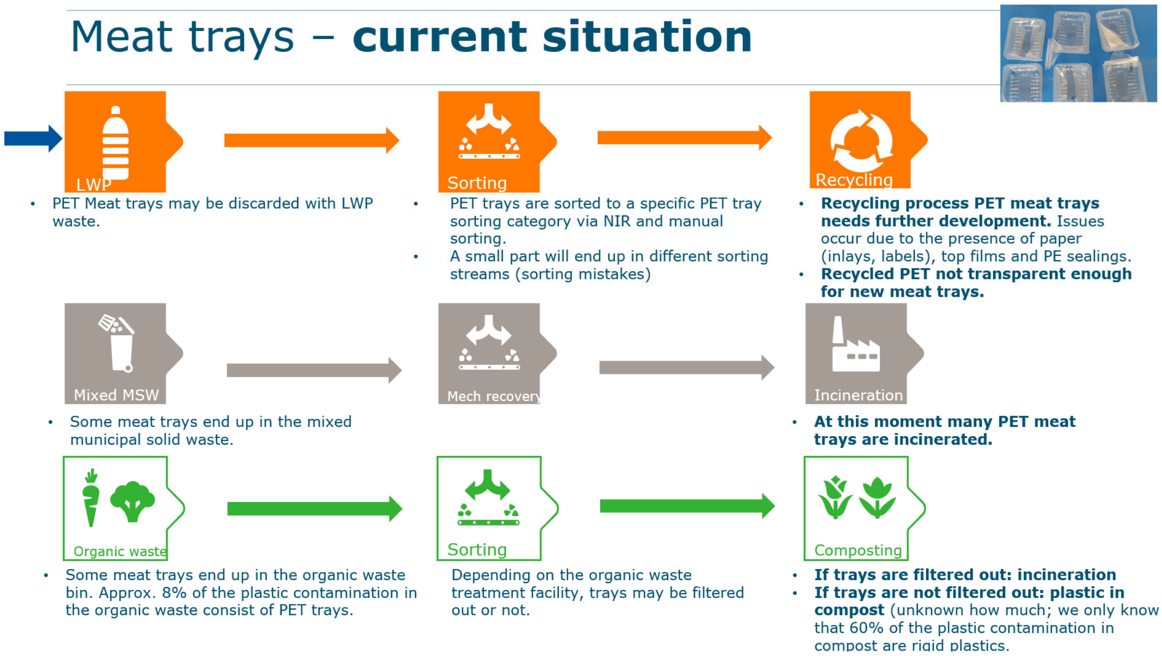

Figure 3 ***Current situation for meat trays.***

During the project we could consider potential alternatives (like redesign of current PET trays, re-usable meat trays, mono-material PLA meat trays) and compare them from a (longer term) sustainability and feasibility point of view. Furthermore we could calculate the impact on other (current and future) recycling streams.

<u>Example 3: Coffee capsules</u>

Current situation: coffee capsules are currently made from plastic (PP) or aluminium. Aluminium capsules are either collected via a separate collection system for coffee capsules (with a relatively low participation grade), or incinerated when they are collected with the mixed municipal waste. In the first case they are recycled. In the second case the aluminium can be recovered from bottom ashes during incineration. Significant (oxidation) losses take place and the organic material (coffee) is lost. For the plastic capsules the recycling rate is close to zero, and the organic material is lost as well. There are no figures on the amount of coffee capsules that are disposed with organic waste, but the product could cause confusion for consumers.

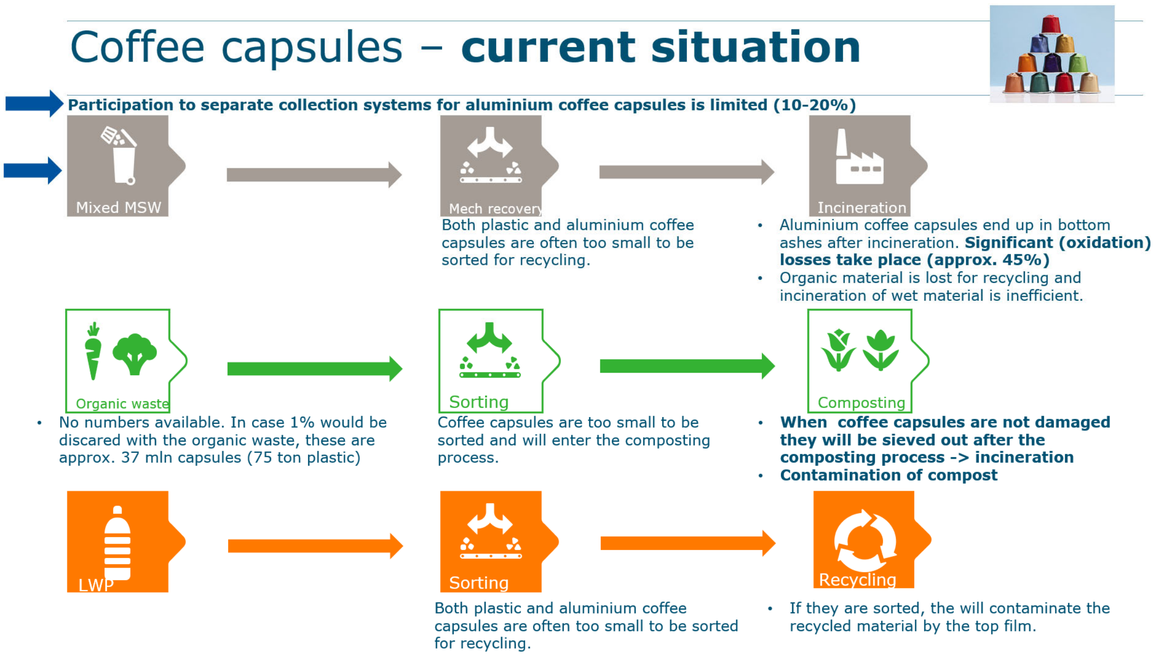

Figure 4 ***Current situation for coffee capsules.***

During the project we could consider potential alternatives (like improving the separate collection system of aluminium capsules, developing a recovery technique for plastic coffee capsules and compostable coffee capsules based on bioplastics) and compare them from a sustainability and feasibility point of view. Furthermore we could calculate the impact on other (current and future) recycling streams.

Based on this identification of issues in the current system and the example cases, we plan the following steps in the project:

1. Create awareness of the challenges for specific products in the current system. Select some specific products for the next steps and explain why these products do not fit in the current system. This issue paper is part of this step.
2. Gain insight in potential alternative solutions, where biobased and/or industrially compostable is one of the solutions.
3. Analyze the circularity and feasibility of potential alternatives from multiple perspectives (sustainability, leakage, food safety, etc.).
4. Define a roadmap to successful implementation: improvement of the quality of recycled materials and compost, required actions from stakeholders, identify barriers etc.

We want to show that by selectively replacing products there are opportunities to improve not only the quality and quantity of the organic waste stream, but it can also improve other recycling routes, like for plastic. To make a successful step towards more circularity the joined effort and commitment of a lot of relevant stakeholders is required, which makes it challenging. In this project we aim to make a start with this!

Literature

Afvalfonds, 2020. Monitoring verpakkingen; Resultaten inzameling en recycling 2019. https://afvalfondsverpakkingen.nl/a/i/Monitoring-Verpakkingen-Resultaten-inzameling-en-recycling-2019.pdf

Brouwer MT, Smeding IW, Thoden van Velzen EU, 2019. Verkenning effect verschuiven meetpunt recycling kunststofverpakkingen, WFBR report 1923, maart 2019, https://doi.org/10.18174/474139/

Brouwer, MT, C. Picuno, E.U. Thoden van Velzen, K. Kuchta, S. de Meester, K. Ragaert, 2019a. The impact of collection portfolio expansion on key performance indicators of the Dutch recycling system for Post-Consumer Plastic Packaging Waste, a comparison between 2014 and 2017. Waste Management 100, p112-121. https://doi.org/10.1016/j.wasman.2019.09.012

Brouwer, M.T., E.U. Thoden van Velzen, K. Ragaert, R. ten Klooster, 2020. Technical Limits in Circularity for Plastic Packages. Sustainability 12 (23), 10021. https://doi.org/10.3390/su122310021

Brouwer, M., U. Thoden van Velzen, Y. Workala, 2021. Recyclebaarheid van Nederlandse kunststofverpakkingen : de status van 2021. WFBR report 2150. Wageningen Food & Biobased Research. https://doi.org/10.18174/546479

Ellen Macarthur Foundation, 2016. The new plastics economy, Rethinking the future of plastics. https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf

EU, 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance). OJ L 312, p. 3–30

Geiger, J.L., L. Steg, E. van der Werff, A. Berfu Ünal, 2019. A meta-analysis of factors related to recycling. Journal of Environmental Psychology 64, 78-97. https://doi.org/10.1016/j.jenvp.2019.05.004

Geiger, J.L., 2020. Context matters: Three ways of how the context influences recycling behaviour. University of Groningen. https://doi.org/10.33612/diss.131464819

Green Deal, 2021. Green Deal on coffee pads and tea bags in organic household waste. https://www.greendeals.nl/sites/default/files/2021-05/Green%20Deal%20on%20coffee%20pads%20and%20tea%20bags%20in%20organic%20household%20waste.pdf

Knickmeyer, D., 2020. Social factors influencing household waste separation: A literature review on good practices to improve the recycling performance of urban areas. Journal of Cleaner Production 245, 118605. https://doi.org/10.1016/j.jclepro.2019.118605

LCKVA, 2017. Samenstelling ingezameld kunststof/PMD verpakkingen – het effect van inzamelsystemen. https://www.nedvang.nl/wp-content/uploads/2019/02/LCKVA-Rapportage_Samenstelling_kunststof_PMD_verpakkingen.pdf

LCKVA, 2018. Samenstelling ingezameld kunststof/PMD verpakkingen – Fase 2. https://www.vang-hha.nl/nieuws-achtergronden/2018/onderzoek-fase-2/@203281/samenstelling/

McDonald, S., C. Oates, 2003. Reasons for non-participation in a kerbside recycling scheme. Resources, Conservation and Recycling 39 (4), 369-385. https://doi.org/10.1016/S0921-3449(03)00020-X

Minelgaitė, A., G. Liobikienė, 2019. The problem of not waste sorting behaviour, comparison of waste sorters and non-sorters in European Union: Cross-cultural analysis. Science of The Total Environment 672, 174-182. https://doi.org/10.1016/j.scitotenv.2019.03.342

NEN, 2000. Standard EN 13432:2000 Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging. https://www.nen.nl/en/nen-en-13432-2000-en-57322

Omrin, 2019. Productvreemde vervuiling in huishoudelijk papier. https://prn.nl/wp-content/uploads/2019/10/Vervuilingsrapport-2019.pdf

Picuno, C., E. Van Eygen, M.T. Brouwer, K. Kuchta, E.U. Thoden van Velzen, 2021. Factors Shaping the Recycling Systems for Plastic Packaging Waste—A Comparison between Austria, Germany and The Netherlands. Sustainability 13 (12), 6772. https://doi.org/10.3390/su13126772

Plastics Europe, 2020. Levenscyclus van plastics in Nederland 2018. https://www.plasticseurope.org/application/files/6915/7951/9883/PlasticEuropeNL_-_Infographic_2018_-_final.pdf Consulted in August 2021.

SAPEA, 2019. A scientific perspective on microplastics in nature and society. https://doi.org/10.26356/microplastics

Sewak, A., J. Kim, S. Rundle-Thiele, S. Deshpande, 2021. Influencing household-level waste-sorting and composting behaviour: What works? A systematic review (1995–2020) of waste management interventions. Waste Management & Research 39 (7), 892-909. https://doi.org/10.1177/0734242X20985608

Strakova, J, Schneider, J and Cingotti, N. Throwaway packaging, forever chemicals, European-wide survey of PFAS in disposable food packaging and tableware, 2021.

Thoden van Velzen, E.U., I.W. Smeding, M.T. Brouwer, 2019. Verkenning effect verschuiven meetpunt recycling verpakkingen. WFBR report 1984. Wageningen Food & Biobased Research. https://doi.org/10.18174/503911

Thoden van Velzen, U., Brouwer, M. T., & Smeding, I. W., 2020. Recyclingpercentage metaalverpakkingen in Nederland in 2017: Volgens de nieuwe EU rekenmethode. WFBR report 2160). Wageningen Food & Biobased Research. https://doi.org/10.18174/536135

Thomas, C., V. Sharp, 2013. Understanding the normalisation of recycling behaviour and its implications for other pro-environmental behaviours: A review of social norms and recycling. Resources, Conservation and Recycling 79, 11-20. http://dx.doi.org/10.1016/j.resconrec.2013.04.010

Van der Zee, M., K. Molenveld, 2020. The fate of (compostable) plastic products in a full scale industrial organic waste treatment facility. WFBR Report 2020, Wageningen Food & Biobased Research. https://doi.org/10.18174/514397.

Website Gemeente.nu, https://www.gemeente.nu/ruimte-milieu/afval/kwaliteit-ingezameld-gft-holt-achteruit/ . Consulted in July 2021.

Website Keurcompost, Beoordelingsrichtlijn Keurcompost Versie 7.1 https://keurcompost.nl/beoordelingsrichtlijn/ . Consulted in July 2021.

Website Overheid.nl, 2021. Uitvoeringsbesluit Meststoffenwet, geldend van 20-02-2021. https://wetten.overheid.nl/BWBR0019031/2021-02-20

Website recycling.nl, http://www.recycling.nl/ladder-van-lansink.html. Consulted in September 2021.

Website Tegengif, https://www.tegengif.nl/pfas-in-wegwerpvoedselverpakkingen/. Consulted in September 2021.

Website VA, https://www.verenigingafvalbedrijven.nl/nieuws/betere-gft-kwaliteit-vereist-ketensamenwerking . Consulted in June 2021.

Website VANG, https://www.vang-hha.nl/ . Consulted in July 2021.

Woodard, R., M.K. Harder, M. Bench, 2006. Participation in curbside recycling schemes and its variation with material types. Waste Management 26 (8), 914-919. https://doi.org/10.1016/j.wasman.2005.08.009