

Pilot beverage carton collection and recycling 2013

Concise technical report

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Colophon

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Abstract

This report gives a technological description of the four common collection and recycling schemes that have been tested in the Netherlands as part of the pilot beverage cartons in 2013. During this pilot the collection and recycling of beverage cartons was tested in 37 different municipalities, with various separate collection systems and 2 recovery facilities.

The pilot demonstrated that it is technically possible to collect and recycle Dutch beverage cartons. The recycled pulp from all tested collection methods is relatively similar in properties. Also, the fibres are relatively strong and the microbiological load is relative high, this limits the applicability. Hence, corrugated boxes are a well-suited application for these pulps.

Four different collection and recycling schemes were tested; separate collection, co-collection with plastics, co-collection with paper & board and recovery. The efficiency of most schemes is limited by the net collection yields and for some schemes also the sorting yield. The net collection yields are determined by different factors, such as the percentage of high rise buildings, the execution of the collection system (service level, communication, etc.) and the space inside the houses to store and keep beverage cartons separate until collection.

The recovery recycling chains were most efficient, although one of the two chains suffered from a relative low sorting yield. Nevertheless, this sorting step can be improved.

Two different co-collection chains with plastic packages were studied; the Milieuzakken and the Kunststof Hergebruik chains. The Milieuzakken-chain is already established for several years and the collection retrieves almost all the beverage cartons that are expected to be present in its collection area. However, the collected material contains also relative large amounts of residual waste, which hampers the sorting and recycling and reduces the overall efficiency. The Kunststof Hergebruik co-collection chain was set-up specially for this pilot and suffered from low collection yields and low sorting yields. Although the rural area around Deventer already reached a near complete collection of all beverage cartons, for most other collection areas more time is necessary to mature the collection system and obtain higher collection yields. For improved sorting ideally an investment is required which would make the sorting process much more efficient, since the current facility was not designed and equipped for the efficient sorting of beverage cartons.

The separate collection scheme suffered from relative low net collection yields, varying from 3% to 57% with a weight-averaged mean of 20%. This collection system needs time to mature and obtain higher net collection yields. For a few municipalities (with relatively low collection yields) some adjustments to the system are necessary.

Also, the co-collection scheme with paper & board in general suffered from low net collection yields. Although in the high-rise area of Etten-Leur the largest net collection yield for a high-rise area was recorded of 50%. The subsequent sorting was inefficient, due to the similarity of the materials. In the future, an ideal co-collection chain would be constructed without a sorting facility. The mixture would be integrally pulped and recycled as is now the current operation in a new facility in Nortrup (Germany).

Samenvatting

Dit rapport geeft een technische beschrijving van vier inzameling en hergebruik ketens voor drankenkartons in Nederland. De pilot voor de inzameling en hergebruik van drankenkartons werd gehouden met 37 verschillende gemeenten en 2 nascheidingsinstallaties en heeft aangetoond dat het technisch mogelijk is om drankenkartons in te zamelen en her te gebruiken. De herwonnen pulp van alle hergebruikssystemen was vergelijkbaar in eigenschappen; de vezels zijn relatief sterk en de microbiologische belasting is relatief hoog, dit is beperkt de toepassingsmogelijkheden. Golf-kartonnen dozen zijn een geschikte toepassing voor deze pulp. Vier verschillende inzamel- en hergebruikssystemen werden getest; gescheiden inzameling, gecombineerd gescheiden inzameling met kunststof verpakkingen, gecombineerd gescheiden inzameling met oud-papier en nascheiding. De overall systeemefficiëntie werd beperkt door het netto inzamelrendement en in sommige systemen ook door het sorteerr rendement. Het netto inzamelrendement wordt bepaald door verschillende factoren, zoals de stedelijkheidsklasse, de uitvoering van het systeem (service niveau, communicatie, etc.) en de plek in huis om de drankenkartons apart te bewaren voor inzameling.

De nascheidingsketens waren het meest efficiënt, ofschoon het rendement van één van de twee ketens werd beperkt door een laag sorteerr rendement voor drankenkartons. Dit laatste kan echter worden verholpen door technische aanpassingen aan de sorteerinstallatie.

Twee verschillende ketens voor het gecombineerd inzamelen met kunststof verpakkingen werden onderzocht; die van de Milieuzakken en van Kunststof Hergebruik. De Milieuzakken-keten is reeds jaren operationeel en de inzameling haalt nagenoeg alle drankenkartons uit het inzamelgebied terug, die daar aanwezig worden geacht. Het ingezamelde materiaal bevat echter eveneens relatief grote hoeveelheden restafval, hetgeen de navolgende sorteer- en hergebruiksstappen bemoeilijkt en het totale ketenrendement verlaagd. De gecombineerde inzamelketen van Kunststof Hergebruik werd speciaal voor deze pilot opgezet en had te maken met lage inzamelrendementen en sorteerr rendementen. Ondanks dat het landelijk gebied van de gemeente Deventer een nagenoeg volledig netto inzamelrendement bereikte, is er voor de andere inzamelgebieden meer tijd nodig om het scheidingsgedrag van de burgers te veranderen en hogere inzamelrendementen te bereiken. De sorteerinstallatie zou idealiter technisch worden aangepast met een aanvullende NIR scheidingseenheid ten behoeve van drankenkartons, aangezien de huidige installatie hier niet voor was ontworpen en toegerust.

De gescheiden inzamelketen had te maken met lage netto-inzamelrendementen, variërend van 3% tot 57% met een gewogen gemiddelde van 20%. Er zal meer tijd nodig zijn om dit inzamelstelsel te laten rijpen en hogere netto inzamelrendementen te verkrijgen. Bovendien zal er voor enkele gemeenten met afwijkend lage inzamelrendementen verbeteringen in het inzamelstelsel moeten worden doorgevoerd.

Het gecombineerde inzamelstelsel met oud-papier had ook last van lage netto inzamelrendementen. Opmerkelijk was dat deze rendementen laag waren voor het laagbouw inzamelgebieden en relatief hoog voor het onderzochte hoogbouwgebied van Etten-Leur. Hier

werd 50% inzamelrendement gehaald, een record voor een hoogbouwgebied. De navolgende sorteerstap was inefficiënt door de grote overeenkomsten in materiaal en eigenschappen. Waarschijnlijk wordt deze sorteerstap in de toekomst overbodig omdat er inmiddels al een groot papierbedrijf in staat is om het mengsel integraal her te gebruiken.

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1 Introduction

1.1 Objective

This report aims to give a complete technological description of the four common collection and recycling schemes that have been tested in the Netherlands as part of the pilot beverage cartons in 2013. The recycling schemes are described from civilians that discard emptied beverage cartons up to the recycling plants that produce fibres and by-products. In Figure 1 the four studied common collection and recycling schemes are drawn.

In order to describe these recycling chains different types of measurements are performed at the various involved parties and facilities. These technical measurements have been combined to yield mass flow schemes in which the flow of the beverage cartons is described from civilians up to the recycled products, both in quantitative terms [kg net/cap.a] and in qualitative terms [% beverage cartons].

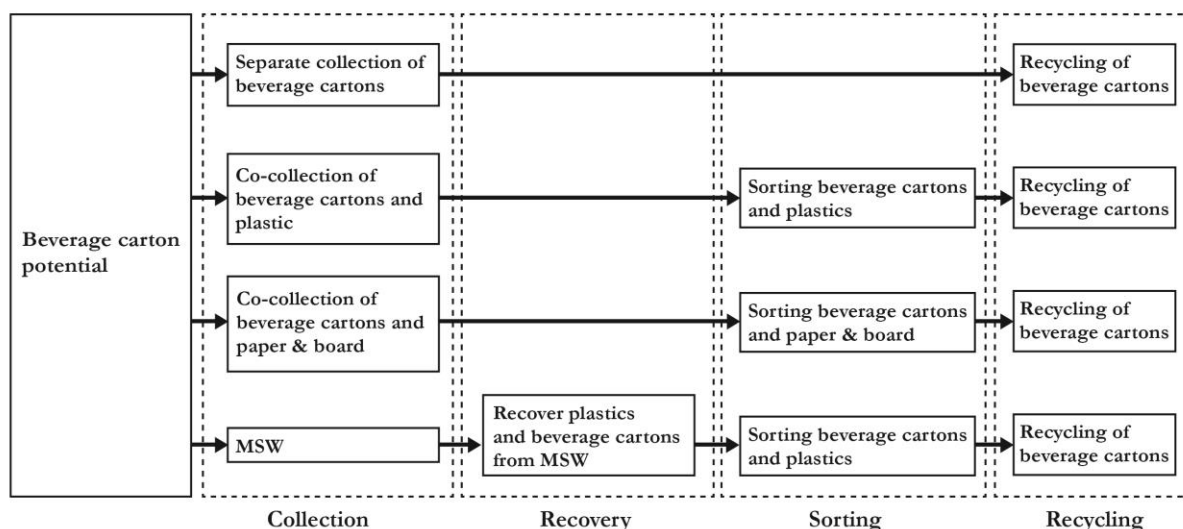


Figure 1: Schematic description of the four common collection and recycling schemes tested during the pilot in the Netherlands in 2013.

Since three of the four recycling chains use a carrier stream for the beverage cartons (plastic packages, paper & board, MSW) the consequences of this combination for the carrying materials has been studied and clarified.

This concise report summarises the main results and conclusions. All the measurement details, calculations, analysis are combined in the extended technical report and its annexes.

2 Methods

2.1 Collection areas

Municipalities have been invited to participate in this pilot. Subsequently municipalities have been selected with the intention of obtaining a representative mix of different municipalities over the 4 collection schemes, collection methods and percentage of high-rise buildings within the collection areas. The selection process has been described in the project plan. The resulting observation matrix is shown in Table 1. In total 37 municipalities participated with 40 different collection areas and in total 830,842 inhabitants in these collection areas. Additionally the MSW of 1,015,640 inhabitants was treated in a recovery facility with the aim to recover the beverage cartons.

Table 1: Matrix of the studied types of collection systems and participating collection areas within municipalities.

Collection	Collection system	> 50% high rise buildings	10-50% high rise buildings	<10% high rise buildings
Separate	<i>Drop off, no PAYT</i>	Gorinchem Rotterdam Tilburg	Katwijk Zoetermeer	Roermond-Swalmen Son en Breugel Voorst
	<i>Drop off, PAYT</i>	Hengelo	Apeldoorn Beesel Oosterhout	Bernheze Bronckhorst Gennep Overbetuwe
	<i>Kerbside</i>	Schiedam	Deventer (center) Oude IJsselstreek Stadskanaal	Leeuwarden Oldambt Zutphen
With plastic as carrier	<i>Kerbside/ drop off, no PAYT</i>	Schiedam	Zeist	Binnenmaas Almere De ronde venen
	<i>Kerbside/ drop off, PAYT</i>	Nijmegen	Vught Geldrop-Mierlo	Marum, Grootegast en Leek Deventer (rural area) Steenwijkerland
With paper & board as carrier	<i>Kerbside/ drop off</i>	Etten-Leur		Winsum Vianen Etten-leur
Recovery	<i>With MSW</i>	Omrin Attero Noord		

2.2 Measurements and data collection

Many different types of technical measurements were performed and data was collected during this pilot, see Table 2 for a schematic overview. The actual research performed differs slightly for the four collection and recycling schemes, since not all the steps are relevant for each scheme and there are often more parties involved per step. This is explained concisely below per recycling chain, the complete approach can be found in the extended report. The recovery and sorting is studied by mass balancing the actual industrial facilities. This is, however, impossible for the recycling step and hence this step was studied in detail on a devoted test-facility.

Table 2: Schematic overview of the measurements performed and types of data collected at the various steps in the collection and recycling schemes.

Step	Type of measurements performed and data collected
1 Potential at the civilians	Distribution of types of beverage cartons present Amount of beverage cartons present, [ktonne net] Material composition of the 14 categories of beverage cartons, [%] Product residues present in emptied beverage cartons, [%]
2 Collection	Response data [kg gross/month] via the pilot management Composition of the collected material per collection area, [%] Moisture and dirt content of collected beverage cartons, [%]
3 Recovery	Mass balancing of the recovery facilities, [%] Composition of the recovered materials per facility, [%] Moisture and dirt content of recovered beverage cartons, [%]
4 Sorting	Mass balancing of the sorting facilities, [%] Composition and quality of the sorted products, [%] Moisture and dirt content of sorted beverage cartons, [%]
5 Recycling	Mass balancing of the recycling facility, [%] Composition of the fibre pulp and by-products, [%]
6 Pulp	Quality analysis of the produced pulp and standardised hand-sheets produced from the pulp

Separate collection chain

For the separate collection chain the steps 1, 2, 5 and 6 are relevant. Due to the large number of participating collection areas the sorting of collected beverage cartons from all the municipalities and the gathering of response data dominated the research effort for this chain.

Co-collection with plastic packaging

For the co-collection chain with plastic packages the steps 1, 2, 4, 5 and 6 (all except recovery) are relevant. Furthermore this recycling scheme is executed by two different operational organisations that utilise two different sorting facilities. The largest organisation is Kunststof

Hergebruik BV that runs the current recycling scheme for plastic packages and that has contracted the sorting facility Sita Rotterdam for this pilot. Secondly, the Milieuzakken-municipalities (Grootegast, Leek & Marum) run a separate co-collection system that uses the sorting facility Schönmackers in Kempen. Both sorting facilities produce different amounts and qualities of sorted beverage carton products that will have to be studied and recycled separately.

Co-collection with paper & board

For the co-collection recycling scheme with paper & board the steps 1, 2, and 4 are relevant. Only three municipalities have chosen for this scheme and all municipalities use different cross-docking and sorting facilities. Therefore the manual sorting process at Kempenaars was studied for the two collection areas in Etten-Leur. The semi-automatic sorting at Sita Soesterberg was studied for the municipality Vianen. And finally Winsum applied a collection system with separate bags for beverage cartons and the sorting of these bags from the paper & board was considered as ideal. The amounts of beverage cartons originating from these municipalities are too limited to allow for a sensible recycling test and therefore, this test was omitted.

Recovery with plastic packages from MSW

For the recovery recycling scheme all the steps 1-6 are relevant. Two recovery facilities (Omrin and Attero-Noord) were selected. Omrin sorts its recovered mixture of beverage cartons and plastic packages on the so-called Rekas sorting facility and the produced beverage carton product was sent to recycling facilities. Attero-Noord produced a mixture of beverage cartons and plastic packages which was sorted by Augustin in Meppen. The sorted beverage carton product is subsequently sent to recycling facilities. This implies that all steps had to be studied in two-fold for this recycling scheme.

3 Results

3.1 Beverage cartons in the Netherlands

Beverage cartons are used in the Netherlands to contain, distribute and sell the following beverages and food products; fresh milk, sterilised milk, juice, yoghurt, custard type desserts, whipped cream, tomato sauce, wine, water, green peas, etc. The approximated market division of the various beverages and food products on the Dutch market in 2013 was derived from the composition of the beverage cartons found in the MSW of both studied recovery facilities and is shown in Figure 2.

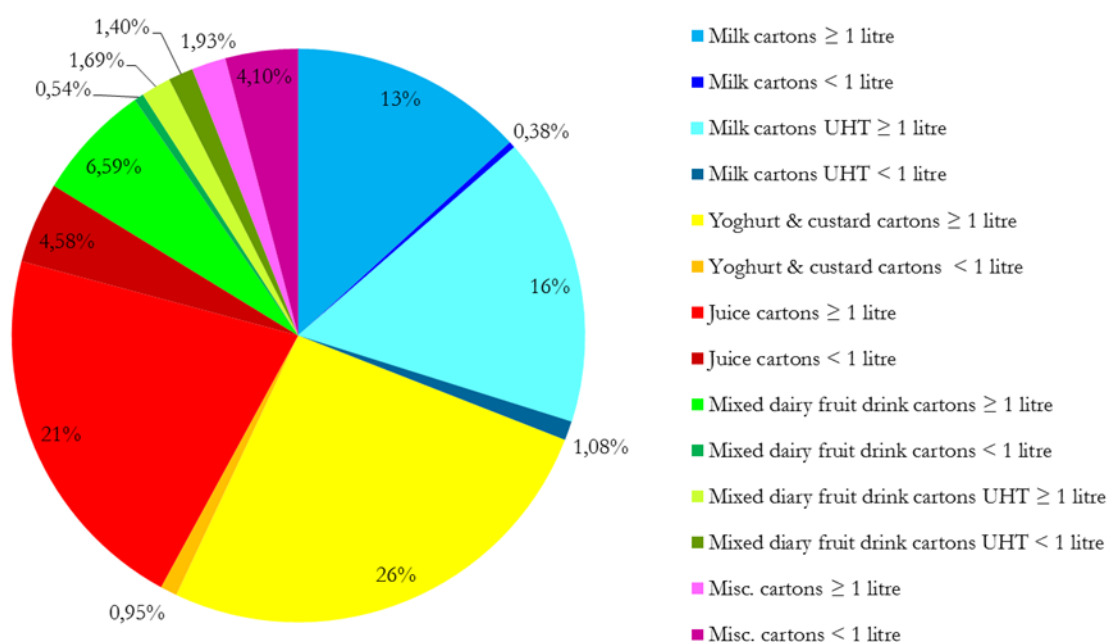


Figure 2: Market division of beverage cartons on the Dutch market 2013.

Approximately 70 ktonne (Gg or million kg) of beverage cartons are put on the Dutch market annually, according to an estimation of the three major producers. In this study two crude estimations of the national consumption could be made of 50 and 80 ktonne with a relative large extrapolation error, for two different areas in the Netherlands. Nevertheless, these crude estimates support that the 70 ktonne is approximately right.

The seasonal variation in beverage carton production and consumption appears to be limited to maximally 10%, as can be deduced from both production numbers from a dairy manufacturer and from the responses of a large municipality that operates a separate collection system for more than 3 years (see project plan). The consumption of juice and buttermilk is higher in the summer months and the consumption of yoghurt and desserts is lower in the winter months.

The regional variation in the consumption of products in beverage cartons is likely to be larger. This study found strong indications for such a regional variation:

- Retailers indicated that the sales numbers in rural regions are higher than in urban regions. This could be attributed to larger households with more children in the rural regions, which results in the use of more beverage cartons for standard products as milk and juice. Whereas in the urban areas the consumption of small cartons, mixed dairy-fruit drinks and desserts would be elevated. They were unable to render accurate estimations of this variation, but expected it to be around 10%.
- This study revealed a large difference in the amount of beverage cartons present in the MSW treated at a recovery facility treating mostly urban waste and another facility treating mostly rural waste. The difference found was overall 30%, meaning a variation parameter of 15%.
- Four rural municipalities that operate a co-collection system of plastic packages and beverage cartons report higher responses than what would be expected to be possible based on a national consumption of 70 ktons and an even distribution. These responses indicate that the regional variation between base-line and rural would be +15%.
- This study clearly shows that the composition of the collected beverage cartons varies between municipalities. Implying that there is not only regional variation in the amount of beverage cartons per inhabitant and year but also in types of products sold in beverage cartons. For example, in most municipalities predominantly fresh milk is consumed, while in some other mostly sterilised milk is consumed.

For this study the national annual consumption was set at 70 ktonnes, and a regional variation parameter of -15% for urban areas and +15% for rural regions was applied.

Beverage cartons are produced from mostly spruce fibres and PE film, but usually also contain other plastics such as PE rigid, PP rigid, PP film and aluminium film. The average composition of Dutch beverage cartons is displayed in Figure 3. Discarded beverage cartons also contain product residues inside the carton. The amount of residues is determined by the type of contained product, the manner of emptying, etc. Most residues are found for viscous products like yoghurt, custard, whipped cream, tomato sauce and much less residues are found for fresh milk, wine and water. The average amount of residues present in Dutch beverage cartons has been determined to be 40% (based on gross carton weight) or 71% (based on net carton weight).

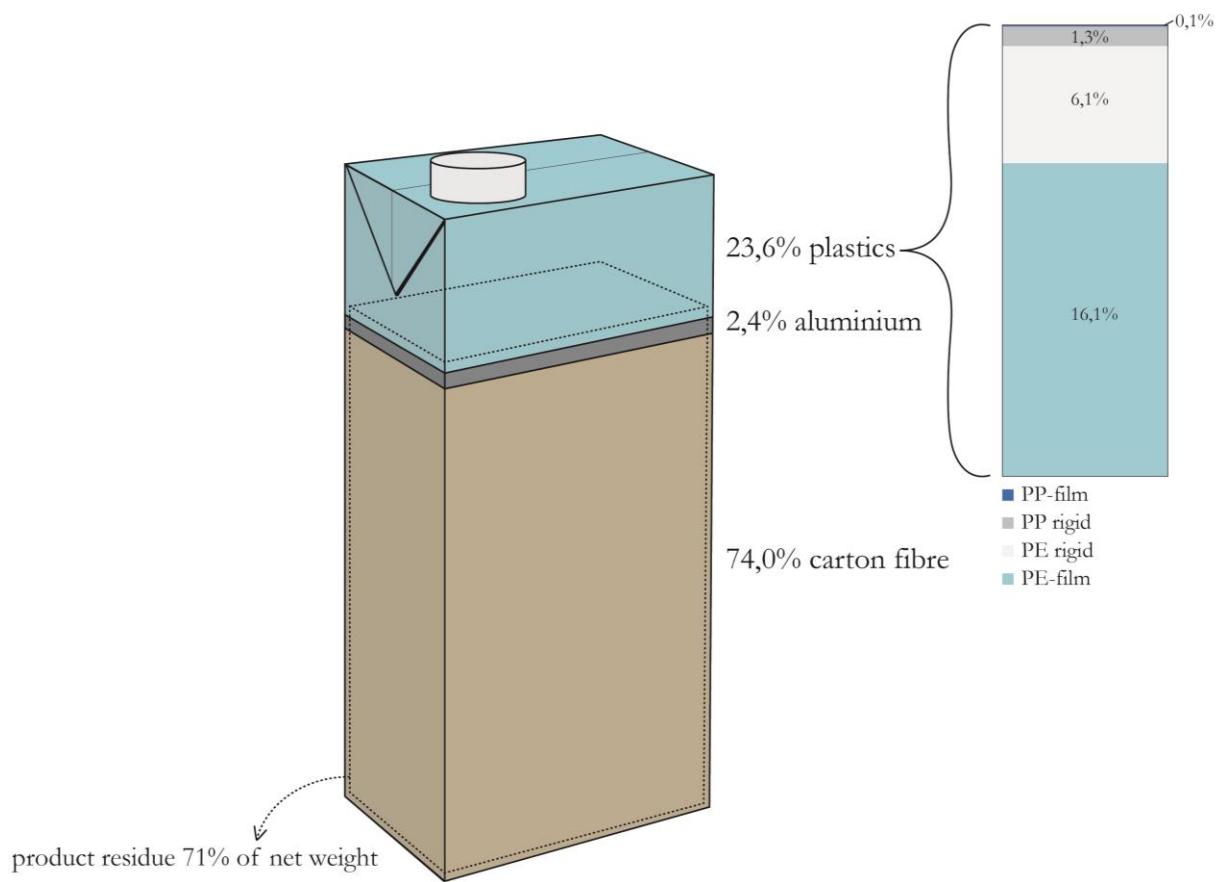


Figure 3: Material composition of beverage cartons on the Dutch market 2013. The overall composition is shown left and the composition of the plastic components is shown right.

3.2 Collection

The net collection yields for all participating collection areas are listed in Table 3 and graphically shown in Figure 4. This net collection yield equals the net amount of beverage cartons collected divided by the amount of beverage cartons present as potential in the collection area.

Table 3: Net collection yields for all participating collection areas.

Collection	Collection system	> 50% high rise buildings	10-50% high rise buildings	<10% high rise buildings
Separate	<i>Drop off, no P.A.Y.T</i>	Gorinchem 17% Rotterdam 20% Tilburg 3%	Katwijk 5% Zoetermeer 8%	Roermond-Swalmen 24% Son en Breugel 19% Voorst 3%
	<i>Drop off, P.A.Y.T</i>	Hengelo 12%	Apeldoorn 33% Beesel 44% Oosterhout 8%	Bernheze 4% Bronckhorst 43% Gennep 19% Overbetuwe 28%
	<i>Kerbside</i>	Schiedam 13%	Deventer (city) 18% Oude IJsselstreek 28% Stadskanaal 48%	Leeuwarden 47% Oldambt 57% Zutphen 32%
With plastic as carrier	<i>Kerbside/ drop off, no P.A.Y.T</i>	Schiedam 5%	Zeist 14%	Almere 61% Binnenmaas 16% De ronde venen 22%
	<i>Kerbside/ drop off, P.A.Y.T</i>	Nijmegen 16%	Geldrop-Mierlo 31% Vught 18%	Grootevast 99% Leek 95% Marum 112% Deventer (rural area) 96% Steenwijkerland 68%
With paper & board as carrier	<i>Kerbside/ drop off</i>	Etten-Leur 50%		Etten-Leur 29% Vianen 3% Winsum 13%
Recovery	<i>With MSW</i>	Omrin & Attero Noord: 100% per definition		

The net collection yields varied from 3% to 100%. The highest net collection yields have been recorded for the co-collection scheme with plastic packages in collection areas without high rise building and a P.A.Y.T (Pay as you throw) scheme for MSW. On the other end, the lowest net collection yields have been recorded for separate collection schemes with drop-off containers and for co-collection schemes with paper & board. Overall, the data variation between observations from the same group is large, implying that there are more important factors determining the net

collection yield. These factors involve a proper information campaign to civilians and a sufficient amount of drop off containers throughout the municipality on strategic locations. Municipalities that perform insufficiently on those factors were found to have net collection yields of 3-8% (Voorst, Bernheze, Oosterhout, Tilburg).

For the separate collection system the net collection yields varied from 3% to 57% with a weighted average of 20%. The lowest value was observed for Voorst with only two drop-off containers for the complete municipality and the highest value for Oldambt with kerbside collection system. Separate drop-off collection systems with a PAYT scheme had a net collection yield of $24 \pm 15\%$, whereas the same system without a PAYT scheme resulted in yields of $12 \pm 8\%$, indicating a tendency for slightly higher yields with PAYT schemes. Separate kerbside collection systems showed higher net collection yields of $35 \pm 17\%$. Only for the kerbside collection systems, a clear relationship between the net collection yield and the percentage of high-rise buildings in the collection area could be observed; the more low-rise buildings, the higher the yield.

For the co-collection system with plastic packages the net collection yield varied from 5 to 100% with an average of 50%. The lowest value was observed for Schiedam, a community of high-rise buildings without PAYT-scheme, the highest values were observed for Deventer-rural¹, Grootegast, Leek and Marum, communities with existing co-collection schemes, PAYT schemes for MSW and low-rise buildings. For the co-collection system with plastics the net collection yield is clearly larger when a PAYT scheme is present and the collection area comprises off mostly low-rise buildings.

For the co-collection system with paper & board the net collection yield varied from 3% in Vianen to 50% in the collection area of Etten-Leur with high-rise buildings. Remarkably, the highest net collection yield was recorded for a high rise area, while the yields in the collection areas with low rise buildings were relatively low.

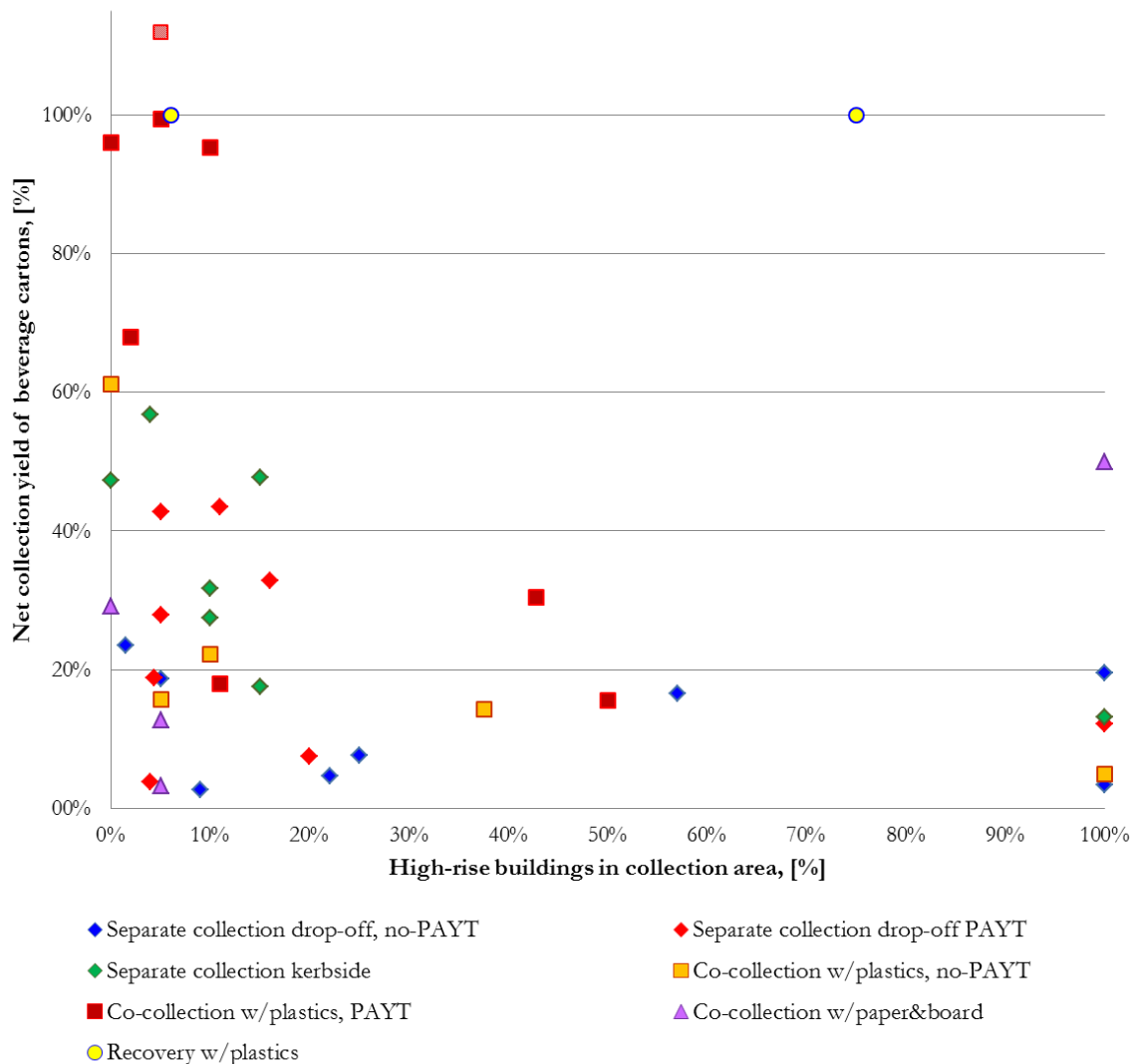


Figure 4: Net collection yields of beverage cartons for all collection areas as function of the percentage high rise buildings in the collection area.

Figure 4 shows the relationship between the net collection yield of beverage cartons for all collection areas versus the percentage of high-rise buildings in the collection areas. For most collection systems, this relationship appears to be almost reciprocal. The only exceptions appear to be the separate collection system without a PAYT scheme for MSW and the co-collection scheme with paper & board.

For collection areas with low-rise buildings the net collection yield can approach 100% for a kerbside co-collection system with plastic packages and PAYT scheme for MSW. Actually, in one municipality (Marum) more beverage cartons were actually collected than what was considered possible based on the total national consumption of 70 ktonnes and the regional distribution

factor of 15%. This number is treated as an outlier and is likely to be caused by uncertainties in both figures.

This collection system is, however, not a general guarantee for success, since other municipalities within the same system have collected much less material. For instance, municipality Vught with 11% high-rise buildings in the collection area has achieved a relatively meagre 18% net collection yield with a fortnightly kerbside collection system. Since the net collection yield for plastic packages is relatively high for the same system, it is more likely that the relatively low net collection yield for beverage cartons in Vught originates from the short time period of the pilot combined with a less effective information campaign to the civilians.

The same co-collection scheme with plastic packages in municipalities without a PAYT scheme results in net collection yields of 5 – 60%. These net collection yields could be considered identical as for the same collection system with a PAYT scheme, with the exception of the four rural municipalities which approach 100% collection yield. Apparently, a PAYT scheme does only result in larger net collection yields under special conditions, such as a frequent fortnightly kerbside co-collection in a rural region with mostly large low-rise farm houses.

Within the same matrix-cell the collection area “Steenwijkerland – de Gagels” performed slightly less good, with instead off nearly 100% net collection yield, 68%. This is a suburban part of the rural city of Steenwijk with typical Dutch townhouses. Townhouses are less spacious than farmhouses and this could be the reason for the slightly lower net collection yield as compared to Deventer rural region, Grootegast, Leek and Marum. Steenwijkerland operates a reverse collection waste scheme, implying that MSW has to be brought to drop-off containers and that recyclables are kerbside collected. This reverse collection system has previously been claimed to yield superb high collection yields of recyclables. In this pilot this claim cannot be validated or refuted, instead the spaciousness of the dwellings appears to be a more relevant factor.

3.3 Recovering, sorting and recycling

Every collection and recycling scheme has a slightly different post-collection scheme with optionally recovering and sorting facilities and a recycling facility. All involved facilities have been studied separately in great detail for each scheme, see the extended report. This research intended to yield a snapshot of four collection and recycling schemes for beverage cartons in the Netherlands in 2013. The net chain yields are given in Table 4.

Table 4: Yields of all involved facilities in the collection and recycling chains with regard to beverage cartons.¹

	Separate collection	Co-coll. w/plastic KH	Co-coll. w/plastic MZ	Co-coll. w/P&B	Recovery Attero	Recovery Omrin	
Collecting*	20%	31%	99%	28%	100% ^α	100% ^α	η_c
Recovering	na	na	na	na	87%	79%	η_r
Sorting	na	39%	55%	~50%	51%	80% ^β	η_s
Recycling fibres	80%	90%	85%	~85%	86%	99%	η_f
Recycling by-products	95%	89%	95%	95%	90%	93%	η_b
TOTAL fibres	16±23%	11±55%	46±20%	11±29%	38±27%	63±26%	$\eta_c^* \eta_r^* \eta_s^* \eta_f$
TOTAL by-products	19%	11%	52%	13%	40%	59%	$\eta_c^* \eta_r^* \eta_s^* \eta_b$

These numbers reflect the actual situation during the pilot in 2013 and are merely of predictive value for yields that could be attained in the future with similar schemes. The significance of the chain yields is limited due to the large errors which are common in collection and recycling schemes. The error in the collection yield is the standard deviation of the recorded collection yields. Since these numbers show a large variance, the standard deviation is also large.

¹ *: weight-averaged net collection yields

α: The net collection yield for the recovery chain is by definition 100% since all the beverage cartons that are present within the household will be discarded with the MSW. Some of the beverage cartons are discarded out-of-home, however, a good inside in these numbers is lacking and hence no correction for out-of-home discarding is made. For the error in collection a estimation of 5% variation is made.

β: The sorting was performed on-site at Omrin and the overall recovering and sorting yield was determined, this sorting yield was deduced from this overall number to facilitate system comparison

na: not applicable

The variance in sorting yields is largely determined by the variance in composition of the sorted products and waste streams and these are substantial on an hour timescale. Hence errors in sorting yields are in the order of 10%.

The error in recycling is predominantly determined by the methodology of measuring the amount of produced fibres and is substantial in two cases. The sum of these three types of error forms the error in the net chain yield and is hence also substantial. These large errors indicate that the net chain yields are indicative values and care should be taken not to use them boldly as a forecast for coming years.

The four studied collection and recycling schemes have strongly varying overall yields for fibres and by-products, with the recovery schemes as most efficient, followed by the matured co-collection system with plastic packages (Milieuzakken) and subsequently all other schemes. The main yield-limiting factors are low collection yields and low sorting yields, which in most instances can be attributed to the juvenility of the tested schemes. This is further explained per recycling scheme.

Separate collection

The weight-averaged net collection yield for the separate collection scheme was only 20%. This low collection yield can be attributed to the juvenility of the collection scheme. Any improvements in this collection yield will have a large impact on the overall fibre yield. The fibre recycling yield was $80 \pm 9\%$, the large error for this yield originates from methodical issues, since very small variations in the concentration of suspended fibres in the 450 m^3 buffer tank results in relatively large yield errors. Nevertheless, this value is relative high and the losses that occur during recycling are from solubilised fibres and non-dissolved fibres. Dissolution of fibre material into small molecular components that run through $0.5 \text{ }\mu\text{m}$ sieves is likely to result from microbiological action on the beverage carton material during collection, cross-docking, transport and storage. The fibre losses to the by-product are limited to about 2%DM of the by-products and are mostly observed on intact polyethylene-aluminium-polyethylene inner linings of beverage cartons near seal lines and folds. This amount of fibre loss to the by-products is relatively small, as the applied recycling facility is relatively very efficient in removing fibres as compared to the large industrial recycling facilities.ⁱⁱ

Co-collection with plastic packages

Two co-collection recycling schemes with plastic packages were tested; the mature Milieuzakken-scheme and the juvenile KH-scheme. Both systems suffered from low sorting yields, but for different reasons. The low sorting yield of Sita Rotterdam in the KH-scheme stems from the fact that this facility was not designed and equipped to sort beverage cartons. The mixture of co-collected plastic packages and beverage cartons was run twice through the sorting facility and this created a small amount of a relatively clean BC product, but the losses to the sorting residues and mixed plastics were substantial. The low sorting yield of Schönackers with the MZ-material

results from the relative high levels of residual waste in the input material, causing more sorting losses and a less clean BC-productⁱⁱⁱ. The subsequent fibre recycling yields mirror the amount of residual waste in the BC-product; slightly higher for the BC-product from the KH-chain than for the BC-product from the MZ-chain.

Co-collection with paper & board

Only three municipalities decided to test this co-collection scheme and insufficient material was available for a full scale recycling test. Therefore, technical research focussed on the sorting of beverage cartons and paper & board and the recycling was estimated from the technical parameters of the MZ-chain, since the composition of the input mixture resembles this the most. The sorting of beverage cartons from paper & board was tested at two facilities and both showed roughly sorting yields of 50%; the similarity of the materials and the flat nature complicates the sorting process.

Recovery of beverage cartons from MSW

The collection yield of a recovery system is 100% by definition, only the relative small area of Leeuwarden-Zuiderburen participated in the pilot as separate collection area, which reduces the potentially available beverage cartons in the MSW with less than 0.5%. The recovery and sorting process is performed differently for both chains. At Omrin's facility the recovered mixture of mixed plastics and beverage cartons is sorted on site with a small facility that produces a BC product and a MKS product. Also the non-ferrous metal product from the recovery facility is treated at this sorting facility, this however, results in a negligible additional BC product. The produced BC-product is relatively pure and was recycled within 2 weeks after recovery. This short logistical lead-time presumably causes the high recycling yield for fibres.^{iv}

Attero's mixture of recovered plastic packages and beverage cartons was sorted by Augustin, Meppen, yielding a BC-product and all plastic products. Augustin normally only sorts recovered plastic packages and removed the beverage cartons by manual sorting from the mixture. This BC product was recycled roughly 4 weeks after recovery.

Both BC-products were recycled to fibres at relatively high yields, the recycling yield of the Omrin and Attero fibres was determined by emptying and sieving the complete buffer tank and was accurate and high.

As a general conclusion the collection and sorting yields have limited the overall recycling chain yield of most systems, but these can be optimised.

- The recovery chains were running directly at relative high efficiencies, although some improvements can still be made in these chains, the results are already very good.
- The mature co-collection MZ scheme with plastic packages resulted in high collection yields, but poorer sorting and recycling yields due to the presence of residual waste.

- The juvenile co-collection KH scheme with plastic packages suffered from low collection and sorting yields, which both can be improved.
- The separate collection scheme suffered from low collection yields.
- The juvenile co-collection scheme with paper & board suffered from both low collection yields and sorting yields, which both can be improved.

3.4 Pulp quality

Six different pulps (also a pulp from German BC's as reference) were studied for chemical properties, fibre size distribution and impurities. These pulps were treated in various manner and hand-sheet papers were produced from pure pulp, cleaned pulp and a common mixture of 20% pulp in recycled paper. These hand-sheet test papers were mechanically tested and also explored for microbiological flora, see the extended report.

In general, the properties of the six pulps were relative similar. In Figure 5 the mechanical compression strength index of hand-sheets made from these pulps is shown and compared to the total aerobic count of these hand-sheets. The former parameter is relevant, since most of this material will be used in corrugated boxes and this compression test-parameter is crucial for this application.

The measurements displayed in Figure 5 are single measurements and relatively similar. The best mechanical properties for papers made from the beverage carton pulps were found for the pulps originating from German beverage cartons, recovered beverage cartons from Omrin and co-collected beverage cartons from the KH system. The differences in quality for the recycled beverage carton pulps originating from the various recycling schemes is, nevertheless, small.

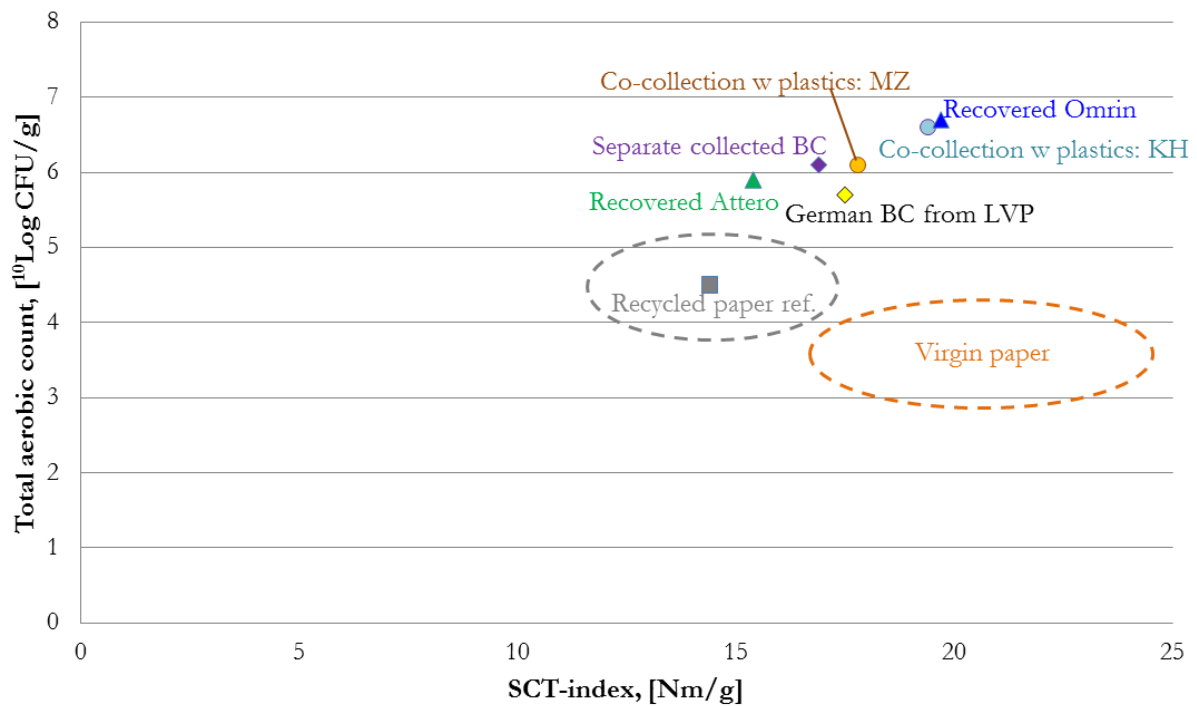


Figure 5: Mechanical compression strength of hand-sheets made from 6 different pulps made from beverage cartons in a 20% mixing ratio with recycled paper versus the total aerobic counts of these hand-sheets.

The general trend is that virgin paper is the strongest and least infested. Normal recycled paper is weaker than virgin and has a higher microbial load. Papers made from recycled beverage carton pulps are stronger than recycled paper and have higher microbial loads.

3.5 Cross contamination issues

During this pilot cross-contamination between beverage cartons and carrier streams were also studied, see the extended report. For the co-collection with plastic packages, cross-contamination was assessed from using four parameters:

- the moisture and dirt level of the co-collected beverage cartons was found to be slightly lower than that of separate collected beverage cartons,
- the moisture and dirt levels of co-collected plastic packages were found to be similar to the ones of separate collected plastic packages, mostly due to the large natural variation in these numbers,
- the beverage cartons end up in several plastic products (PE, PP and MKS) as minor constituents, which reduces the value of these plastic products for recyclers,
- the sorting efficiency of important types of plastic packages can be reduced, indicative analysis of several valuable plastic packages end up to a larger extent in the mixed plastic and rest fraction and to a lesser extent in the desired product category.

These results suggest that cross-contamination of beverage cartons to plastic packages is likely to occur. This could pose a threat to the recycling targets for plastic packages, when it is insufficiently controlled. However, these negative impacts can most likely be mitigated by local information campaigns in which civilians are addressed to rinse the cartons with cold water and closing the lids prior to discarding them in the co-collection bag or mini-container. Furthermore, also adjustments to the sorting facilities could assist in preventing losses due to cross-contamination.

Cross-contamination between paper & board and beverage cartons is also likely to occur. The results of microbiological analysis can neither confirm nor refute that co-collection of paper & board with beverage cartons will increase the microbial load of recycled paper & board directly. The prime effect will be a possible gradual increase in the microbial load of recycled paper, irrespective of the chosen collection system. The microbial load of board products made from recycled beverage cartons is higher than of plain recycled paper & board, as determined in the microbiological analysis. When corrugated board boxes made from recycled beverage cartons are discarded, they are most likely collected as paper & board and will be recycled as paper & board, implying that it is likely that they will raise the microbial load of recycled paper & board indirectly and gradually.

4 Discussion

4.1 Data quality

This pilot beverage cartons has been conducted in 2013 under the strict condition that the complete pilot should be performed and reported within 2013, as described in the framework treaty. This time constraint had strong implications on the pilot and the quality of the data gathered. Most new collection systems require a few years to mature and this pilot just had 6 months of collection time, including the summer season, which is not ideal. Hence, it is very likely that response levels would have continued to grow during the coming months, that several municipalities could address quality issues with the collected material and that sorting facilities could have implemented improvements. Although, the time constraint has influenced the pilot execution clearly, the produced data is of high quality and can be understood, analysed and it compares favourably with results from abroad. Since, the majority of municipalities have agreed with the pilot management to continue, it is likely that even better collection response data will become available in the coming months.

4.2 Factors determining collection yields

Collection and sorting yields are the prime parameters that limit the overall yields of the recycling chain. However, sorting yields for beverage cartons from mixed plastics can in most cases be optimised towards 80% by technical improvements. Hence most attention should be directed towards measures to enlarge the collection response.

The fact that 4 municipalities achieve an almost complete collection of the beverage cartons that are available within their collection areas is promising. Apparently, the ingredients rural regions with larger farm houses, a PAYT scheme for MSW and a fortnightly kerbside co-collection system for plastic packages and beverage cartons can render high net amounts of beverage cartons. For three of these four municipalities the co-collected material, however, also contains substantial amounts of residual waste, which hampers the subsequent sorting and recycling. So caution is needed to find the proper balance between high net collection yields, sortability and recyclability in the design of the collection scheme.

Two related municipalities did not achieve such high collection yields; Steenwijkerland and Vught. Steenwijkerland has a reverse collection scheme (drop-off for MSW and kerbside for recyclables) and the collection area (de Gagels) is residential area with mostly Dutch townhouses. Here the net collection yield is not about 100%, but close to 70%. An impressive result, but also less than the other four, which suggests that perhaps the spaciousness of the dwellings is an important factor that determines the collection yield. In Vught the net collection yield is only 18% for beverage cartons, whereas the factors are remarkably similar (PAYT, fortnightly co-collection with plastic packages). Vught could be considered as a relative rich suburb with

amongst others Victorian-age houses. The net collection yield for plastic packages is in Vught one of the highest of the Netherlands, but the collection yield for beverage cartons lags behind. The factors which contribute to this lower collection yield could be; insufficient information of the civilians to add beverage cartons to the plastic packaging waste, insufficient time for the collection system to mature and possibly insufficient space in the houses to store plastic packages and beverage cartons for a fortnight.

In general, the percentage of high rise buildings in the collection area is a strong indicator for the success of a separate collection system. This indicator is likely to be related to the available space in the houses for the storage of beverage carton material. The only clear exception was the co-collection with paper & board in the high rise area of Etten-Leur. This collection system yielded about 50% of the beverage cartons present, which is a relatively large amount for a collection area with high-rise buildings. Most likely, the inhabitants of these houses were already accustomed to the separate collection of paper & board, had already bins in their houses for paper & board and found the addition of beverage cartons relatively easy to accomplish.

Although the gathered data suggests that a low amount of high rise buildings, a PAYT scheme for MSW and co-collection kerbside collection system with plastics are all positive indicators for high net collection yields, several examples were observed of municipalities with limited facilities and / or poor communication to the civilians that performed below average. Hence, although factors and conditions can be deduced which improve the collection yield, other factors can be far more detrimental and result in very low collection yields; unclear communication, limited amount of drop-off containers, kerbside collection with more than 2 weeks between collection. For example:

- Tilburg started with placing drop-off containers and obtained mostly residual waste until a self-adhesive label was placed on the container “beverage cartons only”. From that moment on the collection results improved.
- Hengelo is an urban centre with a PAYT scheme for MSW and offered their residents of three neighbourhoods the choice, throwing their MSW bags in the paid bin for MSW or in the free adjacent bin for beverage cartons. This resulted in the largest amount of residual waste in separately collected beverage carton material.
- Oosterhout and Bernheze are suburbs with an existing separate collection system; one drop-off container at the municipalities waste park. This resulted in a net collection yield of 8% and 4%, respectively, which is relatively low compared to municipalities like Apeldoorn (33%) that placed drop-off containers in the residential areas and near shopping centres.
- Voorst started with 2 drop-off containers for the whole municipality and achieved a net collection yield of 3%.

4.3 Regional variation

During this pilot evidence was gathered which suggests that there is a regional variation in the consumption of products in beverage cartons (see paragraph 3.1). Based on this indicative evidence an assumption was made that the consumption in the rural regions with <10% low-rise buildings was +15% from the average and that the consumption for the urban regions with >50% high-rise buildings was -15% from the average. This assumption has a strong influence on the net collection yields of individual municipalities and indirectly on the overall chain yields of the systems. Therefore, it is recommended at KIDV to study the regional variation of packaging material consumption in greater depth in the future.

4.4 By-product recycling

In this pilot study fibre recycling was the prime target of beverage carton recycling. Up to a few years ago all by-products of the beverage carton recyclers went to the cement kilns to serve as fuel and reducing agent. However, many technical developments have occurred in the last few years, that will make it likely that the by-products will be recycled differently in the near future. Since, this is a domain with relatively much innovation, it is difficult to predict which direction will prevail in the future. Additionally, the precise future fate of these by-products will not only depend on technical aspects, but also on economic and political factors.

Here is a small list of developments:

- Alucha and Enval have developed a pyrolysis system to obtain thin aluminium flakes and PE-wax,
- APK in Merseburg have a running pilot factory to separate the polyolefines from the aluminium by solvolysis. According to Hedra the Niederauer Papiermühle currently sends its by-products to APK for recycling,
- From exploratory technical work at RWTH Aachen during this pilot test, it was established that the by-products can be mechanically separated in a straight-forward manner into polyolefine caps and closures (possess an economic value), SRF and larger pieces of aluminium-PE laminate films (often the complete inner lining of aseptic beverage cartons).

This pilot study does not consider the by-product recycling in detail, since it would involve a choice for a recycling scheme and the need to mass-balance such a recycling facility. The current pilot study had too much time constraint, to allow for this type of work. Nevertheless, it can imply that the results of a pilot study in about 5 years' time from now, will lead to different results for the approximately 26% of potential by-products.

4.5 Future scenario's

The determined process yields per chain step in Table 4 are snap-shots of the technical situation in 2013. All mentioned yields can potentially be improved, which will result in more efficient collection and recycling chains. Some of these improvements can fairly easy be forecasted, such as the maximal sorting yield of beverage cartons from plastic packages (roughly 80% from German sorting facilities that sort co-collected LVP) and the maximal recovery yield, from our own pilot test. Other improvements, such as the future net collection yields are more difficult to forecast, therefore, two future scenarios are shown in Table 5 which show the chain efficiencies that might be achieved in the coming 5 years for the beverage carton collection and recycling chains, with two different levels of net collection yields.

Table 5: Yields of all involved facilities in the collection and recycling chains with regard to beverage cartons which are technologically likely to be achieved in the coming 5 years.

Scenario 1	Separate collection	Co-collection w/plastic	Co-collection w/P&B	Recovery	
Collecting*	40%	40%	40%	100%	η_c
Recovering	na	na	na	88%	η_r
Sorting	na	80%	na	80%	η_s
Recycling fibres	81%	80%	76%	99%	η_f
Recycling by-products	95%	89%	94%	92%	η_b
TOTAL fibres	32%	26%	30%	69%	$\eta_c^* \eta_r^* \eta_s^* \eta_f$
TOTAL by-products	38%	28%	38%	65%	$\eta_c^* \eta_r^* \eta_s^* \eta_b$

Scenario 2	Separate collection	Co-collection w/plastic	Co-collection w/P&B	Recovery	
Collecting*	75%	75%	75%	100%	η_c
Recovering	na	na	na	88%	η_r
Sorting	na	80%	na	80%	η_s
Recycling fibres	81%	80%	76%	99%	η_f
Recycling by-products	95%	89%	94%	92%	η_b
TOTAL fibres	61%	48%	57%	69%	$\eta_c^* \eta_r^* \eta_s^* \eta_f$
TOTAL by-products	71%	53%	71%	65%	$\eta_c^* \eta_r^* \eta_s^* \eta_b$

na: not applicable

For the co-collection chain with paper & board the sorting process is likely to be omitted in the near future, since it adds costs and it is technically proven that a mixture paper & board and beverage cartons can be recycled. This combined recycling is operational for several years in a paper mill in Nortrup.

5 Conclusions

It is technically possible to collect and recycle Dutch beverage cartons. The efficiency of the overall recycling chain yield is governed by the collection yield and the sorting yield, the recycling yield is already near-optimal.

In this pilot the four most common collection and recycling schemes for beverage cartons have been studied; separate collection, co-collection with plastic packages, co-collection with paper & board and recovery from MSW.

For separate collection systems the net collection yield determined the whole chain efficiency. This net collection yield varied from 3% to 57% and the weight-averaged net collection yield equalled 20%. The large variance in collection yields for similar municipalities, suggests that there is substantial room for improving these net collection yields, and that the following factors are relevant; service level of the collection system, clear communication to the civilians, space inside the houses to store and keep beverage cartons separate until collection.

For co-collection systems with plastic packages four rural collection areas (Deventer rural area, Grootegast, Leek, Marum) approached complete collection of the beverage cartons present in the collection area, while more urban municipalities achieved much lower net collection yields (Vught 18%, Nijmegen 16%, Binnenmaas 16%, Zeist 14%, Schiedam 5%). Here the details of the collection system and area determine the collection yields. The recorded sorting yields were 39% and 55%, which is relatively low for beverage cartons. In case of Sita Rotterdam this yield was relatively low, since the facility was not designed and equipped for the sorting of beverage cartons from mixed plastic waste. In case such a system would be chosen, it is likely that such a sorting center will be fitted with an additional NIR sorting machine devoted to beverage cartons and achieve much higher sorting yields of about 80%. In case of Schönackers the input material (Milieuzakken) contained relatively large amounts of residual waste which hampered the sorting process and resulted in a poor sorting result. Here the remedy should be sought in changes to the collection system which would reduce the pollution level of the co-collected material. Cross-contamination between beverage cartons and plastic packages is likely and should be controlled by asking the civilians to rinse out the beverage cartons with cold water, flatten them and close the lid and to make adjustments to the sorting process.

For co-collection systems with paper & board the net collection yields were relatively low, only for an area with high-rise buildings 50% net collection yield was achieved. This collection and recycling scheme suffered from low collection yields and low sorting yields. However, in case this scheme would be chosen, the sorting process will be omitted from the chain and the material will be recycled as mixture^v to corrugated boxes.

For the recovery scheme, high recovery yields were observed, medium and high sorting yields were found and high recycling yields were determined. The Omrin recovery chain was the most

efficient collection and recycling scheme studied during this pilot. The Attero recovery chain suffered from a relative low sorting yield during this pilot, however this can relatively easily be improved and this chain still has one of the highest overall recycling yields.

All recycled pulps made from different types of beverage cartons could be converted in relatively strong paper materials from which corrugated boxes can be produced. The microbiological load of this material is, however, relatively high, which limits the applicability to non-food packaging and secondary packaging.

List of used abbreviations and terms

BC:	Beverage cartons, drankenkartons
DM:	Dry Matter
KH:	Kunststof Hergebruik BV, the current organisor of the plastic packaging waste recycling scheme in the Netherlands.
LVP	German mixture of Light-weight Packaging materials
MKS:	Mixed Plastics, mengkunststof
MSW:	Municipal solid waste, Gemengd huishoudelijk restafval
MZ:	Milieuzakken, co-collection system of plastic packages and beverage cartons
NIR	Near Infrared sorting machine
PAYT:	Pay As You Throw scheme for MSW collection, Diftar, gedifferentieerde tariefstelling huisvuilinzameling
PE:	Polyethylene,
PP:	Polypropylene,
P&B:	Paper & Board
SRF	Secondary recovered fuels

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References and end-notes

- ⁱ In the previous year, 2012, the municipality of Deventer, Circulus and VAR tested a co-collection system of beverage cartons, plastic packages and metal packages for the same rural area around the city of Deventer. This collection system was altered in 2013 to only beverage cartons and plastic packages on behalf of this pilot.
- ⁱⁱ Opinion of Mr. Boltersdorf, owner of the applied recycling facility, which is likely to be true, since this facility treats the by-products of the other facility and is paid for the amount of fibres it recovers.
- ⁱⁱⁱ The BC product that Schönackers produced from the Milieuzakken did not fulfil the DKR 510 specification, since the amount of residual waste in this product was larger than 10%.
- ^{iv} The relationship between a short logistical lead-time (from emptying the beverage cartons to recycling them) and the fibre yield and fibre quality is likely and suggested by incumbents. The shorter the lead time, the less time microorganisms have to grow in the beverage cartons and break down the cellulose chains. However, care should be taken, since this relationship is not scientifically proven, yet.
- ^v The company Delkeskamp recycles mixtures of paper & board and beverage cartons for approximately 5 years and due to its geographic location close to Drenthe, is keen on contracting Dutch municipalities for such a co-collected mixture.