THE LCA CENTRE
PACKAGING LIFE CYCLE ASSESSMENT

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Issued: 09.12.2020 | Project ID: TLC 20-D41 v2.0

A study of the waste free cup systems at events as commissioned by Rijkswaterstaat in cooperation with Plastic Promise

Cover Photo by Rob Lipsius

CORRIGENDUM

After the publishing of “A study of the waste free cup systems at events as commissioned by Rijkswaterstaat in cooperation with Plastic Promise”, the authors were made aware of a potential erroneous choice of the country of manufacture of one of the cups.

The report was removed from the websites of the publishing parties while this matter was addressed. The cup was remodelled and the associated changes were made to this second version of the report (Project ID: TLC 20-D41 v2.0).

This rectification does not change the conclusions of the study, which were:

1. The assumption that either the Hard Cup or Soft Cup system, as is currently used at Dutch events, will always be the preferred system from an environmental point of view, is incorrect.

2. The point at which one system becomes more efficient than the other system (breakeven point) from an environmental perspective is dependent on the relative impact of the various inputs such as cup types, percentage recycling and cup losses, transports and washing systems impacts, as well as the environmental impact category being studied.

Beuningen, NL

9th December 2020

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Photo by Jan Willem Bullee

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Aanleiding

Plastic Promise is een landelijk platform waarop pioniers hun kennis en ambities delen om het gebruik van wegwerpplastic in de evenementenindustrie te verminderen en het alsnog gebruikte plastic hoogwaardig te recyclen. Dit initiatief introduceerde twee bekersystemen:

- Een Soft Cup-systeem waarbij plastic wegwerpbekers als aparte stroom worden ingezameld zodat ze gerecycled kunnen worden
- Een Hard Cup-systeem waarin herbruikbare plastic bekers na het gebruik ingezameld worden, zodat ze professioneel gewassen kunnen worden en klaar zijn om te worden gebruikt

De pilots van beide systemen waren een belangrijke stap in de richting van afvalvrije festivals, maar het inzicht in de milieubelasting van deze bekersystemen ontbrak. Om de milieu-impact van diverse bekersystemen beter te kunnen begrijpen, is in opdracht van Rijkswaterstaat en in samenwerking met Plastic Promise een onderzoek uitgevoerd.

Dit onderzoek is een extern geverifieerde levenscyclusanalyse (LCA) van beide bekersystemen en hun milieu-impact die voor verschillende scenario's wordt vergeleken, zodat de volgende onderzoeksvraag beantwoord kan worden:

Kan er worden verondersteld dat een hergebruiksysteem met Hard Cups of een recyclesysteem met Soft Cups, die aan dezelfde voedselveiligheidsstandaarden voldoen en representatief zijn voor Nederlandse evenementen, vanuit milieuoogpunt altijd de voorkeur zal hebben ten opzichte van het andere systeem en zo ja, wat is het break-even punt?

Opzet van het onderzoek

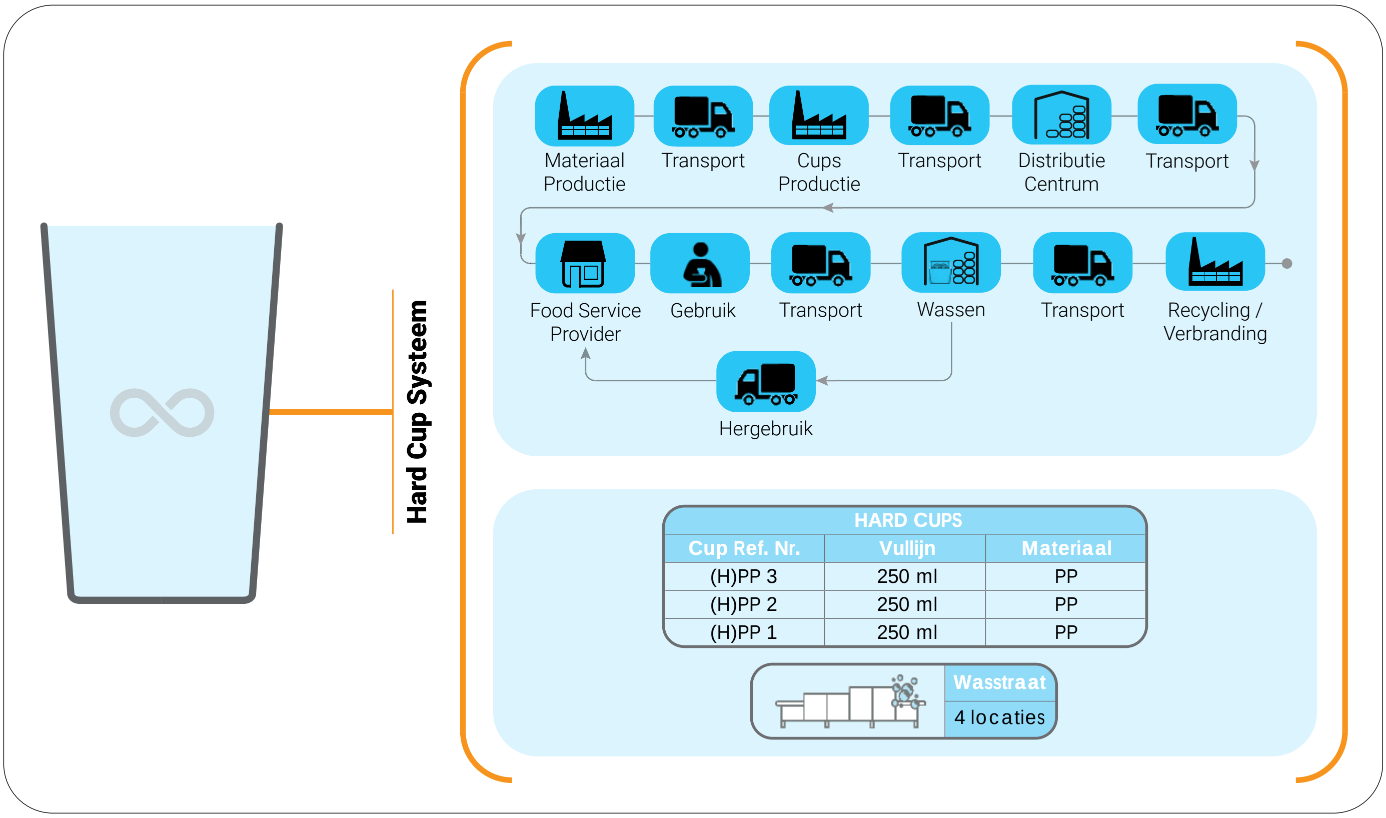
Het is belangrijk voor de vergelijking dat voor alle herbruikbare bekers in alle onderzochte scenario's een hygiëneniveau is bereikt wat gelijk is aan dat van een beker voor eenmalig gebruik. Om die reden is ervan uitgegaan dat elke Hard Cup voor het gebruik gewassen wordt in een professionele wasinstallatie en elke Soft Cup na eenmalig gebruik wordt afgedankt.

Partijen die bij het onderzoek betrokken zijn, zijn onder andere organisatoren van evenementen, ondersteunende organisaties en bekerspoelbedrijven. Er zijn geen specifieke studies gedaan naar de processen die beschreven worden binnen het onderzoek, de gegevens die gebruikt zijn om de impact hiervan te weergeven zijn afkomstig uit openbare datasets. Deze openbare datasets zijn vervolgens gebruikt in rekenmodellen die opgesteld zijn aan de hand van de informatie die door de betrokken partijen zijn aangeleverd.

De informatie met betrekking tot de onderzochte bekers is afkomstig van de pilots die door Plastic Promise in 2019 zijn uitgevoerd en de input die de Plastic Promise deelnemers hebben geleverd. Het onderzoek is gericht op een systeembenadering en niet op de volledige weergave van de huidige marktsituatie.

De bekerwasbedrijven die in dit rapport worden genoemd hebben bijgedragen aan het onderzoek door bedrijfsgegevens als water- en energieverbruik, hoeveelheden gewassen bekers per uur en gegevens over het wassen van kratten te verstrekken. Deze gegevens zijn vertrouwelijk gebruikt en zijn als zodanig verwijderd uit de externe geverifieerde definitieve versie van deze studie.

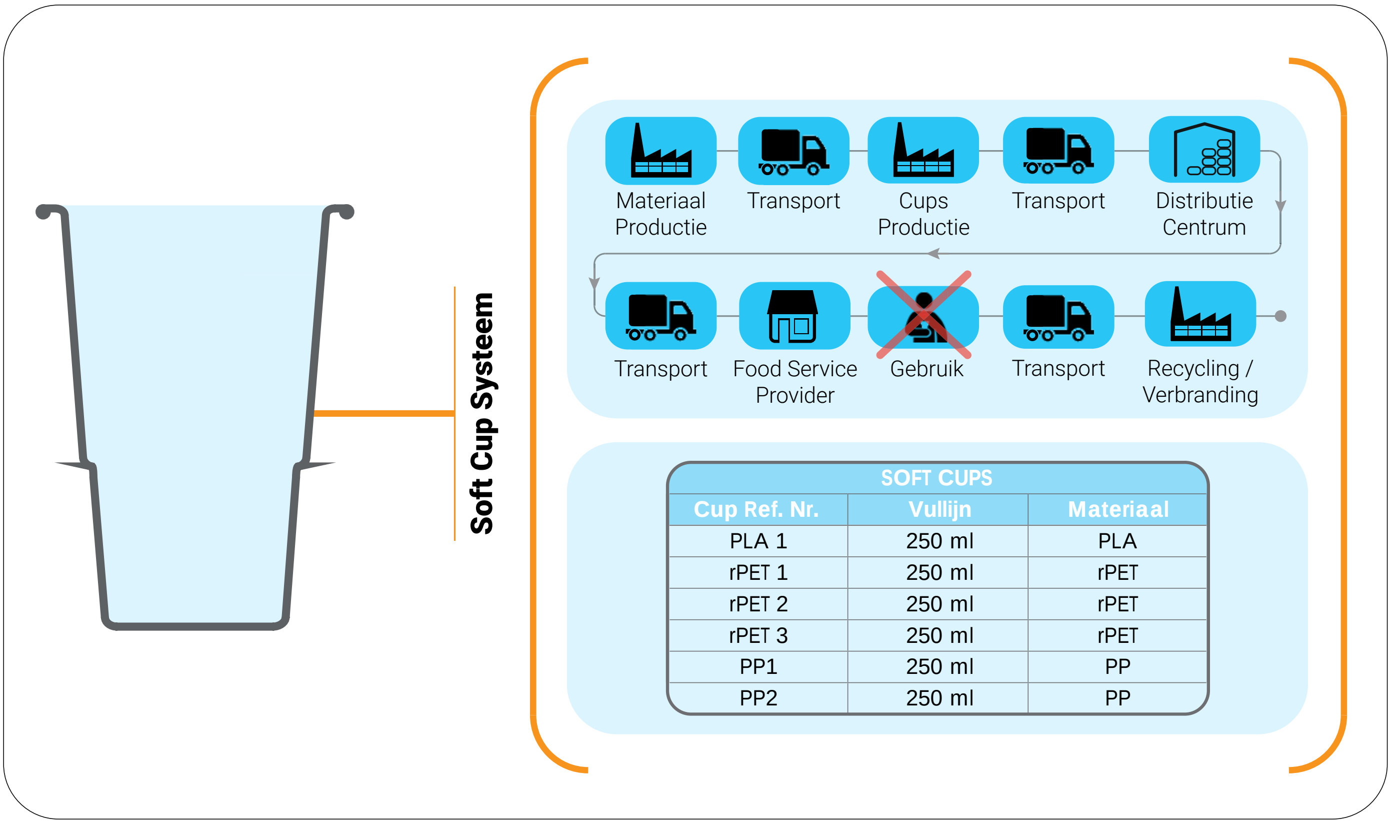
De door de festivalorganisatoren gebruikte Hard Cups zijn bedrukte herbruikbare spuitgietbekers van polypropyleen (PP).



HARD CUPS		
Cup Ref. Nr.	Vullijn	Materiaal
(H)PP 3	250 ml	PP
(H)PP 2	250 ml	PP
(H)PP 1	250 ml	PP

Figure 1: Hard Cup Systeem

De door de festivalorganisatoren gebruikte Soft Cups zijn de volgende bekers voor eenmalig gebruik met het bijbehorende gebruikssysteem.



SOFT CUPS		
Cup Ref. Nr.	Vullijn	Materiaal
PLA 1	250 ml	PLA
rPET 1	250 ml	rPET
rPET 2	250 ml	rPET
rPET 3	250 ml	rPET
PP1	250 ml	PP
PP2	250 ml	PP

Figure 2: Soft Cup Systeem

De aannames voor de recycling- en uitvalpercentages zijn gebaseerd op de uitkomsten van de pilots welke in 2019 door Plastic Promise deelnemers zijn uitgevoerd.

Figure 3: Resultaten Plastic Promise 2019

De studie omvat de milieu-impact van de hele levenscyclus van de producten: van de winning van grondstoffen, tot materiaalconversieprocessen om de bekers te maken, de verpakking van de bekers, energieverbruik, transport en end-of-life scenario's met betrekking tot beide soorten bekers. Doordat de bekers onderdeel zijn van een totaal systeem, wordt ook gekeken naar de bijbehorende transportbewegingen van en naar het evenement en de bekerspoelbedrijven, als ook de voor dit transport benodigde kratten en de wassystemen.

Om de milieu-impact te beoordelen, werden de volgende impactcategorieën in de studie toegepast:

- Aardopwarmingsvermogen of Global Warming Potential (in kg CO_2eq) - GWP - gewoonlijk aangeduid als "Carbon Footprint"
- Waterverbruik (in m^3 H_2O) - H_2O
- Energieverbruik (MJeq) - CED
- ReCiPe (totaal aantal eindpunten)

De resultaten van de LCA-studie werden vervolgens verder gemodelleerd met behulp van een op Excel gebaseerde tool die is ontworpen om het break-even punt te identificeren op basis van verschillende gebruiksscenario's. Deze break-even berekeningstool zal in deze studie verder worden aangeduid met BCT (Breakeven Calculation Tool). Dit is in overeenstemming met het tweede vraagstuk in de hoofdvraag, namelijk "op welk break-even punt?".

Er zijn om dit onderzoek uit te voeren een aantal aannames gedaan, met als belangrijkste uitgangspunt dat aangenomen wordt dat alle bekersystemen beschikbaar zijn voor alle evenementen. Er wordt verder geen rekening gehouden met factoren als: de indeling en logistiek op een evenemententerrein, kosten, soorten drank, type statiegeldsysteem, beschikbaarheid van personeel en bezoekersaantallen welke allen de keuze voor het type bekersysteem zouden kunnen beïnvloeden.

Ten tweede wordt aangenomen dat alle soorten bekers die worden ingezameld gerecycled worden. Voor de Soft Cups is dit na een enkel gebruik, voor de Hard Cups aan het einde van hun levensduur. Alle soorten bekermaterialen kunnen worden gerecycled in het gebied waar de studie is uitgevoerd. Dit is specifiek uitgezocht.

Van de Soft Cups die niet worden ingezameld wordt aangenomen dat deze worden verbrand. Alle uit het systeem verloren Hard Cups worden eenvoudigweg als verloren beschouwd.

De onderstaande resultaten zijn gebaseerd op de producten en systemen zoals hierboven beschreven. In deze studie worden specifieke producten en wassystemen vergeleken. Het gevolg hiervan is dat deze resultaten niet gebruikt kunnen worden voor andere producten die er misschien op het eerste gezicht hetzelfde uitzien. Enkele parameters zijn gemiddelden zoals bijvoorbeeld de afstanden tussen de festivals en wasbedrijven, echter de meeste andere gebruikte parameters zijn allemaal specifiek.

Resultaten

De belangrijkste conclusie van het onderzoek is dat er niet kan worden aangenomen dat ofwel het Hard Cup ofwel het Soft Cup systeem, zoals dat momenteel wordt gebruikt bij Nederlandse evenementen, vanuit milieuoogpunt altijd de voorkeur zal hebben.

De reden hiervoor is dat de berekening van het break-even-punt afhankelijk is van een aantal factoren. Waarbij onder break-even-punt het volgende wordt verstaan: het aantal keren dat een Hard Cup binnen een bepaald systeem gebruikt moet worden voordat er sprake is van milieuvoordeel ten opzichte van een Soft Cup welke binnen een bepaald systeem wordt gebruikt.

Kortom – het break-even punt cijfer geeft antwoord op de vraag: na hoeveel gebruiken/ rotaties is het Hard Cup systeem duurzamer dan een Soft Cup systeem vanuit het oogpunt van het milieu. Eventuele andere socio-economische aspecten die van invloed kunnen zijn op de keuze van het bekersysteem wegen hierin niet mee.

De factoren die van invloed zijn op het break-even punt zijn voor Hard Cups en Soft Cups verschillend. Onderstaand figuur illustreert niet alleen welke factoren dat zijn, maar ook hoe groot het belang ervan is bij de uiteindelijke berekening.

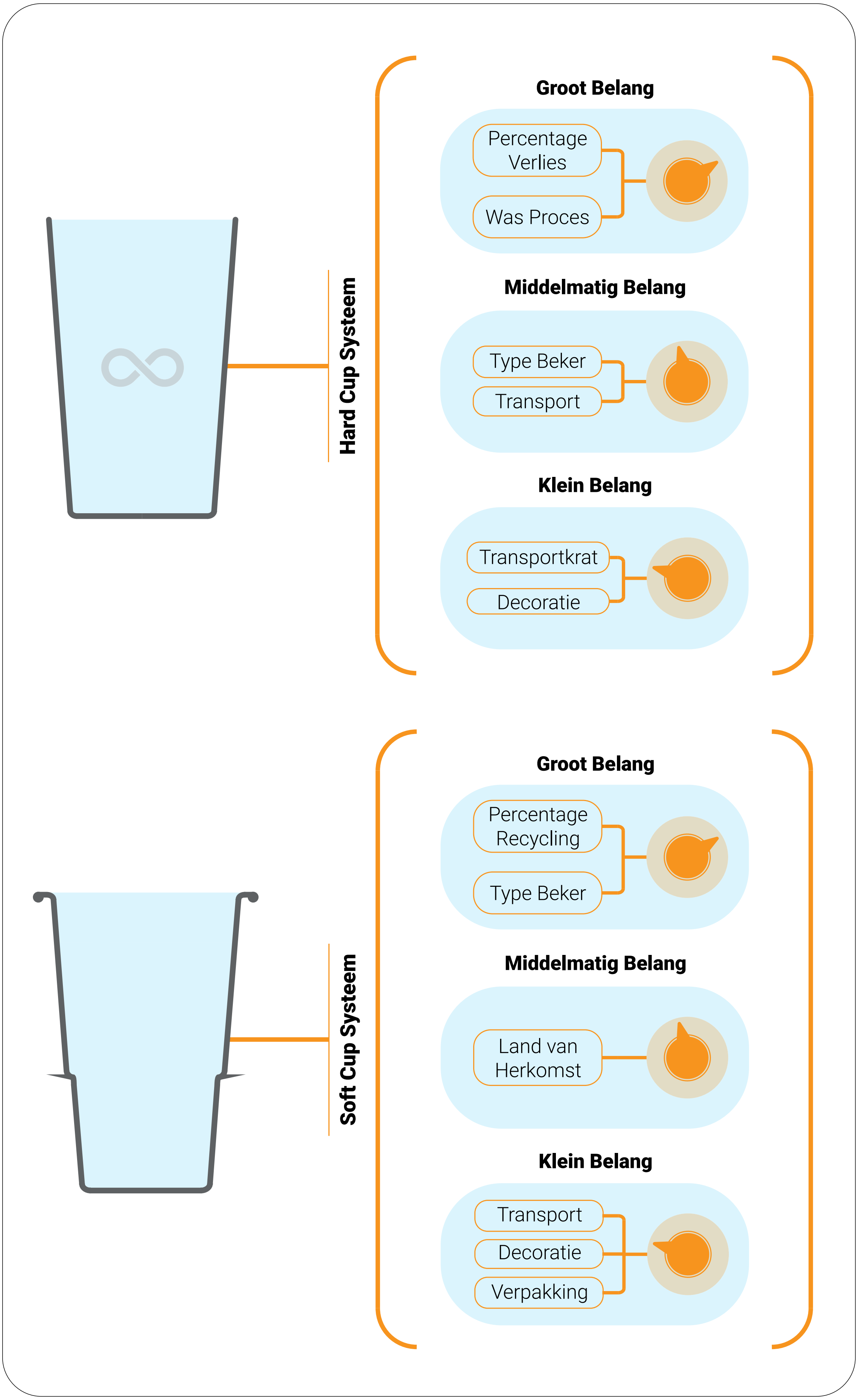


Figure 4: Factoren en mate van invloed

Deze factoren kunnen gezien worden als knoppen waaraan kan worden gedraaid. Elke verandering van de stand waarop een of meerdere knoppen zijn ingesteld leidt tot een verandering in de break-even punt berekening. Hierdoor ontstaan talloze mogelijke scenario's, welke in talloze mogelijke combinaties met elkaar kunnen worden vergeleken, zoals onderstaande figuur illustreert.

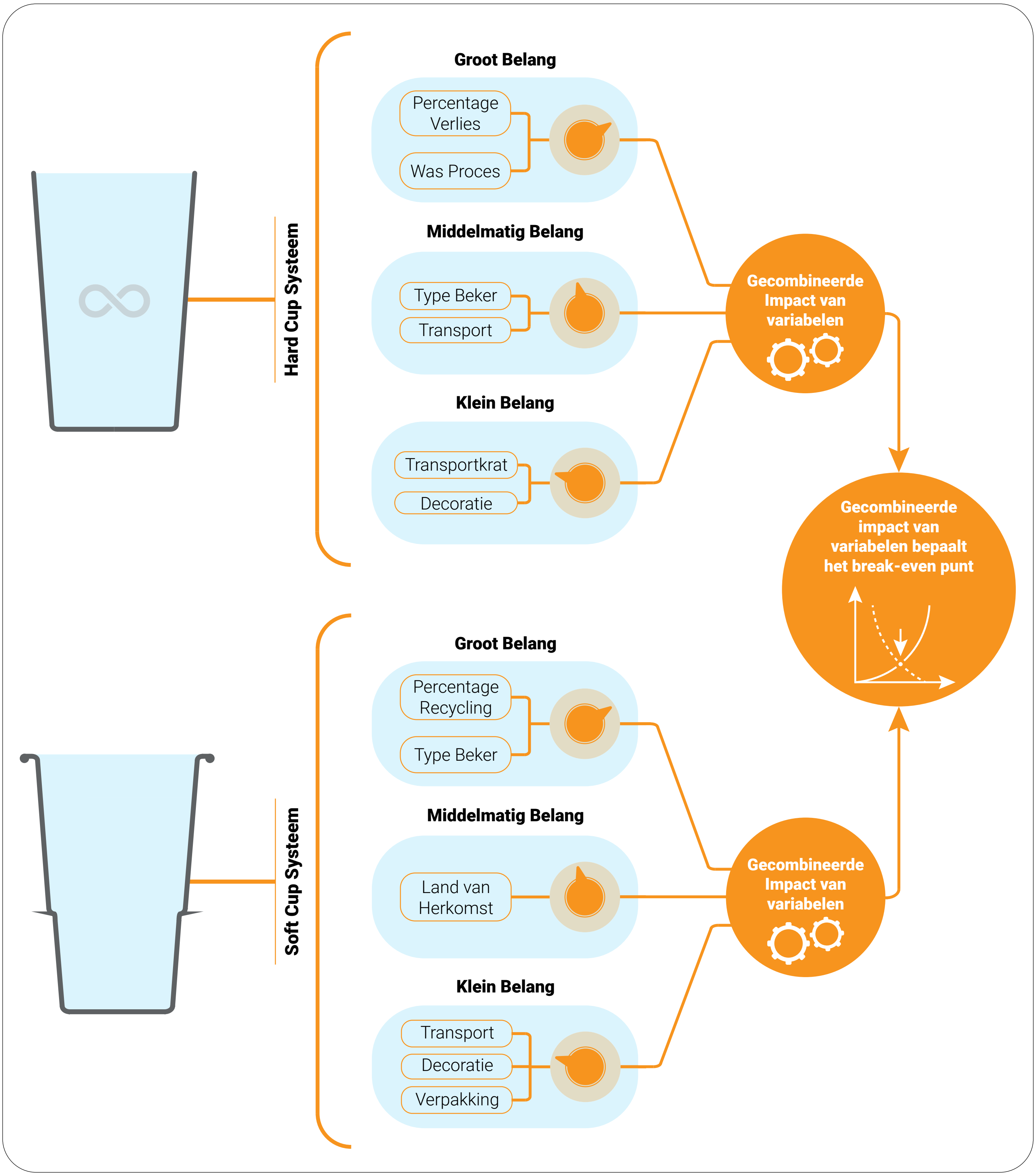


Figure 5: Factoren en invloed op de break-even punt berekening

Van alle onderzochte Soft Cups hadden de PLA bekers de hoogste milieu-impact, gevolgd door (r)PET bekers. De onderzochte PP bekers hadden de laagste milieubelasting.

Vanuit het oogpunt van circulair materiaalgebruik is deze uitkomst misschien verrassend. Het laat echter duidelijk zien dat het materiaalgebruik niet het enige criterium mag zijn waarop producten moeten worden beoordeeld.

PLA en PET zijn beide polyesters, PP is een polyolefine. Polyesters zijn complexe moleculen die ook qua verwerking meer complexiteit eisen. Zo zijn voor zowel (r)PET als PLA extra conversieprocessen noodzakelijk, welke niet nodig zijn voor PP.

PLA heeft een paar unieke uitdagingen die geënt zijn op de intrinsieke materiaaleigenschappen van PLA. De PLA korrel is zeer hygroscopisch – wat inhoud dat deze erg gevoelig is voor vocht, hetgeen vergaande gevolgen heeft voor het gehele verwerkingsproces van PLA als materiaal. Per saldo resulteert dat in een relatief hogere overal milieu-impact van PLA bekers ten opzichte van bekers gemaakt van andere materialen.

Onderstaande grafiek illustreert de verschillen in de milieu-impact van de onderzochte Soft Cups uitgedrukt in Global Warming Potential (CO_2-voetafdruk). Het laat duidelijk de verhouding zien tussen de milieu-impact van de grondstof (RM= Raw Material) en de milieu-impact van het verwerkingsproces (Processing) welke nodig is om van de grondstof een Soft Cup te verwaardigen.

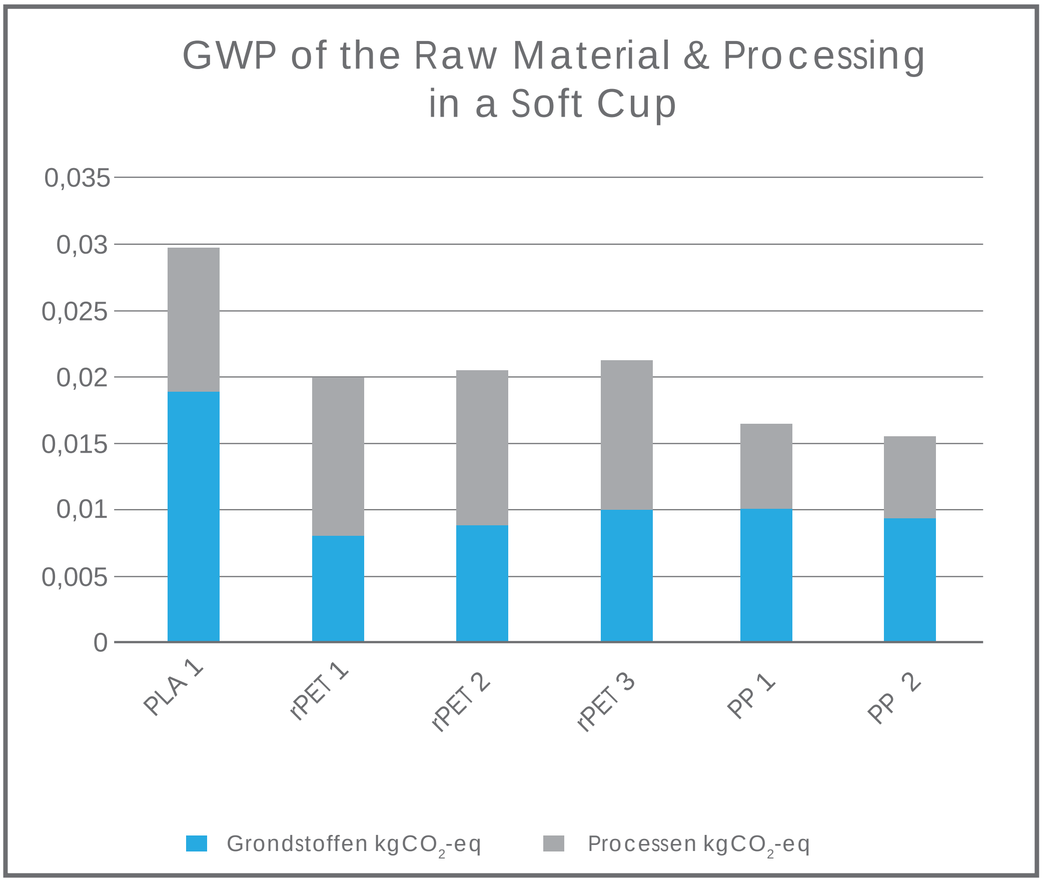


Figure 6: Milieu impact soft cups uitgedrukt in Global Warming Potential

Voorbeeld break-even-punt berekeningen

Ter illustratie van de mogelijke systeemvergelijkingen zijn hieronder enkele scenario's uitgewerkt. In al deze scenario's is ervan uitgegaan dat wanneer men voor een Hard Cup systeem kiest, er ook direct een keuze wordt gemaakt voor de beker met de minste milieu-impact en een wasstraat met de hoogste efficiëntie en dus ook de laagste milieubelasting.

Ook bij de keuze van de Soft Cup is gekeken naar de beker met de laagste milieu-impact uit alle onderzochte bekers die van hetzelfde materiaal zijn gemaakt. Er is uitgegaan van een nationale energiemix voor de berekening van alle processen.

De knoppen waaraan in onderstaande scenario's wordt gedraaid zijn de drie belangrijkste factoren

- Percentage verlies voor een Hard Cup systeem
- Percentage recycling voor een Soft Cup systeem
- Type beker voor een Soft Cup systeem

Hoe kleiner het aantal keren dat een Hard Cup gebruikt moet worden om het break-even-punt te bereiken, des te hoger de milieu-impact is van het Soft Cup systeem waarmee het Hard Cup systeem vergeleken wordt.

Scenario 1.

Dit scenario laat het break-even punt zien tussen een Hard Cup systeem zoals hierboven omschreven met 10% verlies en de best case scenario's voor de Soft Cups zoals hierboven omschreven - namelijk 92% inzameling van diverse Soft Cup Systemen.

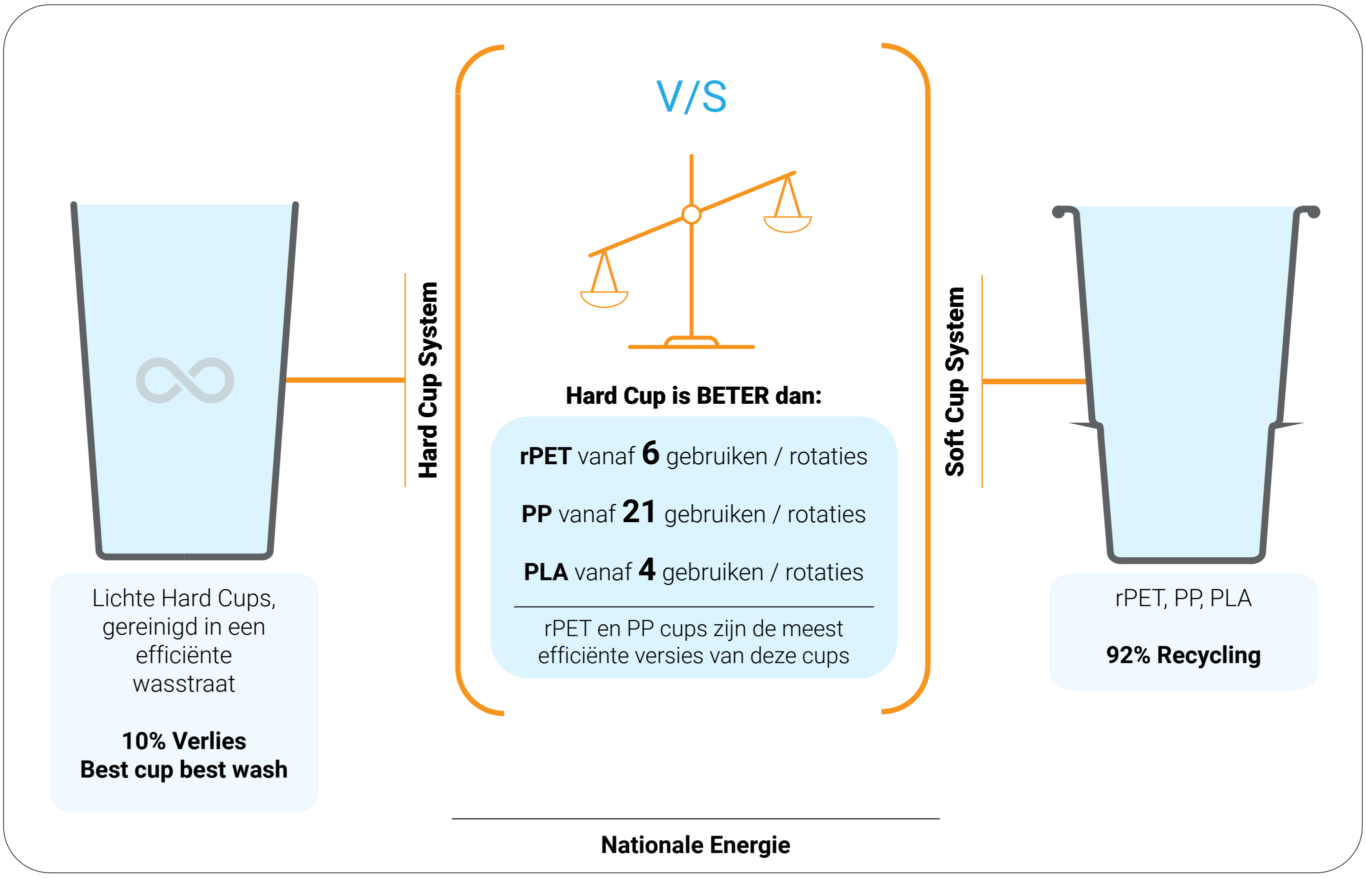


Figure 7: Scenario 1

Scenario 2.

Dit scenario laat het break-even punt zien tussen een best case Hard Cup systeem – namelijk zoals hierboven omschreven met 2% verlies en een best case Soft Cup rPET systeem zoals hierboven omschreven – namelijk 92% inzameling voor recycling.

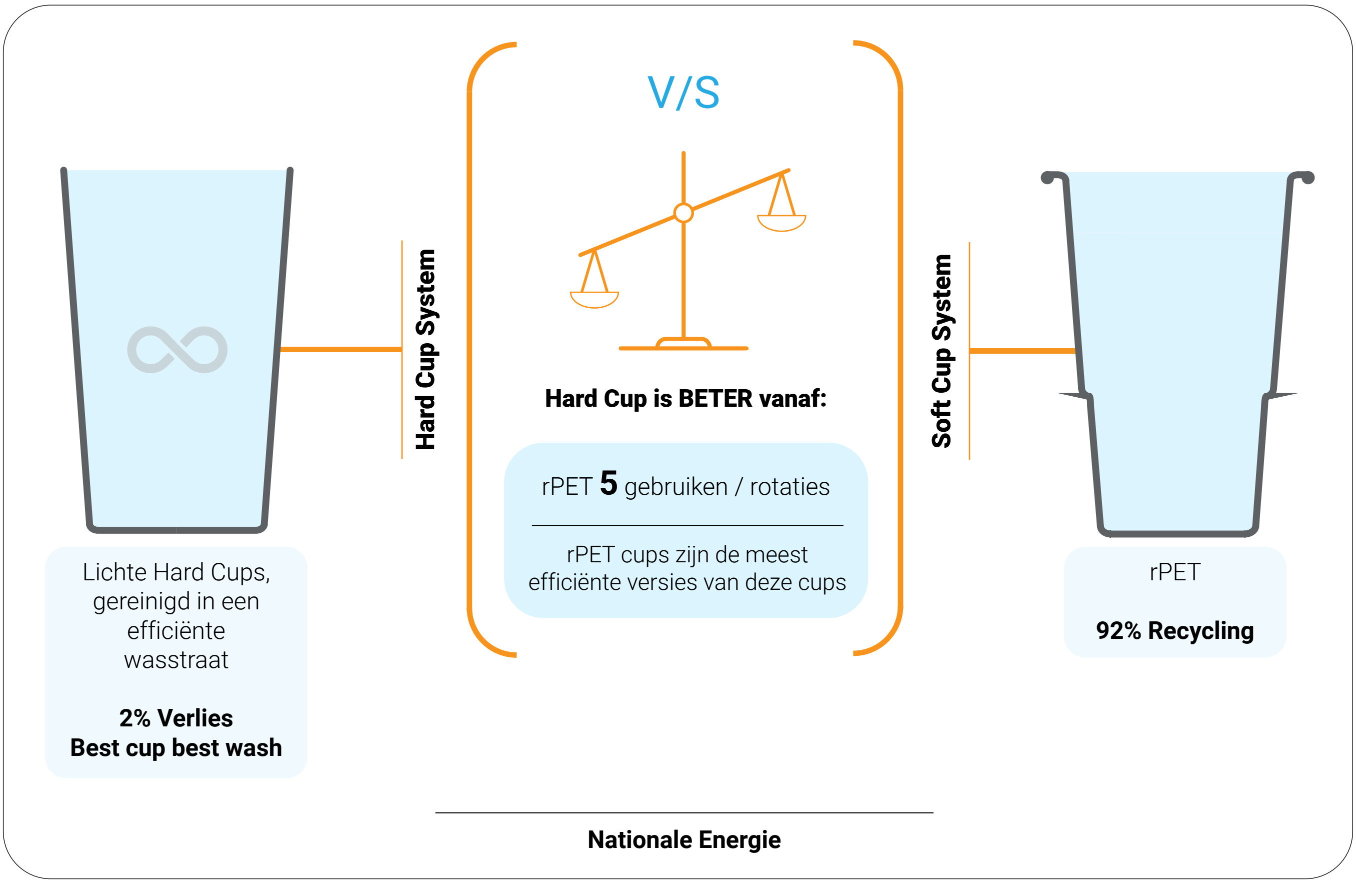


Figure 8: Scenario 2

Scenario 3.

Dit scenario laat het break-even punt zien voor de meest genoteerde uitkomsten van de pilots in 2019. Voor het Hard Cup systeem zoals hierboven omschreven was dat 10% verlies en voor het Soft Cup rPET systeem zoals hierboven omschreven was dat 75% inzameling voor recycling.

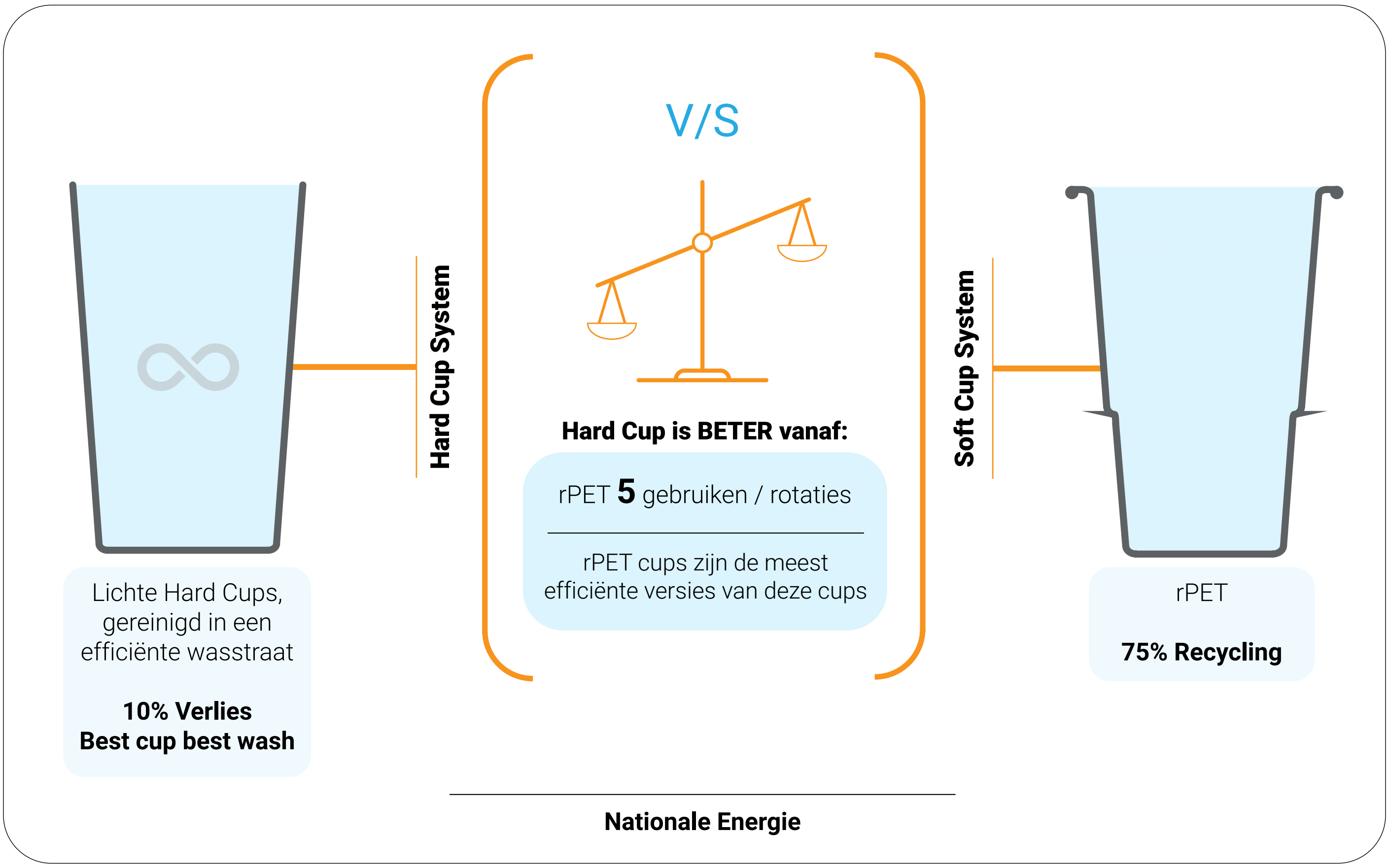


Figure 9: Scenario 3

Executive Summary

Situation

Plastic Promise is a national platform that allows pioneers to share their knowledge and objectives in order to reduce the use of plastic disposables in the event industry and to recycle those disposables used in the most sustainable way possible. It introduces two cup systems:

- Soft Cup system in which disposable plastic beverage cups are separately collected in dedicated waste bins and recycled.
- Hard Cup system in which reusable plastic beverage cups are collected so that they can be professionally washed and reused.

The campaign was a significant step towards a waste free festivals goal but was lacking insight into the environmental impact of adopting these systems. To better understand all environmental implications of both cup systems, a study has been commissioned by Rijkswaterstaat, with the cooperation of Plastic Promise.

The study is a peer reviewed life cycle assessment (LCA) of the two cup systems and their comparative environmental impact under various use scenarios, in order to seek to address the following Central Research Question of the study:

Can it be ascertained whether either a Reusable Hard Cup system or a Recyclable Soft Cup system, of equivalent guaranteed cleanliness and as currently used at Dutch events, will always be a preferred option from an environmental point of view, and, if so, at what breakeven point?

This LCA study assesses the following cups as can be seen in Table 1 below.

Table 1: Soft and Hard Cups Researched within this Study

SOFT CUPS		
Cup Ref. No.	**Fill Line**	**Material**
PLA 1	250 ml	PLA
rPET 1	250 ml	rPET
rPET 2	250 ml	rPET
rPET 3	250 ml	rPET
PP 1	250 ml	PP
PP 2	250 ml	PP
HARD CUPS		
Cup Ref. No.	**Fill Line**	**Material**
(H)PP 3	250 ml	PP
(H)PP 2	250 ml	PP
(H)PP 1	250 ml	PP

While there are many reuse scenarios discussed within this study, the scenario that is modelled involves rendering each reuse cup to a guaranteed hygienic level of cleanliness as would be expected of a new cup, such as is the case for single use cups. Hence, each Hard Cup is cleaned by an external washing company before each serving and each Soft Cup is used once before disposal.

Parties involved in the study are the event organisers and support organisations, as well as cup washing companies. No specific studies were made of the associated processes within the study, impact data being sourced from publicly available datasets.

The Hard Cup types identified by the event organisers were printed PP injection moulded reusable cups. The Soft Cup types identified by the event organisers were printed PP, rPET and PLA sheet extrusion and thermoformed single use cups.

The purpose of the study was to prepare a basis for decision-making as regards the more environmentally beneficial cup options between reusable and single use cup systems, based on the cup types reported as being currently used by the event organisations.

Figure 10 below includes the results of a study by Plastic Promise in 2019. The details from this Plastic Promise study will be used in assessing the results of this study.

Figure 10: Plastic Promise 2019 Results

The information related to cups studied in this report is derived from the Plastic Promise pilots that took place in 2019 and input provided by the participating Plastic Promise members. The study focuses on a system approach and is not attempting to provide a full representation of the current market situation.

Method

This generic LCA study assesses the various Hard Cups and Soft Cups introduced by the event organisers. It encompasses the environmental impact of the entire life cycle of the products: from raw materials extraction, to materials conversion processes to manufacture the cups, the packaging, energy, transports and end-of-life scenarios related to both cup types. As the cups become part of a use-system, the associated transports to and from the event/washer, the crates required for this transport and the washing systems are also studied.

To assess the environmental impact the following impact methodologies were adopted within the study:

- Global Warming Potential ($kgCO_2eq$) – GWP - commonly referred to as "carbon footprint"
- Water Resource ($m^3 H_2O$) – H_2O
- Cumulative Energy Demand (MJeq) -CED
- ReCiPe (endpoints total)

The study follows the relevant ISO standards associated with LCA and has hence been peer reviewed, by:

- Prof. Dr.Ir. Roland Ten Klooster – Professor and Head of Chair, Packaging Design and Management, at Twente University, member of the Committee of Independent Experts at Dutch Institute of Sustainable Packaging (KIDV) and co-owner of Plato Product Consultants
- Dr. Leigh Holloway – Honours degree in Mechanical Engineering and a PhD in EcoDesign examined by one of the UK's leading materials scientist (Mike Ashby, Cambridge University)

Although a full peer review was not carried out by Natuur & Milieu, they did provide basic comments after a brief readthrough, these being from Lieke van Adrichem - Project Leader Food and Circular Economy and Jelmer Vierstra - Senior Program Leader Circular Economy.

The results of the LCA study were then further modelled using an Excel based tool designed to identify the breakeven point based on various use scenarios. This Excel based Breakeven Calculation Tool will be further referred to as the BCT within the text of this study, this being in accordance with the second requirement of the central research question, notably "at what breakeven point?".

The BCT permits the breakeven point to be identified, taking sensitivities into account, for all Hard Cup types, associated washing systems and Hard Cup losses compared to all Soft Cup types at all recycling levels.

There are a number of assumptions that have had to be made to perform this study, with the primary assumption being that it is assumed that all cup systems are available to all events. No account is taken as regards event terrain layout/logistics, costs, beverage provision types, deposit-return system types, available personnel, venue visitors, etc. as may influence the choice of cup system type.

Secondly, all cup types that are collected are assumed to be recycled, with the Hard Cups being recycled at the end of their useful life. All cup material types can be recycled within the territory of study; this has been vetted. All Soft Cups that are not collected are assumed to be incinerated. All Hard Cups lost from the system are simply assumed to be lost and are considered as cut-off.

Sensitivities regarding cup weight tolerance and conversion energy mix type have been considered within this study.

As regards the washing companies mentioned within this report, they contributed to the study by providing operating data such as water and energy use, quantities of cups washed per hour, and crate washing data. This data is confidential to these washing companies and as such have been redacted from the peer reviewed final version of the study text.

Although a general background description of the Hard Cup and Soft Cup types is given in the introductory text, the body of the text will not refer to the manufacturer names. Each cup will be referred to by a reference number.

Results

The results that are presented below are based on the products and systems as described above. In this study, specific products and wash systems are compared. As a result, these results cannot be projected onto other products that might look similar from a first perspective. The parameters that have been averaged are for example, the distances between the wash companies and the festivals where most other parameters are all specific. Information related to the country of origin, cup weight and cup manufacturing is specific for each cup. In this study, in the case of the Soft Cups, two waste management scenarios have been modelled which are: recycling and incineration. However, in countries other than the Netherlands, End-of-Life options like Landfill, Anaerobic degradation and Composting might exist. For the Hard Cups, only the recycling scenario has been modelled. This is one of the reasons why these results cannot be easily projected onto another country.

Based on the Central Research Question of this study and the associated research, the following can be concluded:

1. The assumption that either the Hard Cup or Soft Cup system, as is currently used at Dutch events, will always be the preferred system from an environmental point of view, is incorrect.

2. The point at which one system becomes more efficient than the other system (breakeven point) from an environmental point of view is dependent on the relative impact of the various inputs:
    - Cup types
    - Percentage recycling
    - Hard Cup losses
    - Transports
    - Washing systems impacts
    - Environmental impact category

The breakeven point displayed is the serving number from which serving the Hard Cup becomes the better system.

Cup types

The effect of the cup type on the relative overall result is very important. This applies to both the Hard Cups as well as to the Soft Cups. For the Hard Cups, the weight varies between approximately 25 and 33 grams for the 3 Hard Cups in this study. Additionally, the country of origin is different for each of those 3 Hard Cups. In this study, the Hard Cup, manufactured in the lowest GWP energy country, could be considered as the product with the lowest GWP performance compared to the other two Hard Cups.

For the Soft Cups, 6 different cups are compared, each made from different materials and/or at a different location/country. In addition, there are variances in the weight and the way in which they are manufactured, due to differences in processing these various materials. When looking at the GWP impact indicator only, the lightest weight cup is the product with the best environmental performance compared to the other five Soft Cups.

Percentage recycling

All Hard Cups are modelled based on the assumption they are recycled at the end of their useful life. For each of the 6 Soft Cups, seven different End-of-Life scenarios have been modelled. This is the percentage of cups that will be recycled after they have been disposed of by the consumer. Scenarios for 0%, 25%, 41% 50%, 75%, 92% and 98% recycling have been modelled.

It is difficult to generalise as regards the mix of these scenarios, as the Soft Cup recycling scenario cannot be seen separately from the Hard Cup loss percentage. At a 2% loss scenario for the Hard Cups and a recycling percentage of 75% for the Soft Cups, a breakeven point with the PP Soft Cups starts to become difficult to achieve. At this same recycling percentage, there is still an acceptable Hard Cup breakeven number for the rPET and PLA Soft Cups. At a 92% Soft Cup recycling scenario and the 2% Hard Cup loss, the PP 2 Soft Cup could be seen as the better option for 3 out of the 4 wash systems studied based on their GWP impact factor. At a 41% or lower recycling rate for the Soft Cups and 2% Hard Cup loss, it is less likely that one or other Soft cup will have a lower GWP impact. However, this is based on a favourable scenario of only 2% Hard Cup losses.

Hard Cup losses

The percentage of Hard Cups that are lost during each serving is a factor which is of importance and which has been modelled. With every loss percentage increase, the breakeven point with one or other Soft Cup increases. The more efficient cups and wash systems can accept higher loss percentages compared to cups and wash systems that have higher environmental impacts. A general conclusion is difficult to come to as all the other factors also influence the outcome, but higher Hard Cup loss percentages will render the Hard Cups breakeven at a higher serving number. Some Hard Cup and wash system combinations would already have difficulty breaking even with the PP Soft Cups at Hard Cup loss percentages of 5%. At 11% Hard Cup loss and 50% Soft Cup recycling, there are still enough possible combinations whereby the Hard Cup system would be the lower GWP impact option. What can be concluded is that the Hard Cup loss has less effect on a shift in breakeven point than the Soft Cup recycling rate and the choice of Hard Cup washing company.

Considering the Hard Cup system by itself, a major objective from an environmental perspective is to reduce the percentage loss of Hard Cups. However, the current business model as regards cup rental charges favours cup loss, as this is income generative for the event organisation and cup rental company.

Transport

Transport does play a role within the reuse system. In the case of the most efficient Hard Cup, the GWP impact of transport is less than 4% for the first serving. As the number of servings increases, the impact of transport grows in comparison to the reducing Hard Cup impact per serving. For most Hard Cups, the GWP impact of transport will be in the region of 15-25% as related to the overall system impact, at between the 10th and 50th serving. For the Soft Cups, transport is influenced by the raw material source of the cups, the cup weight and distance from the manufacturer to the Netherlands. The transport impact for the Soft Cups remains the same for each serving at a specific recycling percentage; for the GWP impact, the percentage contribution of transport lies between 2 and 7%.

Washing systems impacts

For this study, 4 different companies that have the ability to wash reusable cups in large quantities have shared information about their washing process for this study. The efficiency between the studied wash systems varies significantly. The GWP impact of one system can be three times higher than that of another system. The freshwater consumption also varies significantly between the different systems; from approximately 30 ml/cup up to more than 200 ml/cup. What can be seen is that a Hard Cup which is washed at a less efficient wash company might not be able to break even with an efficient and recycled Soft Cup. By contrast, when the most efficient wash system is used, the Hard Cups break even at an early stage compared to the rPET and PLA cups. The influence on the breakeven point is significant for the actual wash system in place.

Environmental impact category

In this study, several impact categories are listed. One of the conclusions that can be made is that the choice of wash system, for example, has a huge effect on the water resource footprint. The most efficient Hard Cup and wash system still have a higher water resource footprint than the PP Soft Cups. A choice for a more water intensive wash system also renders some of the rPET cups the better option. The Hard Cup system is always better than the PLA Soft Cup system at the 1st serving for the water resource impact. In addition, the impact category CED shows different breakeven points compared to the GWP impact. This impact factor will show that the rPET Soft Cups have a slightly lower CED footprint than, for example, the PLA and PP cups which are made from virgin raw materials. As regards the ReCiPe endpoint-total impact, the PP Soft Cups are of a lower impact followed by the rPET and then the PLA Soft Cups. A Hard Cup (system) or Soft Cup that would score best across all impact categories does not exist.

Recommendations

From the above results, the authors of this study can make the following recommendations regarding the use of Hard Cups and/or Soft Cups at an event.

Hard Cups

It is evident that legislation is driving a move to a reusable Hard Cup type system and away from a single use plastic Soft Cup solution, this being evident in the EU Packaging & Packaging Waste Directive 92/64EC and the EU Single Use Plastics Directive EN2019/904.

This Hard Cup approach makes sense from a resources perspective unless the level of Hard Cup loss is high, which contributes again to further resource use exceeding that of the Soft Cup system. The average PP Soft Cup weighs 4.55g and the average PP Hard Cup weighs 28.8g, thus, at the Plastic Promise 2019 highest reported loss figure of 20%, rendering the resource amount for the Hard Cup 1.2g heavier per serving.

Hence, any Hard Cup system should work to achieve as high a return of used cups as possible, this being vital to the viability of a Hard Cup system. A number of methods and technologies to achieve maximum Hard Cup percentage return and hence reuse are discussed within this study.

The Hard Cup type and design has to permit the maximum number of reuses, or servings, over its useful life. To achieve this maximum number of servings, the cup will need to be used over more than just one annual event. An event organiser would logically go for a lightweight Hard Cup, if his decision is based on cost and the impact of the cup over his event only. Hence, this renders the responsibility for the cup type and design that of the party offering the Hard Cup system.

As the number of uses is a defining aspect of the reuse Hard Cup system, it could be important for the party operating the Hard Cup system to prove the number of uses the cups have already undergone. This would have to take account of the quality of the Hard Cups after a large number of uses.

Further to the Hard Cup losses, the cup types and number of uses, the cup washing system impact needs to be considered. As 95% of the cup washing GWP relates to the energy required to operate the washing machinery, it could be wise to check the energy source of the cup washing company. Additionally, this study shows a large difference in the quantity of cups washed per hour, which also contributes significantly to the washing impact.

Questions are asked as to the cleanliness of reusable cups compared to single use cups; this issue may be of even greater concern given the current pandemic. The event organiser should ask for the appropriate audit based certification related to the washer's system as regards their resultant cup cleanliness.

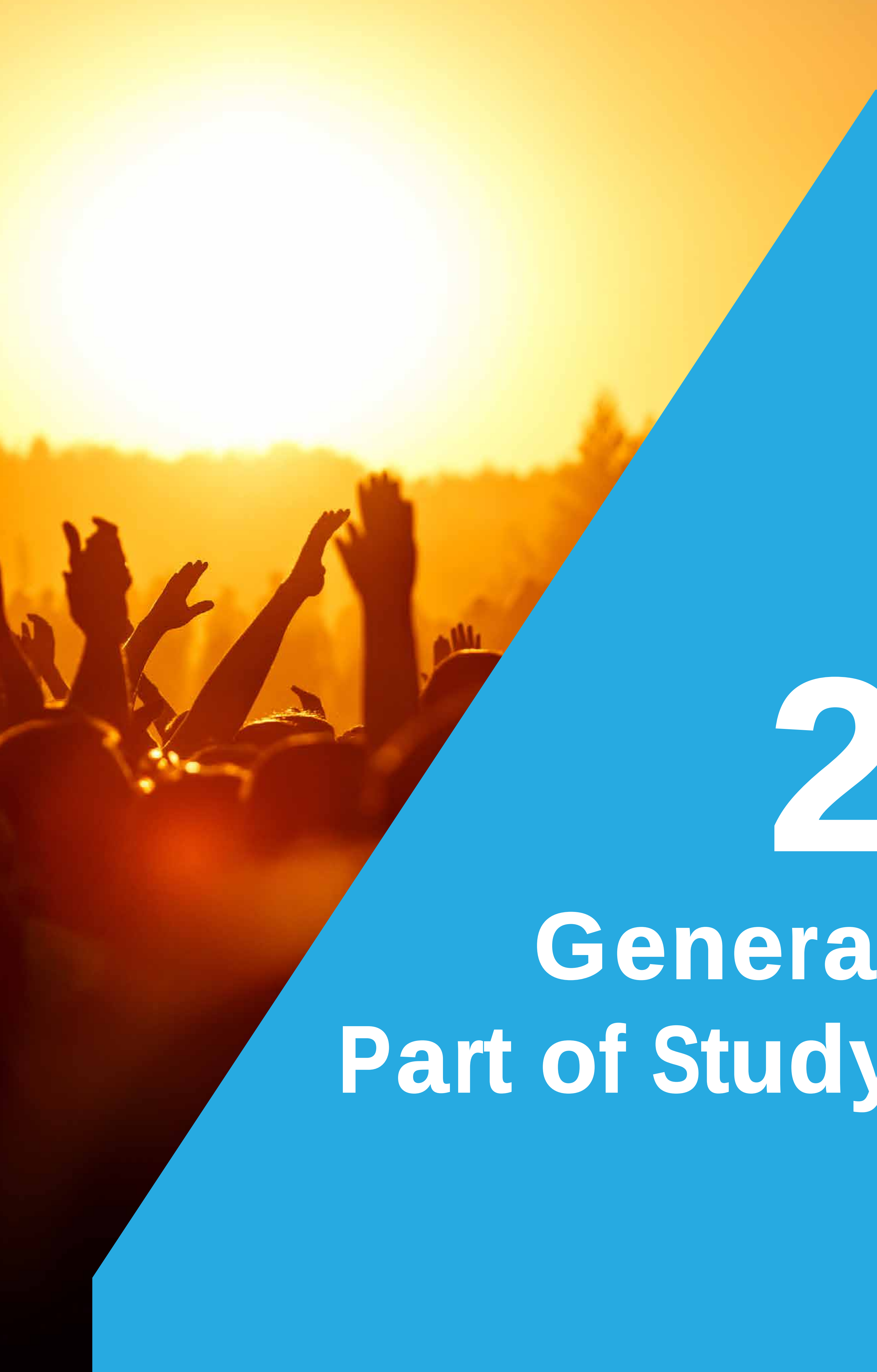
Soft Cups

While the future is likely to be defined by aspirations for well-designed Hard Cup systems with low loss rate and efficient washing services, it should be recognised that the lack of necessary infrastructure and/or consumer willingness for change of behaviour may render the implementation of such systems impossible in the current situation.

Should an event organiser wish to adopt a Soft Cup system, they, as with the Hard Cup system, should put in place systems to recover the maximum amount of these cups in a clean waste stream to achieve a maximum recycling level. This may also be achieved using a deposit-return system in which returned cups are simply replaced with a new cup at each serving or the deposit after the last serving has been consumed.

Unlike with the Hard Cup system, where the cup needs to be durable for a maximum number of uses, the Soft Cup requires to be of the lowest weight design and material type to meet the function based on a single use. In this study, the Soft Cups researched were manufactured from three material types. The lowest environmental impact Soft Cups, in almost all cases, were the PP Soft Cups. Soft Cups made from PP are typically lighter in weight than other cup types and the manufacturing of cups from PP is a relatively lower impact process compared to manufacturing using the other material types.

This recommendation seems contradictory to the circularity principles whereby the use of recycled materials within close loop systems is encouraged. As the only recycled plastic type in a cup-to-cup recycling system currently available for food contact is rPET, it has been promoted by Plastic Promise as a preferred Soft Cup option. However, the study clearly shows that a rPET based Soft Cup system does not result in the lowest environmental impact compared to other Soft Cup systems. In order to achieve the full circular potential at the lowest environmental impact, a development of a closed loop cup-to-cup recycling system for PP Soft Cups is recommended. This recommendation is in line with the ongoing activities of the Food2Food PP recycling working group.



2

General Part of Study

Topics

Background

The LCA Centre uses its extensive knowledge of packaging materials and technologies to support companies who want to further understand, measure, compare and manage the environmental performance of their packaging and disposables.

The LCA Centre takes a comparatively unique position in terms of LCA services due to the specific packaging knowledge available and a strong inventory analysis focus in the study. This focus seeks to maximise the quality of the input data through laboratory-based materials analysis techniques and a as full as possible understanding of the production and end-of-life implications and inputs.

The life cycle assessment (LCA) process starts with a detailed laboratory analysis of the material composition of the product samples. In a comparative LCA study, involving no stakeholder cooperation, a laboratory material analysis is the way to be sure the correct materials and processes are being accounted for, as competing or uncooperative stakeholders are unlikely to divulge the full material composition of their products.

In order to compare the like-functionality of items being studied so as to establish a fair product category, the lab provides instrumentation that measures the physical and mechanical properties of the products. This is used to establish equal strength and functionality.

Typically, the LCA approach starts at raw material extraction and goes on to evaluate the manufacture of the materials, the conversion processes, the various transports and the final end-of-life scenario. The approach taken follows the ISO: 14040&14044 standards for LCA and can, upon agreement, be used to support the ISO: 14025 standard for 3rd Party Claims.

Generic datasets are used from reputable third-party sources, and where these are not available, the missing data is generated by a specific LCA Centre study. Any other missing data is then highlighted within the report. All data types and sources are reported within the study.

Generic data is used in place of specific data which would be derived from a manufacturer's unique product or process.

The conclusions as to the results of the study must be considered in relation to the input data and the methodology choices made. An LCA does not demonstrate any direct linkage between cause and effect; its results act as a directional indicator. Conclusions drawn from the study should not be the sole basis for comparative assertions; issues of an economic and social nature may also need to be considered.

LCA services are only relevant for the exact product studied, assessed, tested or advised and not for the whole batch or future productions of the same product. LCA services and the results thereof can only give an indication of the situation at a given moment (in time). Products are typically made of materials that are not homogeneous, or can vary in formulation, or could be made in a different location and are subject to weight tolerance differences.

Generic impact data is used unless otherwise stipulated in writing, which generic data is only as accurate as the dataset supplier stipulates. Should The LCA Centre tests and processes be later proven to be incorrect, no claim can be made by any party for any claims or results derived from these incorrect procedures.

While this document may be a translation into a language other than English, it is the original English version of the study that should be considered as the intended central findings derived from the study.

Central Research Question

Can it be ascertained whether either a Reusable Hard Cup system or a Recyclable Soft Cup system, of equivalent guaranteed cleanliness and as currently used at Dutch events, will always be a preferred option from an environmental point of view, and, if so, at what breakeven point?

Parties to the Study

Numerous organisations were involved within this study, the following list identifies and describes those organisations:

Rijkswaterstaat - Kenniscentrum Afval Circular (Knowledge Centre Circular Waste Materials)

The Kenniscentrum Afval Circulair is a knowledge centre for waste and the circular economy. Its aim is to achieve a circular economy for materials by converting waste to resources. It is an internal knowledge partner for the Dutch Ministry of Infrastructure and Water Management, and works closely with other governmental and commercial institutions.

Plastic Promise

Plastic Promise is a national platform providing sustainable practice pioneers with an opportunity to share their knowledge and ambitions to become 'plastic smart' by reducing the event industry's use of plastic disposables, with a focus on the recycling of the remaining disposables in the most sustainably efficient method. It is an initiative of Green Events Netherlands and the Green Deal 'Waste-free Festivals'.

In addition to organisers of festivals, sports and business events, Plastic Promise is also associated with beverage brands and other suppliers in the events sector.

The Plastic Promise participants who provided input for this study are mentioned below:

Event Organising Companies

- Apenkooi Events – organiser of festival brands such as DGTL, Amsterdam Open Air, STRAF_WERK, Pleinvrees, By the Creek, Valhalla, Elrow Amsterdam and The Gardens of Babylon.
- Best Kept Secret – organiser of a festival under the same name.
- Dekmantel – organiser of a festival under the same name.
- Elevation Events – organiser of festival brands such as Soenda, Smeerboel, OHM and Duikboot
- Kairos – organiser of festival brands such as Ploegendienst, Ploegendiest Winterfestival, Kerkdienst, Het Grote Kinderfeestje, Trailerfest and Haveneiland
- MOJO Concerts – organiser of festival brands such as A Campingflight to Lowlands Paradise, North Sea Jazz Festival, Pinkpop, Down The Rabbit Hole, WE ARE ELECTRIC and WOO HAH!. Mojo also organises various large concerts and reoccurring performances like Symphonica in Rosso, Night of the Proms and Cirque du Soleil.
- Monumental Productions – organiser of Awakenins festival and co-organiser of Drumcode Festival and CONNECT
- Vierdaagse Feesten – organiser of the largest free accessible event in the Netherlands held annually during the 4 Day Marches in Nijmegen.
- Zwarte Cross – organiser of a festival under the same name

Event Support Organisations

- LOC7000 – event agency providing services in the field of event production, event horeca and event payment systems, involved in organisation of large concerts and festivals including amongst other events like Lowlands, North Sea Jazz, TT Festival Assen and ID&T concerts.
- Your Productions – horeca management company for large public events, providing services for events such as Awakenings, Defqon.1, Decibel, Amsterdam Open Air, SuperSized Kingsday and Q-Base Beverage Companies

Cup Cleaning Companies

Based on the information provided by the above-mentioned organisations and market research performed by The LCA Centre, the following cup cleaning companies have been interviewed:

- Cupking
- CupStack
- De Bekerwasstraat
- Dutch Cups

Relationship between the Cup Washers, Cup Suppliers and Cup Producers

Typically, the party that washes the cups also supplies the cups as a full package. Those cups can be manufactured by different producers. It is possible in the future that washing will be provided as a service separate from the cup supply.

Due to the confidential nature of the inventory data provided by the washing companies to assess the impact of their process, the washing companies will be referred to as company A, B, C and D.

Cup producers were not parties to this study

Recycling Companies

Knowledge derived from previous contacts with a variety of recycling companies has contributed to this study. Notably, Morssinkhof for PP and PET, QCP for PP, and PET360 for PET. In the case of the less common PLA recycling, specific contact was taken up with Looplife in Belgium, for this study.

Peer Reviewers

The peer review team are experts in the field of packaging technology, engineering life cycle assessment and the environment. The peer review comments are within Appendix F of the report.

- Prof. Dr. Ir. Roland Ten Klooster – Professor and Head of Chair, Packaging Design and Management, at Twente University, member of the Committee of Independent Experts at Dutch Institute of Sustainable Packaging (KIDV) and co-owner of Plato Product Consultants

- Dr. Leigh Holloway – Honours degree in Mechanical Engineering and a PhD in EcoDesign examined by one of the UK's leading materials scientist (Mike Ashby, Cambridge University)

Although a full peer review was not carried out by Natuur & Milieu, they did provide basic comment after a brief read through. These being from Lieke van Adrichem - Project Leader Food and Circular Economy and Jelmer Vierstra - Senior Program Leader Circular Economy.

Declaration of Competing Interest

The LCA Centre regularly carries out studies and research into both disposable and reusable packaging products from an LCA, microbiology (hygiene) and eco-innovation perspective. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

The LCA Centre is a separate legal entity within the Royal Dutch Paardekooper Group. This group is active in the marketing of both Hard and Soft Cup products and reuse and disposable packaging systems.

Aspects relating to the LCA study

In this comparative study, a single use cup is used once and is then either incinerated or recycled and a reusable cup is used multiple times.

- When a single use cup is incinerated its materials and form is lost.

- When a single use cup is recycled its material is retained but its form is lost.

- When a reusable cup is reused its material and form are maintained.

However, for a reusable cup to maintain its material and form, it is subject to a closed loop system of transport and washing. Every time a reusable cup is reused, the impact of the cup itself, per serving, decreases

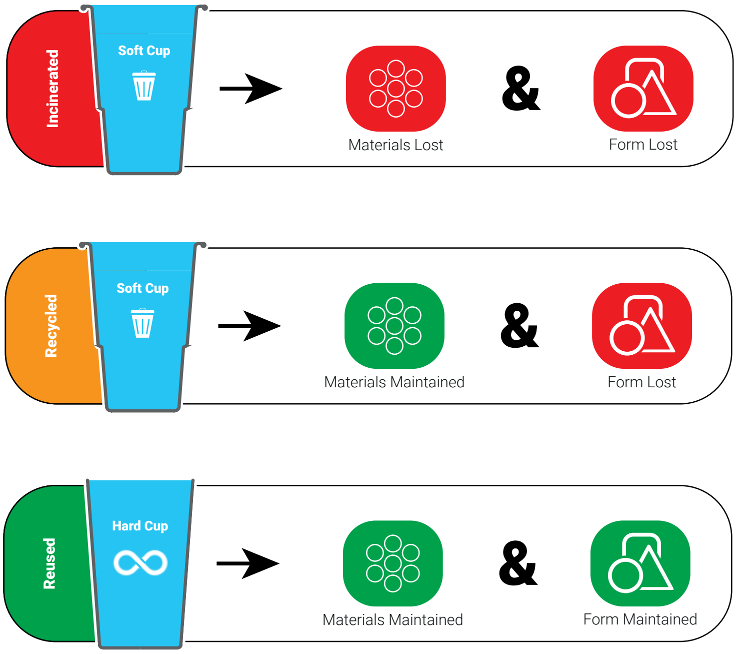


Figure 11: Effect on material and form

exponentially while the impact of the closed loop system of transport and washing for the cup increases linearly. It should be noted that after its useful life, the reusable cup is recycled. The cup impact of single use cups use also increases linearly with each serving as new cups are used each time.

To establish the environmental impact of the cups and cup systems, used by the parties to this report, an LCA study is required.

Introduction to LCA

"Life Cycle Assessment is a tool to assess the environmental impacts and resources used throughout a product's life cycle, i.e., from raw material acquisition, via production and use phases, to waste management" (Finnveden, G., et al., 2009).

LCA is a method that quantifies environmental stressors, such as resource use and emissions, that occur over the life cycle of anthropogenic systems and translates these stressors into metrics of environmental interferences for a number of mutually exclusive and collectively exhaustive "impact categories", such as climate change, eutrophication, and eco-toxicity (Bjorn, A., et al., 2015, p. vii).

LCA standard procedure and methodologies are explained within Appendix A.

Introduction to Forensic LCA

Forensic LCA (Campbell, A. 2019) functions to increase the accuracy of product economic inventory data, in the inventory analysis stage, for input into LCA, this being especially important if the product manufacturing stakeholder is not willing or available to give component and processing data. It functions to reduce the chance of GIGO (garbage in – garbage out) in product comparative LCA studies.

Forensic LCA requires the use of laboratory instrumentation to assess like-functionality in defining product compliance to the functional unit and to facilitate forensic techniques to identify material component composition and processing. It also requires to be carried out exclusively by packaging technologists who can interpret the findings in a technologically relevant manner, as the lack of product technological relevance has been a major criticism of LCA.

Previous Studies into Reuse vs Single Use Systems

A limited meta-analysis has been made of previous studies into reuse versus single use systems involving beverage cups.

Meta-analysis

The following three studies have been studied for this meta-analysis:

1. Mountain Riders. (2011, June). Comparaison des impacts environnementaux des gobelets dans l'évènementiel.

2. Österreichisches Ökologie-Institut, Carbotech AG, & Öko-Institut e.V. Deutschland. (2008, September). Comparative Life Cycle Assessment of various Cup Systems for the Selling of Drinks at Events.

3. OVAM. (2020, April). Update studie: drink- en eetgerei op evenementen.

Comparaison des impacts environnementaux des gobelets dans l'évènementiel - Mountain Riders 2011

This is a relatively basic study conducted in France consisting of only 17 pages comparing a PP reusable Ecocup with a PP Soft Cup, a PLA Soft Cup and a paper cup with PLA coating. The Functional Unit is a 250 ml serving of beverage and the number of reuses is set at 14.

The exact chosen processes and production locations are unknown. In addition, losses, for example, are not considered. Therefore, it is not very robust and difficult to verify. However, there is some information about the wash process.

The conclusion of the study is that after 7 servings, the PP reusable Ecocup is the better option compared to the PP Soft Cup. Compared to the PLA cup, the PP reusable Ecocup breaks even at even fewer servings. The PLA cup does not break even for water resource use.

For the scenario whereby the reusable cups will be used 14 times, the PLA and paper cup with PLA coating have a GWP impact which is twice as high as the PP Soft Cup and four times as high as the PP reusable Ecocup.

Table 2: Least to Most Impactful Cup Types

Classement des gobelets du moins impactant au plus impactant, par indicateur, sur tout le cycle devie. (Prise en compte des 14 réutilisations; voir tableau 1)				
	1	2	3	4
Consommation d'énergie NR	Réutilisable	Carton	Jetable	PLA
Effet de serre	Réutilisable	Jetable	Carton	PLA
Ecotoxicité aquatique	Réutilisable	Jetable	Carton	PLA
Consommation d'eau	Jetable	Réutilisable	Carton	PLA

The results are visualised in Table 2 above.

- Réutilisable = PP Hard Cup (29g)
- Jetable = PP Soft Cup (5g)
- Carton = PLA Coated Paper Cup (8g)
- PLA = PLA Soft Cup (6.5g)

- Consommation d'énergie NR = non-renewable energy consumption
- Effet de serre = GWP
- Ecotoxicité aquatique = aquatic ecotoxicity
- Consommation d'eau = consumption of water resource

Comparative Life Cycle Assessment of various Cup Systems for the Selling of Drinks at Events - Österreichisches Ökologie-Institut, Carbotech AG and Öko-Institut e.V. Deutschland - 2008

The above study is very extensive and well presented. The study compares several types of reusable PP cups with and without branding, with a broad selection of disposable Soft Cups made from PS, PET, PLA, board+PE and Belland.

The conclusion of the study is that reusable PP cups are recommended for major events in favour of the studied disposable cups. It must be said that this study is already 12 years old and that there was no PP or rPET Soft Cup in the study. In this study, the paper cup with PE coating had the lowest impact of all the disposable cups studied. However, for all the reusable PP scenarios the environmental burden was lower compared to the disposable cup scenarios.

Update studie: drink- en eetgerei op evenementen – OVAM 2020

The OVAM study is a meta-analysis combined with a quickscan.

Part one of the OVAM study is the meta-analysis. The conclusion of their meta-analysis is that for reuse systems, ceramics/glass have the same score as the reusable PP cups, receiving an "A" rating. The impact of the PC/ copolyester cups is less beneficial with a "B" rating. However, related to disposable systems with selective collection for recycling, the impact of the rPET and PLA cup shows the lowest impact with PP and PET cups achieving a "C". In the disposable cup scenarios, no cup scores an "A" which means that the reusable system with PP cups is still preferable.

The second part of the OVAM study is a quickscan. In this quickscan, two reusable cups, PP (29g) and PC, are compared with three Softcups; PP (4.5g), rPET (6.5g), PET (6.5g) and one PET bottle. Several best and worst case scenarios have been modelled.

Their conclusion is that PP reusable cups have the potential to achieve the lowest environmental impact, provided that the cups are reused for 10 servings or more. The impact of the PC reusable cups is about twice as high as the PP cups.

For the disposable cups, the conclusion of the OVAM study is that the lightweight rPET cup, provided that it is recycled afterwards, has the best impact score in the case of one-off beverage packaging.

The fact that this rPET cup scores better than the lightweight PP Soft Cup, which is also in the OVAM study, is counter to what is seen in this LCA Centre study. A further look into their data shows that the GWP impact of their rPET raw material is about 10% of the GWP of virgin PET. There is a possibility that data has been used related to recycled material from Switzerland instead of using the European number.

Further conclusions of the OVAM study in relation to how much effect certain variables have on the relative position of each product are visualised in Figure 12 below. These relative influences differ somewhat from those within this study.

Relative Influence of Variables examined on the environmental impact of cups

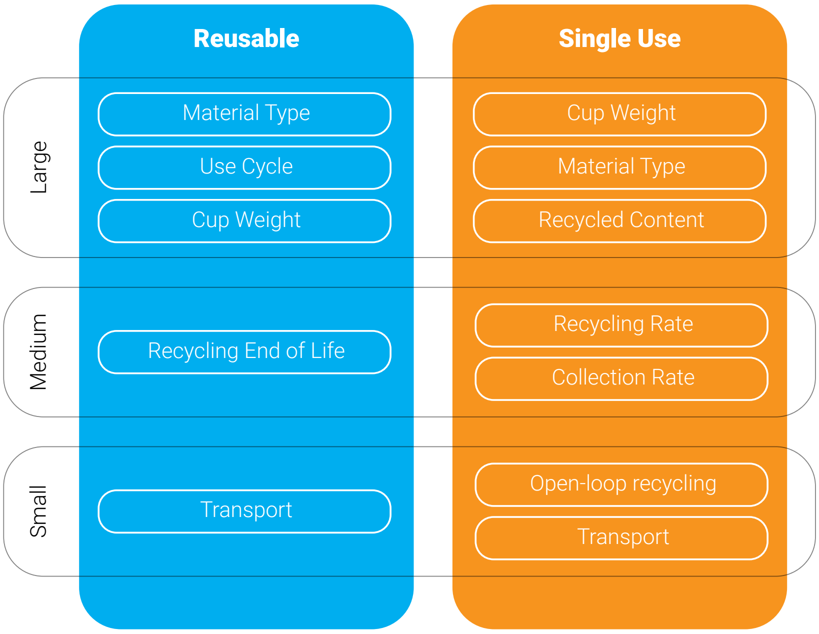


Figure 12: OVAM Study Conclusions

Meta-analysis – Conclusion

The overall conclusion of these three studies are that Hard Cups are often the better system. However, assumptions and scenarios differ between the studies, as do the age of the study and the studied cup types.

Goal definition

The goal of the study is to identify if either a clean Reusable Hard Cup based system or a Recyclable single use Soft Cup system will consistently be the preferred option from an environmental perspective. It will also be to identify the breakeven point, in terms of the serving number, at which the environmental impact of one of these systems exceeds that of the other.

Scope and limitations

Scope

The scope adopted of the two cup systems within this study is shown in Figure 13 and Figure 14 below.

These items are then subject to recycling or incineration at their end of life. They are transported to the recycling or incineration facility. For the recycled product, the cut-off method is adopted, and the benefit of recycling is occurred by the user of the resultant recyclate, such as in the case of the use of rPET. For the incinerated product, the impact of incineration is adopted with any potential benefit from the incineration being occurred by the user of that benefit.

All Hard Cups are prewashed prior to first use. All Hard Cups are washed between each serving at one of the cup washing companies listed in this study in order to achieve cleanliness comparable with the Soft Cup and to a level that would be guaranteed by the Hard Cup system provider and/or washing company.

Any Hard Cup lost to the system that could have been taken as a souvenir will be considered using the cut-off method.

The scope of the washing systems within the study includes the energy, water, detergent and wastewater within the four washing systems studied.

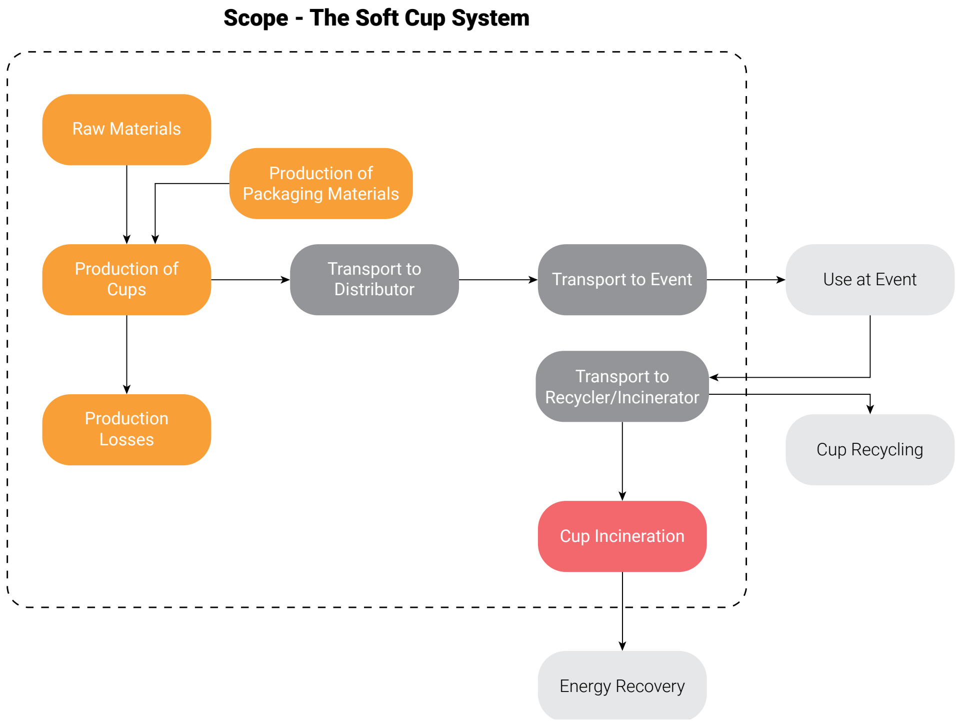


Figure 13: Scope - The Soft Cup System

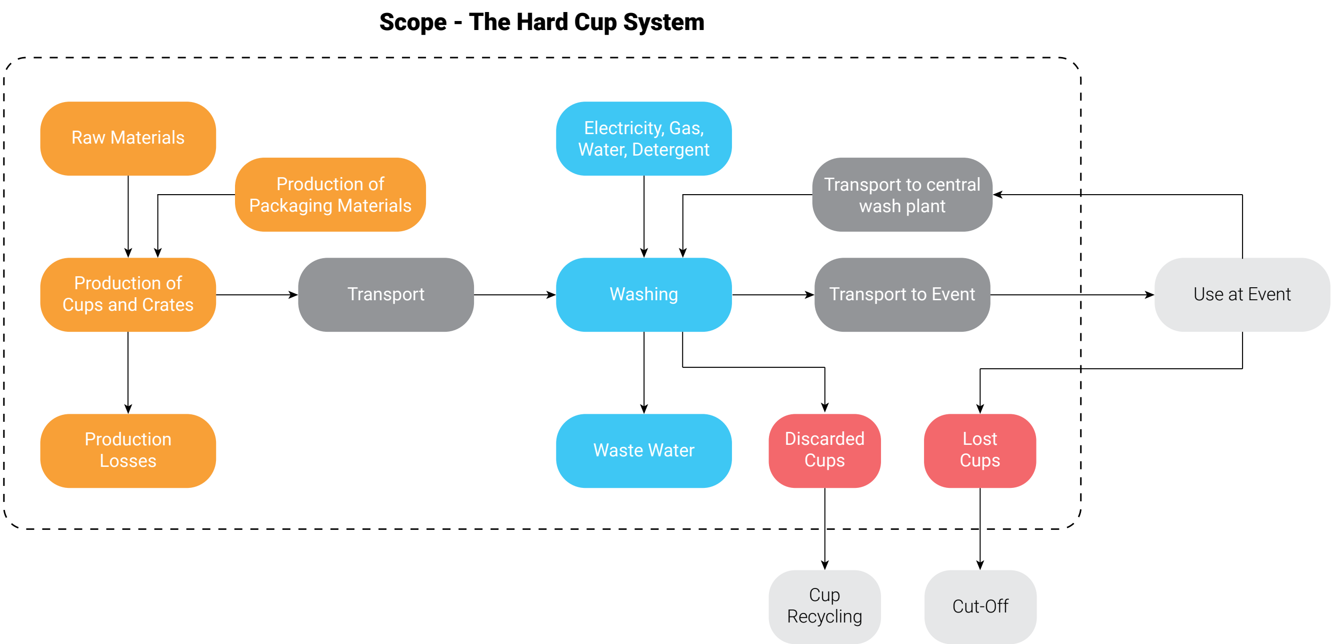


Figure 14: Scope of the Hard Cup system

Limitations

This study, commissioned by Rijkswaterstaat in cooperation with Plastic Promise, is a non-specific study using generic LCIA data, as agreed by the parties. All LCIA data is generic for the cup raw materials, manufacturing, printing, packaging, energy, waters, transports, and end-of-life scenarios plus the related systems processes. The source is EcoInvent v3.5 released in 2018.

Specific inventory data was collected from the washing companies as, unlike the other processes, this inventory was not accessible in publicly available datasets. This washing inventory was then applied to generic LCIA data.

The impacts presented in this report are GWP, CED, H_2O and ReCiPe Endpoints Total, while this is indicative of the relative environmental impact of the product options, it is not an exhaustive list covering all potential impacts.

The secondary impact results relate to the territory for which the data was chosen, hence the results of the study will not be representative for all territories.

Reusable cups can be subject to breakage/damage, loss or non-return, and the point at which this occurs is inherently difficult to define. This is evident in other reuse system scientific studies. This is addressed by adopting a range of likely loss percentages in the BCT; these percentages will not cover every possible loss scenario.

What happens at the end of the useful life of the lost cups varies. A cup that is taken home as a souvenir or dropped on the ground as litter will go through a number of processes which can vary. End-of-life scenarios have been predefined within this study.

Cup and reuse system types can vary. Conclusions can be drawn from this study, but they may not be indicative of all possible available cups and reuse systems.

It should be noted that every event or festival will have its own challenges in terms of the space, logistics, beverage dispensing/retail, type of client and management of the cups. In the sub-chapter titled Scenarios below, a large number of potential use scenarios are described. These have not been considered in the study. The study assumes that both cup systems are available (reusable clean Hard Cups and single use Soft Cups) to the events.

Uncertainty

Life cycle assessment is open to uncertainty, derived from subjective choices and/or missing data.

In this study, the component materials are clearly identified and quantified using laboratory instrumentation and information from the supplier's text within their websites and/or other public documentation.

All materials are taken as their gross weight, any waste being assumed to have the typical material specific end-of-life scenario for this process waste. Process waste weight values per material have been calculated by The LCA Centre. The data used is generic or secondary data that, while indicative of the process, may not fully reflect the impact of the specific processes actually in use.

Conversion process energy type is unknown and hence a national and a European energy figure has been adopted when calculating the impact of both the Hard and Soft Cup.

The common uncertainty in reuse system studies would be the actual quantity of reuses of a specific cup. Within this study, any number of cup losses from the system can be applied to the BCT to understand the sensitivity of Hard Cup loss.

The efficiency and actual energy use of the washing systems has not been measured onsite. Data related to the washing related inputs of energy, water, wastewater, cups/wash etc has been reported by the washing companies and not verified by The LCA Centre.

The uncertainty for transport types has been addressed by modelled transport based on the smallest likely vehicle type for each specific transport route - see the chapter on transport below.

Uncertainty as regards the potential end-of-life scenarios of the cups is addressed by assuming a range of scenarios. This is explained below on page 39. While specific end-of-life scenarios are studied for collected cups, it is likely that an amount of cups may be littered, especially those perceived as being of little value. Litter percentages are a matter of uncertainty. Additionally, accounting for litter using LCA is challenging.

Data Accuracy

A life cycle assessment study between two products that displays a similar, or close, result does not necessarily indicate that the product with the lower of the two similar results is the more environmentally efficient product. When reporting on a breakeven number of servings derived from the BCT, variances in impact of 5% or under (between the Hard and Soft Cup impact figure) will be considered to be equal.

Assumptions

Various assumptions have had to be made in order to address this study, the principal of which are as follows:

1. It is assumed that all cup systems are available to all events. No account is taken as regards event logistics, costs, beverage provision types, deposit-return system types, available personnel, venue visitors, etc. as may influence the choice of cup system type.
2. It is assumed that the same Hard Cup system is applied over a number of events and over a period of time. It is not the serving at an event but the serving over the useful life of the Hard Cup.
3. All Hard Cups are pre-washed prior to their adoption within the Hard Cup system and are washed between each serving to meet the hygienic level of cleanliness found in the single use Soft Cups and as guaranteed by the Hard Cup system providers.
4. All Soft Cups that are collected are recycled. Those that are not recycled are incinerated.
5. All Hard Cups are recycled after their useful life.
6. All Hard Cups that are lost are assumed to have been removed from the system with no further follow up and are considered to be cut-off from the system.
7. All Hard Cup types are equally likely to be lost with no cup having a more desirable print that could cause event attendees to retain more of the cups for use at home.
8. All deposit-return systems function to achieve the Soft Cup and Hard Cup collection. No consideration is given to the effectiveness and accuracy of the deposit-return systems.
9. No Soft Cups or Hard Cups are fitted with a track-and-trace system. The probability that a cup is lost or collected is assumed to be the same for each cup system type.
10. All primary raw materials used to manufacture cups are delivered by tanker from a drive radius of 250km, the exception being for the PLA material as mentioned in the raw materials chapter below.

11. All conversion process energy sources are based on the national energy mixes available for the country of production. Due to extremes in GWP impact (i.e. between France and Poland), a sensitivity study was made involving a European energy mix.

Scenarios

There are many reasons why a Hard Cup or Soft Cup could be the better or worse system solution for venues and festivals. This study does not incorporate the multitude of unique scenarios that could influence their use, as no exact data on the consumption patterns and the specific circumstances of each event were provided. However, these scenarios can heavily influence the viability of using one system over another and the results of this study have to be seen in light of this.

Examples of these scenarios could be:

1. Venue size: it could be that Hard Cup systems are better suited to smaller venues and Soft Cups to larger venues.

2. It could be that a venue orders an amount of printed cups that exceeds the number of servings of cold beverage they actually sell. The functional unit in this study is a single serving of 250 ml of cold beverage, so takes no account of unused cups.

3. It could be that venues have partial washing availability, such as a spool system, while also using a washing company. Hence, cups are used several times before they are sent for external washing.

4. It is possible that a festival goer uses their Hard or Soft Cup multiple times before they are collected for respectively reuse or disposal, if refill is available. While this could lead to greater Hard Cup damage and hence an increased loss figure for the Hard Cup, it will also lead to a lower GWP per serving

5. Differences in Hard Cup design may lead to one cup type being more quickly damaged than another type when used in the Hard Cup system. The criteria for deciding that a cup is no longer viable for use could vary.

6. It could be that Hard or Soft Cup systems are not suited to the HORECA or beverage retailers operating system, i.e. as regards the collection and managing of deposit monies.

7. It could be that a Hard or Soft Cup system is not compliant with the geographical or terrain constraints of the event or festival, i.e. available storage for dirty cups.

8. It could be that a cup has a higher propensity to be littered or lost depending on its design or print, i.e. an attractively printed Hard Cup may be more likely to be taken as a souvenir or an unprinted lightweight Soft Cup may be more likely to be littered.

9. Differences in deposit-return systems may exist that influence collection percentages.

10. Social aspects of offering a “round of beers” may make the use of Hard Cups more problematic, leading to lower beverage sales, i.e. the person offering the round will have to return the dirty cups and pay deposits on the clean cups.

11. Availability of bins for easy disposal may influence the collection of single use cups for recycling.

12. It could be that Hard or Soft Cup systems collection is influenced by the nature of the event and the

mentality of the attendees. Certain attendee mentality types may have a greater propensity to reclaim Hard Cup deposits or correctly dispose of Soft Cups compared to other attendee mentality types.

13. It could be that the operating rules of Hard Cup systems companies do not suit a specific venue, i.e. as regards replenishment, financial deposits, etc.

14. The storage of Hard Cups is more voluminous than for Soft Cups, so the bars need to have the space to facilitate the Hard Cup system. Both clean and dirty Hard Cups need to be stored.

15. If a deposit is applied to the Hard Cups, they need to be securely stored so as not to be stolen and returned for the deposit.

16. The events must have as much access to the Hard Cups and Soft Cups in terms of available quantities of cups when they need them.

17. If the washing facility is on or off the terrain, this may address some of the challenges associated with the use of Hard Cups.

18. There could be logistic or supply issues related to peaks and troughs in demand for cups.

19. There could be issues related to Hard Cup washing if the dirty cups have been stored for a longer period in a hot and sunny environment. This could also lead to issues of odour and infestation, but this could also occur with stored Soft Cup waste.

20. Issues with Hard Cups that have been stored for too long prior to washing might have to be discarded as developed odour cannot be removed.

21. The above issue in point 19 might be resolved with storage of dirty cups in a chilled environment prior to washing. This is not an aspect that has been considered in comparison to a Soft Cup system.

22. There could be safety reasons which do not permit the use of Hard Cups at a venue due to a potentially higher risk of injury. Even though PP makes for the softest material for Hard Cups, they are still heavier than Soft Cups.

23. It may be advised to use PP Hard or Soft cups instead of PLA or rPET cups due to the sinking of those polyester type cups in the event that an area of open water is present at the venue. A floating product is easier to collect.

24. It could be that the quantities of Hard Cups needed for an event are not available in a certain period of time in the year due to huge demand from multiple venues that all organise a festival in the same weekend.

25. Festivals might have less income from promotion if unbranded Hard Cups are to be used as a replacement for a Soft Cup with promotion. This could lead to higher ticket prices.

26. In this study, it is presumed that the % loss per serving is constant for every serving. In reality, this is unlikely to be the case. Would an older cup have a higher probability of being broken, i.e. would the percentage loss increase rather than remain constant? Equally, would a newer cup have a higher probability of being taken home and therefore still be lost to the system?

27. In a best case scenario, it is always the oldest cups that are lost to the system. If this were to happen, a Hard Cup system could go on indefinitely, simply replacing the x% of cups lost each serving. In a worst case scenario, it is always the newest cups that are lost to the system. If this were to happen, a Hard Cup system

would have to completely renew its original batch when they came to the end of their life. The reality will be somewhere in between, meaning there will always be some cups remaining in the system but without a track and trace system, it would be impossible to say how many cups and how many uses they have already had.

These barriers or challenges associated with using one or other cup system should be addressed to optimise the two systems prior to a further study of the resultant exact systems environmental impact.

Scenario 3) and 4) above are commonly referred to as potential scenarios, although within the context of this study, cups following these two scenarios would not have a guaranteed level of hygienic cleanliness. The impact of using the same cup for a second serving would have significant impact on the per serving environmental impact of the cup. It could be possible that a Soft Cup is used for a second serving, rendering the impact of the Soft Cup half that of if it was only used for a single serving. In the case of a Hard cup used twice between washes, the impact would be considerably lower but not halved, particularly at a low number of servings but even at high numbers of servings. For example, for the best Hard Cup system at 2% loss, the GWP at the 10th serving is 16.43 and at the 5th serving is 11.64. At the 50th serving, it is 54.75 and at the 25th serving, it is 30.80.

Due to the lack of data on the frequency of multiple servings between washes, the number of servings between washes and concerns as regards the guaranteed level of cleanliness of the cups, these multi-servings scenarios have not been modelled in this study.

Functional Unit

The functional unit in this study is a single serving of 250 ml of cold beverage, in a cup of a consistent hygienic quality.

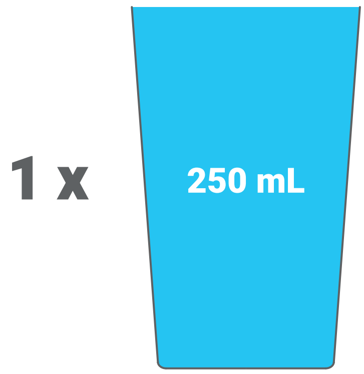


Figure 15: Illustration of the Functional Unit

Methodology

The methodologies as regards the LCA and the LCIA impact categories are described in Appendix A.

Hygiene

The hygienic aspects of reusable containers are a topic which is much discussed, as equivalent single use systems typically offer superior off-the-shelf cleanliness. To reduce the risk of cross-contamination in a reuse system, it is vital that the products are cleaned to a level which is comparable to a single use product.

The Central Research Question in this study states: “equivalent guaranteed cleanliness”. What is meant by this is that the hygienic condition of the reusable cups does not preclude any adverse effects to the health of the consumer. The cleaning of washware as cleaned with a multi tank conveyer dishwasher is described in DIN10510 see Table 3 below. This Norm also provides guidance on how the cleanliness of washware can be checked.

Scientific studies have shown that contact times in multi tank dishwashers of approximately 2 minutes and temperatures as listed above ensure the thorough removal of food residues and microorganisms. To conform to DIN10510, no more than 5 cfu1/10 cm2 should be found on the surface using a “contact slide test”.

Table 3: DIN 10510		
DIN 10510 - Multitank Transport Dishwashers		
Area	Temperatures without disinfection component (°C)	Temperatures with an adequate quantity of a disinfection component in the detergent solution (°C)
Fresh water pre-wash	up to 40	25 to 40
Pre-wash zone	40 to 50	40 to 50
Wash tank	60 to 65	55 to 65
Auxilary rinse	60 to 70	60 to 70
Fresh water rinse	80 to 85	80 to 85

The Hard Cup washing companies involved in this study all work according to this DIN standard and deliver a product which is washed according to strict rules; some even provide guarantees of cleanliness to various HACCP, DIN and FSSC norms. The rinsing in cold water with detergent of cups during an event does not guarantee a clean product and could therefore not be an alternative scenario.

At the current time, concerns as regards contamination are central to many consumers thinking. Various government/academic organisations have produced documents recommending cleaning procedures to be adopted.

"Simply rinsing the beer glasses in cold water with a rinsing agent is not sufficient. Machine dishwashing is preferable to hand dishwashing" (https://economie.fgov.be/nl/file/183976/download?token=FkrcOFut).

"Ware-washing at high temperatures with additional sanitizing procedures are standard in the industry and provide more than adequate protection against virus transmission" (https://storage.googleapis.com/planet4-international-stateless/2020/06/26618dd6-health-expert-statement-reusables-safety.pdf)

These types of recommendations would further bring into question the level of hygiene achieved when rinsing a cup with cold water, as is often the case at events.

Product Category Considerations

In order to make comparative assertions relating to the various cup types within the study it was necessary to perform several functionality studies and consider the cup differences, this being to ensure they qualify to be compared and that they are able to perform the function as described in the study Functional Unit. The approach and results of these functional tests can be seen in Appendix B. Appendix B also describes the method of cup weight assessment within this study.

Life Cycle Impact Factors

An LCA does not demonstrate any direct linkage between cause and effect; its results act as a directional indicator. It should be noted that LCIA impact indicators are useful in terms of assessing the direction of relative movement between product or system designs. However, they should not be considered as an absolute value.

Global Warming Potential is adopted as it is a very commonly used impact indicator. Water Resource is adopted due to questions around water consumption within the washing system. Cumulative Energy Demand is a total of the energy demand embodied in the product and system. This leaves a large number of other impact factors that need to be addressed. This is achieved by using a weighted method, notably ReCiPe, which covers a large number of impact factors. The methodology associated with these four impact categories is to be found in Appendix A.

The use of these four methods of impact factor should provide a robust representation of the direction of movement in environmental impact between product and system choices. Such choices should be aligned with the sustainable practice blueprint defined within the United Nation Sustainable Development Goals (SDGs).

Their relation to the chosen LCA impact factors can be seen below:

- Global Warming Potential (GWP – kg CO_2eq) – SDG No.13 Climate Action
- Water Resource (H_2O – m^3)– SDG No.6 Clean Water and Sanitation
- Cumulative Energy Demand (CED - MJeq) – SDG No.7 – Affordable and Clean Energy
- ReCiPe (Total – total endpoints) – SDG Nos. 3 Good Health and Well-being, 14 Life Below Water, 15 Life on Land

Figure 16: UN Sustainable Development Goals

3

Main Part of Study

Topics

The Cups

The cups are divided into two groups as follows:

1. Hard Cups – those being cups designed to be reused
2. Soft Cups – those being cups designed for single use

As regards weaponisation, all cups have open tops (unlidded) to avoid being filled and thrown as a projectile.

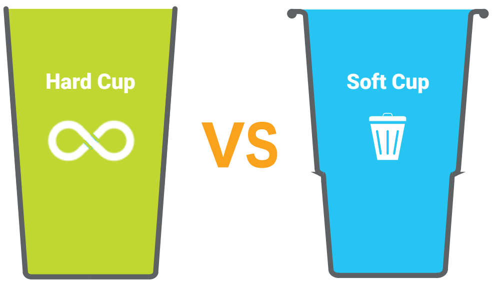


Figure 17: Illustration of a Hard Cup and Soft Cup

Hard Cups

The Hard Cups within this study are injection moulded polypropylene (PP) cups. Three common sources of these cups are mentioned on the intake form filled out by the parties involved in this study, these being from Ecocup (France), Cupking (Spain) and Dutch Cups (The Netherlands).

The Hard Cups will be referred to as (H)PP 1, (H)PP 2 and (H)PP 3. This numbering does not follow the order of the names of the Hard Cup manufacturers above.

Unlike the Soft Cups, the Hard Cups are all very similar, using the same raw material, conversion processes and printing type. The shape and strength are also very similar. The Hard Cups weights are spread between 25.39g to 33.23g.

Figure 18: The Hard Cups

Soft Cups

The Soft Cups within this study are thermoformed from extruded sheet made of either polypropylene (PP), recycled polyethylene terephthalate (rPET) or Polylactide (PLA) granule. Four sources of these cups are mentioned on the intake form filled out by the parties involved in this study, the sources being Huhtamaki, Paccor, Propac and Bordex.

The Soft Cup weights are spread between 4.40g to 7.33g.

Due to various pieces of missing information in the intake forms and to simplify the approach to the study, the Soft Cups will be modelled based on the above cups and sources only. The following sensitivities will be addressed:

1. As regards the Soft Cups, only one of the cups is unprinted, hence all cups will be modelled with printing. It should be noted that the EU Single Use Plastics Directive is to require single use beverage cups to have plastic content warning markings as of mid 2021. It is possible that these markings may also have to be printed on the cups.

2. Each cup within this study is considered as having been manufactured using local national energy and a European energy mix figure. This sensitivity is required due to the significance of manufacturing energy in the conversion processes and the possibility that the converter could be using energy other than that which is reported as locally available. Hence, the use of a European energy mix figure is also adopted across all cup types, in order to set a level playing field.

3. Transport types and transport distances can vary. A default delivery from the cup manufacturer to central Netherlands (Utrecht) will be modelled, and thereafter extremes of distance within the Netherlands are modelled as required by the systems.

Cup Weight Comparison

The average Soft Cup weights 23% of the (H)PP 3 Hard Cup, 17% of the (H)PP 2 Hard Cup and 21% of the (H)PP1 Hard Cup. On average, the Hard Cups under study are 5 times heavier than the average Soft Cups.

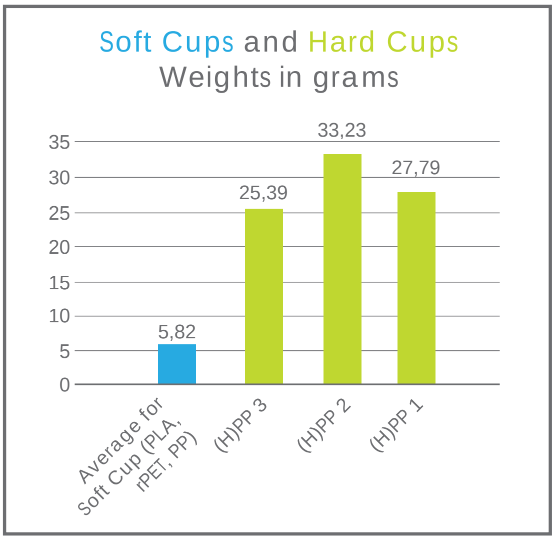


Figure 19: Soft Cups and Hard Cups Weight

Raw Materials

The cups within this study are manufactured from PP, rPET and PLA plastic granules. While such cups are traditionally referred to by their material names, such as “PP cup” or “rPET cup”, it is important to understand that the raw material only makes up a portion of the cup life cycle impact. The numerous studies of reuse cups versus single use cups do not typically focus significantly on the non-material aspects of the cup life cycle.

Raw material types have differing physical and mechanical performance characteristics and yields, may require additional raw material packaging or logistics, may require additional processes and different processing parameters, and will contribute different impacts based on end-of-life scenarios. Hence, it was seen as important to focus more extensively on the non-raw material impacts within this study, to the extent to which it is possible to do so in a generic study of this type.

The Soft Cups in this study are manufactured by thermoforming extruded sheet. This form/cut/stacking process produces skeletal waste (as round cups are cut from a flat sheet-based roll). This skeletal waste is ground into flakes and reused, to varying degrees, in the extrusion process. This material is referred to as regrind in this study and should not be confused with recycled/recyclate which occurs after the cup is used. Exceptions to this rule exists where direct quotations are taken from technical data sheets, at which point the meanings will be clarified.

There are considerable differences in the Polypropylene and Polyester (rPET and PLA) materials and their conversion processing.

Polypropylene

For the manufacturing of the PP Hard and Soft Cups, the granules are assumed to be delivered by road tankers from a local source.

Hydrophobic materials like PP cannot absorb any significant amount of moisture. Any moisture that could be present in these materials will remain on the surface of the pellets and seldom rises to a level greater than 0.01%, not enough to cause any cosmetic or structural problems. Hence, drying is not commonly required for PP and is not part of the conversion process within this study as relates to PP cups.

PP regrind derived from thermoforming skeletal waste can be added back into the conversion process without further treatment.

Polyesters

The polyester cups in this study are the rPET and PLA cups. Polyesters suffer irreversible structural damage due to hydrolysis and hence require to be dried and agitated within the conversion process. This can be carried out by an inline or offline dryer adapted for polyester agitation and drying. Issues related to the crystallization of the amorphous skeletal waste regrind also has to be considered.

rPET

Recycled polyethylene terephthalate (rPET) is assumed to be used at the level of 100% in the rPET cups. Where reference is made to a lower percentage figure, the cups are modelled with the reported level of rPET and the associated remaining percentage level of virgin PET.

rPET granulate is assumed to be delivered by road tankers from a local source. The Ecoinvent v3.5 dataset for rPET assumes the material is supplied as a granulate. It should also be noted that within this dataset 1.25kg of post-consumer PET is added to the process to produce 1kg of rPET granulate, the dataset specifically describes the process as commencing with bales of post-consumer PET.

While rPET can be supplied as either a flake or a granule or a mixture of both, the choice of granule is derived from information on one of the rPET Soft Cup manufacturers website.

Since water causes hydrophilic degradation (intrinsic viscosity breakdown), rPET must be dried to a low moisture level before melt extrusion; a significant reduction in intrinsic viscosity, i.e., molecular weight, will result in a reduction in physical properties, particularly impact strength.

Typical drying times is between 4 to 6 hours.

During the thermoforming process to form the rPET soft cups, there is a significant amount of process skeletal waste or regrind; this amorphous regrind must be crystallized prior to drying to ensure that agglomeration problems do not occur. This type of process requires the regrind to be subject to a set temperature for a number of hours, typically in a rotating drum with air or infra-red warming. If this crystallized regrind is warm, it can be immediately reused in the extrusion/thermoforming process.

Alternative systems exist using twin screw extruders that can take mixed PET regrind and directly produce high-quality thermoformable sheet.

There are a variety of LCIA datasets for recycled PET in Ecoinvent v3.5. The dataset with the lowest GWP is a Swiss dataset with a very low GWP approaching that of the GWP of extrusion processing which is required for conversion of flakes to granules only, while many other energy consuming processes exist in the recycling process.

Additionally, the rPET granule source for the cups in this study is not necessarily Switzerland and the Swiss GWP/kWh figure is lower than the average European figure by a factor of 4.5 times. Hence, this Swiss dataset has not been adopted.

A Europe-minus-Switzerland figure has been adopted which aligns more with the GWP in studies such as those of Franklin Associates (Life Cycle Impacts for Postconsumer Recycled Resins: PET, HDPE, AND PP. December 2018).

PLA

Polylactide (PLA) is currently available from limited sources. Typically, PLA would be sourced from NatureWorks in Nebraska USA (a study member mentioned Thailand and USA against NatureWorks but the NatureWorks website only mentions Nebraska USA and Thailand is PTT). The PLA LCIA data in this study is from Ecoinvent v3.5, as is all other such data for materials within this study. This Ecoinvent data set refers to PLA from Nebraska.

PLA is produced by a condensation reaction. This reaction, which also produces water, is reversible. Therefore, when undried PLA is melted, the resin and water chemically react. Hydrolysis occurs and key mechanical properties of the PLA are reduced. This hydrolysis reaction also changes PLA melt viscosity and the crystallization rate, making it very difficult to process into a quality end product. Hence, there is a requirement for specific watertight raw material packaging types, drying within the process and potential crystallization of skeletal waste regrind dependent on the levels of such waste.

PLA is supplied in Octabins with laminated liners in which one of the layers is aluminium to provide a barrier to moisture. NatureWorks processing documentation states, “Material is supplied in foil-lined containers” and “The resin is sold in boxes with moisture resistant foil liners to maintain that moisture level” (Crystallizing and Drying of PLA – NatureWorks PDF).

PLA also requires drying and the drying time is expressed as between 2 to 4 hours. NatureWorks documentation refers to drying as being “absolutely essential”.

During the thermoforming process to form the PLA soft cups, there is a significant amount of process skeletal waste or regrind. This regrind from clear thermoformed cups is highly amorphous and there is a maximum limit for which amorphous regrind can be immediately added to the process if dry. Any amorphous regrind that is not dry and immediately used will require a further period of up to 12 hours of drying.

However, NatureWorks state “most processors of recycled PLA choose to crystallize the recycle in order to eliminate any problems with drying’’. Hence, depending on the specific process, all or part of the regrind may require to be crystallized. Crystallized regrind can be added back to the process up to 100% with no loss of either process control or sheet properties. Hence, heating, and agitating crystallizing equipment is likely to be used in the PLA cup conversion process.

Documents related to the processing of NatureWorks PLA is to be found in Appendix B.

Conversion Processes

The conversion processes related to the cups within this study are:

1. Drying – for rPET and PLA Soft Cups
2. Crystallization – for rPET and PLA Soft Cups regrind
3. Sheet Extrusion – for PP, rPET and PLA Soft Cups
4. Thermoforming – for PP, rPET and PLA Soft Cups
5. Offset printing for Soft Cups
6. Injection moulding for PP Hard Cups
7. In-mould printed labels for PP Hard Cups
8. Those processes required to manufacture the packaging for raw materials and finished goods

Although reference is made above to various additional processes that occur in the production of cups made from polyesters beyond extrusion and thermoforming, the conversion process modelled only considers additional energy for drying. The conversion process models do not consider differences in processing temperatures.

All Soft Cups are thermoformed from extruded sheet, with the removal of round cups from a sheet producing a large amount of skeletal waste, approximately 48%. This skeletal waste is drawn off the thermoforming machine into a regrind machine to produce plastic flake for later reintroduction back into the manufacturing process.

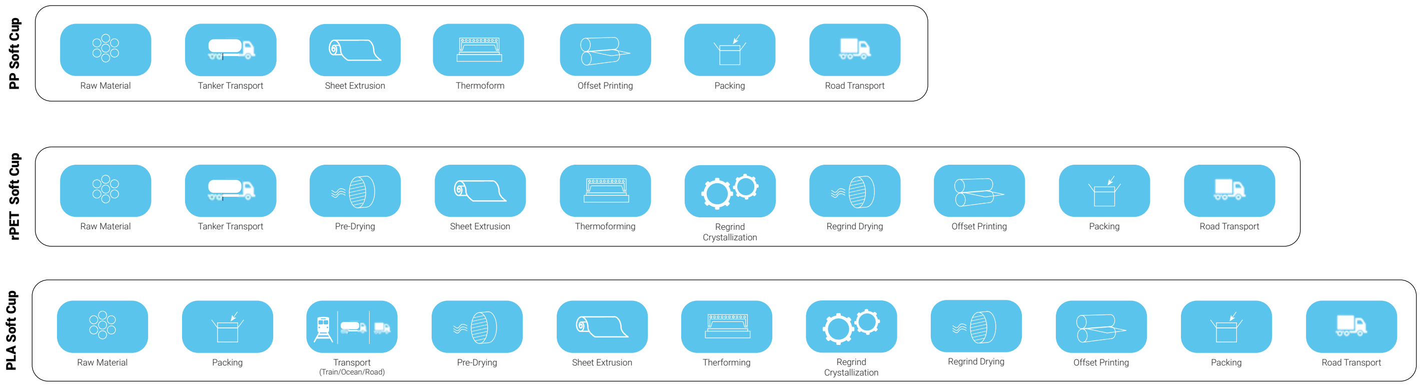


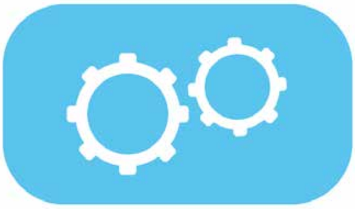
Figure 20: Soft Cups - Life Cycle Stages from Raw Material to Delivered Cups

In an ideal situation, the converter process of each cup would be studied for the collection of specific life cycle inventory data.

Drying Process

A general figure for the process of drying polyesters is adopted, sourced from the study LIFE11 ENV/IT/000184 (2014) in which 1kg of PET was dried at a consumption of 0.82kWh, the energy for this process being electrical energy, modelled in this study based on medium voltage electricity for the country of production and on average

European medium voltage electricity.



Crystallization Process

The crystallization process has not been accounted for in the modelling but is mentioned within the text to show that different materials require additional processes. These processes would be best accounted for in a specific study of the relevant polyester soft cup manufacturers process.

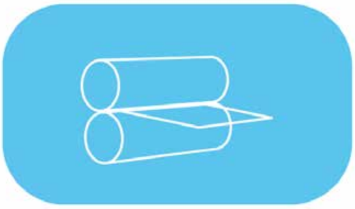
Extrusion and Thermoforming Process

The forming process for the Soft Cups involves the extrusion of a sheet from which the cups are then thermoformed. Within this study, it is assumed that both processes are inline, as would be most efficient. The Ecoinvent v3.5 Inline extrusion and thermoforming LCIA dataset is used within this study for all Soft Cup types.

It is assumed that for each 1.0kg of plastic granule entering the process, there will be an output of 0.94kg of cups. The process involves in-process recycling of the skeletal waste and open loop recycling of 0.06kg related to start up waste.

The energy for this process is electrical energy, modelled in this study based on medium voltage electricity for the country of production and on average European medium voltage electricity.

Product weight tolerance varies by 5% for thermoformed cups. This tolerance is addressed in the BCT identification of the breakeven point between processes.



Offset Printing Process

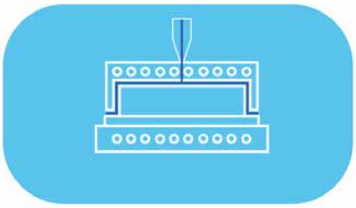
Several of the Soft Cups are printed. It is assumed that the Soft Cups are printed within their production facility.

The printing process adopted for the printing of Soft Cups within this study is offset print (OSMO KeyCup 7 colour). This process prints 400 cups/minute using 900 litres of compressed air (6 bar) per minute and consuming 30kW.

The energy source for this process is electrical energy, modelled in this study based on medium voltage electricity for the country of production and on average European medium voltage electricity.

Cup rejection waste throughout the printing process is assumed to be 2% (based on previous study experience).

Due to the varying coverage and weight of ink on cups, no account for the ink itself is taken up in this study.

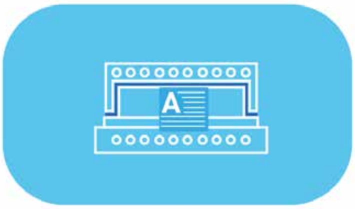


Injection Moulding Process

Injection Moulding is the process used to manufacture the Hard Cups, which are all manufactured from PP in this study. In an injection moulding process, PP granules are melted and injected into a forming tool. It is assumed that for each 1.0kg of plastic granule entering the process, there will be an output of 0.99kg of cups. The Ecoinvent v3.5 injection moulding LCIA dataset is used within this study for all Hard Cup types.

The energy source for this process is electrical energy, modelled in this study based on medium voltage electricity for the country of production and on average European medium voltage electricity.

Product weight tolerance varies by 2% for injection moulded cups. A tolerance of 5% is addressed in the BCT identification of the breakeven point between processes.



In-Mould Labelling

The sampled printed Hard Cups have printed in-mould labels. It is assumed that these labels are sourced locally to the Hard Cup manufacturing supplier. In-mould label weight, skeletal waste, extrusion, printing, and printing ink are taken up in the in-mould label model. Average Hard Cup surface area was computed, using Solid Works software, as being 0.0231m2. One of the Hard Cup suppliers confirmed their in-mould label to have a thickness of 0.1mm, based on shape and density the label weight is assumed to be 2.12g plus 15% skeletal waste. This inventory data was used to model the in-mould label.

The energy source for this process is electrical energy, modelled in this study based on medium voltage electricity for the country of production and on average European medium voltage electricity.

Energy as regards the Processes

The cups within the study are manufactured in various European countries. Energy use in the conversion of the cups is predominately electricity and from these various countries. Market for medium voltage electricity is used for each country.

Each cup within this study is considered as having been manufactured using local national energy and a European energy mix figure. This sensitivity is required due to the significance of manufacturing energy in the conversion processes and the possibility that the converter could be using energy other than that which is reported as locally available.

Hence, to remove differences in country of conversion energy impact, a European Average figure is adopted for all production locations. This permits the understanding of the sensitivity of the various national energy impacts. It is to be noted that the raw material datasets used within the

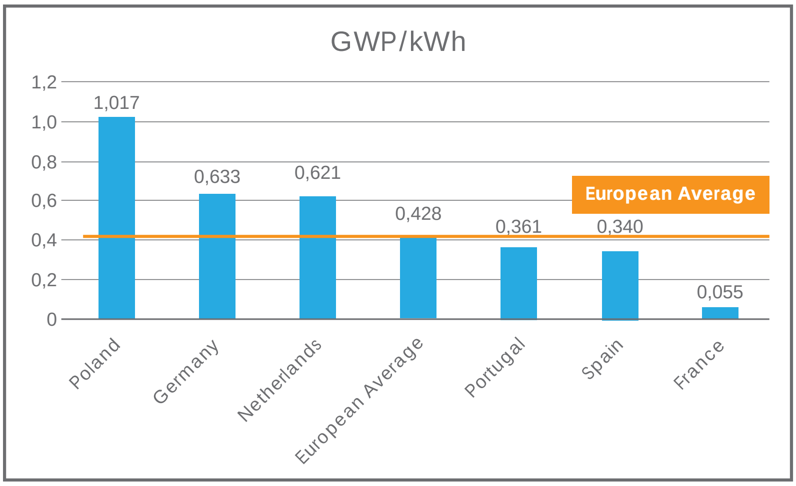


Figure 21: GWP/kWh of Medium Voltage Electricity in Cup Manufacturing Countries

models in this study are already based on a European average figure, as is typical of material secondary data within such studies.

Transport

Both the raw materials and the final formed cups are required to be transported between the various destinations. All journeys in Europe will use:

- Euro 6 >32 metric ton lorries for raw materials
- Euro 6 16-32 metric ton lorries from the cup manufacturers
- Euro 6 3.5-6 metric ton lorries for journeys within the Hard Cup reuse system

External to Europe is the manufacture of the PLA granulate, this will involve train, ship and road transport. The train transport is assumed to be USA diesel freight train, the sea transport being transoceanic ship and the road transport being Euro 6 >32 metric ton lorries.

Transport sensitivity has been addressed by taking the average of the closest and second closest recycling and incineration facilities for the end-of-life scenario of the Soft Cups.

One of the Hard Cups is listed on their website as being manufactured in one of three sites in France. One of the event organisers identified the cups as being manufactured close to a specific city, this was correlated with the closest manufacturing site, which was used to model this Hard Cup.

Another Hard Cup was listed as being manufactured in Spain, no exact location in Spain was identified and hence a central point in Spain was used to model this Hard Cup.

Transport within the reuse system in the Netherlands was calculated based on the various festival locations, the cup washing facilities, the material recycling installations, and the incinerators.

1. The average distance between the festivals and the closest cup washing facility is 77.67km. The average distance between the festivals and the second closest cup washing facility is 98.01km.

2. The average distance between the festivals and the closest cup recycling facility is 107.33km. The average distance between the festivals and the second closest cup recycling facility is 158.34km. In the case of the PLA cup, the PLA recycling facility is in Belgium at a distance of 227km.

3. The average distance between the festivals and the closest waste incinerator is 56.91km. The average distance between the festivals and the second closest waste incinerator is 73.35km.

An average of the closest and second closest distance between the festival and the above facilities is used in the modelling of the transport impact.

Hard Cup washing requires two journeys, to and from the festival, and EoL requires a single journey.

The Hard Cup transport between the washing companies and the festivals is based on transporting the weight of the cups in a crate

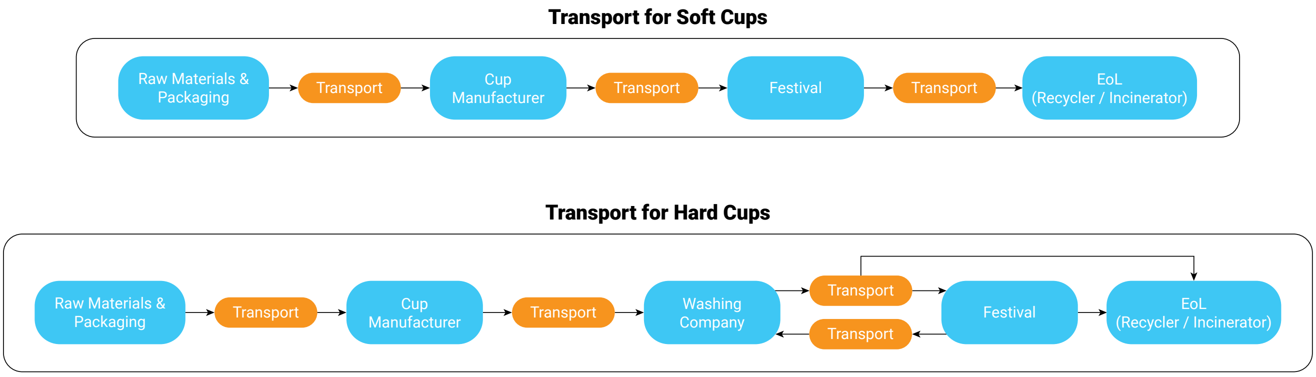


Figure 22: Transport of Soft and Hard Cups

Table 4: Location of Manufacturer and Distance to Utrecht, The Netherlands		
Cup Type	**Country**	**Distance (km)**
Hard Cup	France	845
Hard Cup	Spain	1740
Hard Cup	Netherlands	65
Soft Cup	Germany	280 - 360
Soft Cup	Poland	1110 - 1170

with a film bag liner. The transport from the festivals to the recycling or incineration facilities, of both cup types, is based on purely the weight of the cups as it is not known in what type of container any waste cups will be collected.

Packaging

All Soft Cups are delivered in polyethylene film sleeves within carton boxes. One party to the study stated they were receiving PLA Soft Cups in PLA sleeves. However, the PLA cup manufacturer stated they had never supplied in PLA sleeves. This sleeve-based packaging configuration is designed to keep the Soft Cups clean prior to use. Hard Cups are delivered from the cup manufacturer in carton boxes without an inner plastic liner, as these cups are washed before use.

Every PP and PLA Soft Cup is reported as being packed 100 cups/sleeve and 2500 cups/box. Where the rPET packaging configuration in the intake forms is filled in, it suggested that the packaging is 100 cups/sleeve and 2000 cups/box from the manufacturer of rPET 2, and 50 cups/sleeve and 1250 cups/box from the manufacturer of rPET 1. The rPET 3 cup packaging was confirmed by its manufacturer as 50 cups/sleeve and 1250 cups per box.

Every new single use Soft Cup supply requires these same sleeves and cartons. For every new reusable Hard Cup, a carton is required and no sleeve. However, once the Hard Cup is within the reuse cycle, they no longer require cartons. Instead, they are transported in crates, with a PE

Table 5: Soft Cup Packing Array			
SOFT CUPS			
Print	**Cup Ref. No**	**Qty/Sleeve**	**Qty/box**
Yes	PLA 1	100	2500
Yes	rPET 1	50	1250
Yes	rPET 2	100	2000
No	rPET 3	50	1250
Yes	PP 1	100	2500
Yes	PP 2	100	2500

film liner bag, specifically designed for cup reuse systems.

The (H)PP 3 Hard Cups and (H)PP 1 Hard Cups are packed 500 cups/ carton and the (H)PP 2 Hard Cups are packed 300 cups/carton.

Sleeves

All Soft Cup packaging included polyethylene film sleeves, and these are included in the cup model. Hard Cup reuse crates also include a plastic bag liner which is incorporated into the Hard Cup models. Sleeves and liner bags have been taken up within this study with the weight and type being supplied by the cup manufacturers or washing facilities, with Soft Cup sleeve weight averaging 0.075g/cup.

Cartons

Corrugated carton boxes are included in all Soft Cup models, the weight being supplied by the cup manufacturers. Corrugated carton boxes are included in the Hard Cups study but only for the first journey from the cup manufacturer to the washer. The use of carton box PP sealing tape and its associated adhesive layer has been modelled within the study with the average tape weight of 1.71g/carton. Soft Cup carton weight being approximately 0.9g/cup and Hard Cup being 2g/cup.

Reuse Crates

Reuse crates are used to transport Hard Cups within the festival/washing process. These reuse crates are then unloaded and cleaned.

All reuse crate materials, production processes, transports and washing are included in the system model. All reuse boxes are assumed to be manufactured in Germany. Three crate weights and quantities of cups per crate were reported by the washing companies from 3g/cup to 7g/cup.

The reuse boxes are a two-part construction made of injection moulded PP. The quantity of stacked cups within the boxes varies based on the design of the cups.

Figure 23: Example of a Reuse Crate

End-of-Life Scenarios

In this study there are three end-of-life scenarios as follows:

Recycling – various recycling percentages are adopted for the Soft Cups, all collected Hard Cups are recycled after the end of their useful life.

Incineration – those Soft Cups that are not recycled are incinerated.

Lost – an amount of Hard Cups are lost to the system with an unknown end-of-life scenario; these are cut-off from the system at the point they are lost. Typically, these Hard Cups will be taken home as souvenirs and as such, it cannot be know if they end their useful life in the recycling or incineration system.

Discarded - the washing companies, which incur a small number of Hard Cup rejections based on reduced quality, confirmed that these discarded Hard Cups are sent for recycling.

At various points within the study, mention is made of litter which is a likely end-of-life scenario for a portion of the cups within this study. Litter has not been modelled for this study.

Systems Losses

At each stage within the study, raw material and cup losses are reported and modelled, such as during the production, printing, and washing stages.

As regards losses within the festival itself, in the Plastic Promise report "Resultaten Plastic Promise 2019: een nieuwe norm voor Nederlandse evenementen is gezet: hergebruik of recycling!" it was reported that:

1. 80 to 98% of Hard Cups were returned for reuse when a deposit return system is adopted.
2. 41 to 92% of Soft Cups are returned and recycled when a deposit return system is adopted; however, when the deposit return system is not adopted and the cups are put into waste bins, the resultant cups are between 0 and 75% recycled.

Hard Cup Losses

In this study, Hard Cups will be studied based on the percentage loss entered into the BCT. This loss is assumed to be cups taken as souvenirs with an unknown end-of-life and as such are modelled as cut-off.

The method of accounting for the lost cups in the reuse system varies from the way in which material losses are accounted for in the raw material conversion processes:

1. For cup conversion raw material losses, the required output is divided by the net output figure.
2. For the Hard Cup reuse system, the loss is accounted for by replacing the lost cups with new cups at each reuse. The remaining cups are each divided by the number of uses they have been subjected to.

It is not the intention of the authors to imply that the latter may be the only way to account for lost Hard Cups, when considering the number of uses they would have had prior to their loss.

Increased Hard Cup loss percentages can contribute heavily to the environmental impact of the Hard Cup system. There is a potential conflict between the cup supplier company and the environmental impact, as both the event and the cup supplier benefit from non-returned cups against which a deposit has been paid. Hence, the only motivation for returned cups is to protect the environment.

It could be questioned that the financial model related to cup rental is not designed to encourage reuse. One Hard Cup supply company website reports charging €0.05 per cup, €0.05 per wash, a non-return cup charge of €0.50 per cup, and a €500 one-time charge for transport. Were an event to charge €3.00 per cup deposit across 100,000 cups, they would only have to lose 4.2% to still end up with no cost related to the reuse Hard Cup system. Taking the Plastic Promise 2019 20% Hard Cup loss, the event would achieve an additional net earnings of €40500.

These net earnings are income for the event organiser whereas Soft Cups are a cost, minus a potential smaller income from the raw material recycler. It could be that this income motivates the use of a Hard Cup system over a Soft Cup system, however it comes at the cost of lost cups which is counter to the environmental objective. This income could also be used to pay for any additional onsite labour associated with the Hard Cup system management.

While the €3.00 deposit is an incentive for the attendee, the incentive level for the event itself is potentially too small. As a result, the level of the non-returned cup charge set by the cup rental company may need to be reconsidered.

Soft Cup Losses

For this reason, the study adopts a number of Soft Cups waste related scenarios as follows:

- 0% recycled – 100% incinerated
- 25% recycled – 75% incinerated
- 41% recycled – 59% incinerated
- 50% recycled – 50% incinerated
- 75% recycled – 25% incinerated
- 92% recycled – 8% incinerated
- 98% recycled – 2% incinerated

Cups that are not recycled are considered to be incinerated.

While the effects of littering cannot be calculated, it should be noted that Soft Cups could be lost from the system due to littering, particularly as single use Soft Cups are commonly found littered at open air events. Litter is a powerful driver for societal change and could be negatively associated with Soft Cups.

Breakeven Calculation Tool (BCT)

The BCT has been developed to simulate the above Hard Cup loss scenarios, including the reuse system activities (i.e. washing, transports, crates), in comparison with the single use Soft Cup system, permitting the addition of loss percentage input. This facilitates the computation of the breakeven point across all variables and all Hard Cup loss percentages. A screenshot of the BCT can be seen in Figure 24 below:

Number of cups in the system:	100	Washing company:	GWP $kgCO_2$-eq/cup
% of lost/discarded cups:	2	Company A	0.005545664

Hard Cup (HC):	GWP $kgCO_2$-eq/cup			
	Hard Cup	Crate	Transport to Wash	Transport EoL
(H)PP 1 National	0.09196000	0.02299000	0.001543708	0.001402869

Select scenario for Soft Cup and transport: Case 4: 75% collected / 75% recycled - National Energy

	National Energy or European Energy					
	PLA 1 (SC)	rPET 1 (SC)	rPet 2 (SC)	rPet 3 (SC)	PP 1 (SC)	PP 2 (SC)
GWP of single use cups (Soft Cup):	0.035490	0.033870	0.027980	0.034300	0.021120	0.019840
GWP end-of-life transport to recyler (SC):	0.000337	0.000338	0.000370	0.000315	0.000237	0.000222

	Reusable cup (HC)		PLA 1 (SC)		rPET 1 (SC)		rPet 2 (SC)		rPet 3 (SC)		PP 1 (SC)		PP 2 (SC)	
Servings, n	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings
1	10.07	0.1007	3.58	0.0358	3.42	0.0342	2.84	0.0284	3.46	0.0346	2.14	0.0214	2.01	0.0201
2	11.13	0.0557	7.17	0.0358	6.84	0.0342	5.67	0.0284	6.92	0.0346	4.27	0.0214	4.01	0.0201
3	12.20	0.0407	10.75	0.0358	10.26	0.0342	8.51	0.0284	10.38	0.0346	6.41	0.0214	6.02	0.0201
4	13.27	0.0332	14.33	0.0358	13.68	0.0342	11.34	0.0284	13.85	0.0346	8.54	0.0214	8.02	0.0201
5	14.33	0.0287	17.91	0.0358	17.10	0.0342	14.18	0.0284	17.31	0.0346	10.68	0.0214	10.03	0.0201
6	15.40	0.0257	21.50	0.0358	20.52	0.0342	17.01	0.0284	20.77	0.0346	12.81	0.0214	12.04	0.0201
7	16.47	0.0235	25.08	0.0358	23.95	0.0342	19.85	0.0284	24.23	0.0346	14.95	0.0214	14.04	0.0201
8	17.54	0.0219	28.66	0.0358	27.37	0.0342	22.68	0.0284	27.69	0.0346	17.09	0.0214	16.05	0.0201
9	18.60	0.0207	32.24	0.0358	30.79	0.0342	25.52	0.0284	31.15	0.0346	19.22	0.0214	18.06	0.0201
10	19.67	0.0197	35.83	0.0358	34.21	0.0342	28.35	0.0284	34.62	0.0346	21.36	0.0214	20.06	0.0201

Figure 24: Screenshot taken of the GWP BCT

A full explanation of the BCT and its associated calculation methods can be seen in Appendix D.

When reporting on a breakeven number of servings derived from the BCT, variances in impact of 5% or under (between the Hard and Soft Cup impact figure) will be considered to be the same. In Table 6 below:

- The green cells represent the number of servings in which the Soft Cup has a lower impact than the Hard Cup.
- The red cells represent the number of servings in which the Hard Cup has a lower impact than the Soft Cup.
- The serving where the first red cell appears is the breakeven point. The serving number related to the first red cell is reported as the breakeven serving.

A further part of the BCT considers the sensitivity of cup weight tolerance. Yellow cells in Table 6 below mark the number of servings in which the Soft and Hard Cups are within 5% of the breakeven point, this being considered due to the typical tolerances in thermoformed Soft Cup weight (5%) and injection moulded Hard Cup weight (2%).

Graphs derived from the BCT provide a visual aid to the resultant data, as can be seen in Figure 25 and Figure 26 below.

The BCT also computes the impact of the various Hard Cup system products and processes per serving. It can be seen below in Table 7 that the cup impact in the 17th serving is below that of the washing and by the 11th serving the cup is below half of the total system GWP.

It is important to note that the figures in this section of the report have been based throughout on a 100 cup system so that the impacts can be seen as percentages. Actual systems used will be much larger than this.

For example, for system of 100 000 cups, the impact figures seen in the report will be multiplied by 1000. Figure differences that appear small in terms of percentage will be much larger in terms of actual figures.

Table 6: Yellow Cells in BCT +/- 5% of the Breakeven Point

Servings	PLA 1	rPET 1	rPET 2	rPET 3	PP 1	PP 2
1	67%	69%	75%	69%	82%	83%
2	40%	44%	55%	43%	67%	69%
3	18%	24%	39%	22%	54%	57%
4	0%	6%	25%	5%	44%	47%
5	-16%	-8%	13%	-10%	35%	39%
6	-29%	-21%	3%	-23%	28%	32%
7	-41%	-32%	-6%	-35%	21%	26%
8	-51%	-42%	-13%	-44%	15%	20%
9	-61%	-50%	-20%	-53%	10%	15%
10	-69%	-58%	-26%	-61%	6%	11%
11	-76%	-65%	-32%	-68%	1%	7%
12	-83%	-71%	-37%	-74%	-2%	4%
13	-89%	-76%	-41%	-80%	-6%	1%
14	-94%	-81%	-45%	-85%	-9%	-2%
15	-99%	-86%	-49%	-90%	-11%	-5%
16	-104%	-90%	-53%	-94%	-14%	-7%

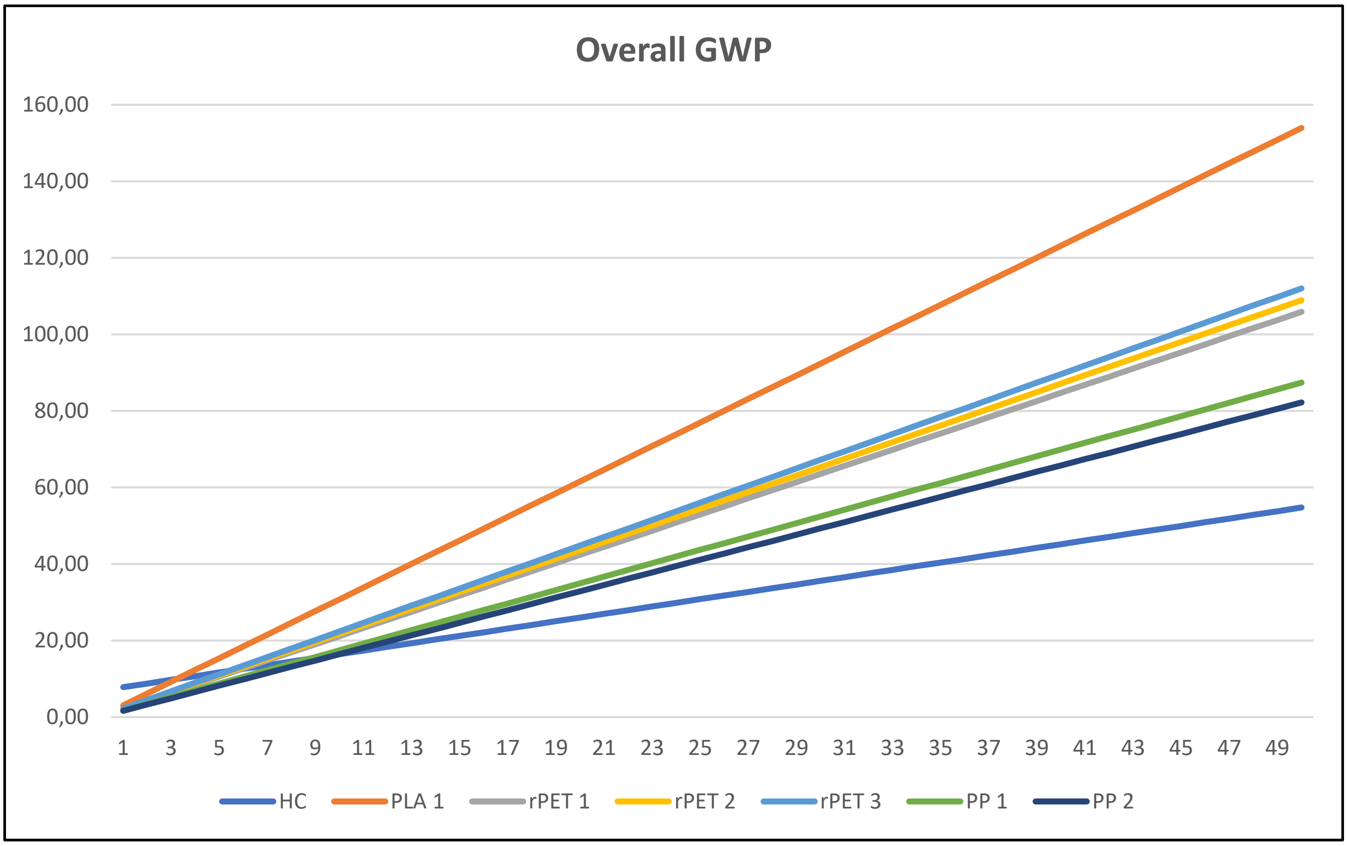


Figure 25: Graph of Overall GWP for Hard and Soft Cups

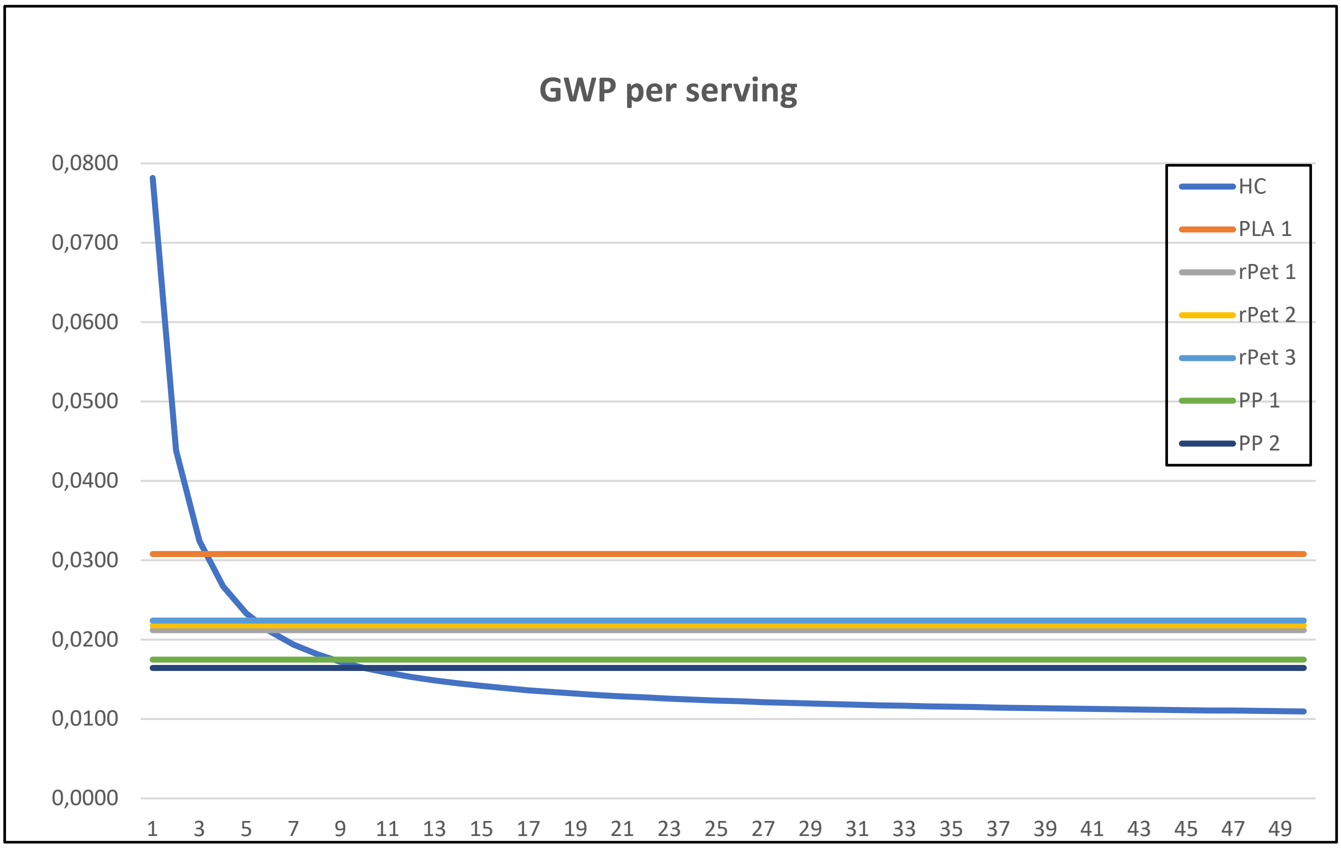


Figure 26: Graph of GWP per serving for Hard and Soft Cups

Table 7: Contribution per serving of Hard Cup Products & Processes

Servings	% Cup	% Crate	% Washing	% Transport event - washer	% EoL Transport
1	89.53%	0.13%	7.10%	1.64%	1.61%
2	81.35%	0.24%	12.65%	4.34%	1.43%
3	74.77%	0.32%	17.10%	6.51%	1.29%
4	69.38%	0.39%	20.76%	8.30%	1.18%
5	64.88%	0.45%	23.81%	9.79%	1.08%
6	61.06%	0.50%	26.40%	11.05%	1.00%
7	57.77%	0.54%	28.63%	12.13%	0.93%
8	54.93%	0.57%	30.56%	13.08%	0.87%
9	52.43%	0.60%	32.25%	13.90%	0.81%
10	50.23%	0.63%	33.75%	14.63%	0.76%
11	48.26%	0.66%	35.08%	15.28%	0.72%
12	46.51%	0.68%	36.27%	15.86%	0.68%
13	44.93%	0.70%	37.34%	16.38%	0.65%
14	43.49%	0.72%	38.31%	16.86%	0.62%
15	42.19%	0.74%	39.20%	17.29%	0.59%
16	41.00%	0.75%	40.00%	17.68%	0.57%
17	39.90%	0.76%	40.74%	18.04%	0.54%
18	38.90%	0.78%	41.43%	18.38%	0.52%
19	37.97%	0.79%	42.06%	18.68%	0.50%
20	37.11%	0.80%	42.64%	18.97%	0.48%

Hard Cup Washing Process*

Within this study, data from four hard cup washing companies has been collected and built into a model. It should be noted that the inventory data supplied by the four washing companies is confidential, hence specific data will not be correlated to the company names within the study. The companies are all located in the Netherlands.

All of the four companies use a multi-tank conveyer dishwasher with a dryer section. From these companies, data on the number of cups and crates that can be washed per hour was collected together with information on electricity, water and detergent consumption. The quantity of cups that can be washed in one hour depends on the size of the machine and the selected speed of the conveyer. Within this study, the cups that could be washed per hour varied between and . for the different companies involved.

Multi-tank conveyer dishwashers mainly function in a similar way in terms of how water is used in the machine. Clean fresh hot water with a rinse aid enters the machine in the final rinse section. This water is collected in the tank underneath the rinse section and transported to the main wash section where the detergent is added to the water. The water is again collected in a tank underneath the main wash section and transferred to the pre-wash section. Between these steps, sieves are installed to remove larger impurities from the water. The dirty water then passes a heat exchanger where fresh water is heated with the wastewater. The slightly cooled wastewater is emptied into the sewage after this step.

The drying section is located after the final rinse station. Depending on the designed speed of the machine, multiple hot and cold air blowers are installed. Also, in this step, heat recovery systems are often installed to heat water with excess heat from the blow drying section in a heat exchanger.

Per company the following inventory data have been used:

Cup washing company A:

Location of wash plant:

Number of cups washed per hour:

Number of crates washed per hour:

Reported loss percentage:

Energy consumption per hour:

Water use per hour:

Detergent use per hour:

Washing machine Year of construction:

Cup washing company B:

Location of wash plant:

Number of cups washed per hour:

Number of crates washed per hour:

Reported loss percentage:

Energy consumption per hour:

Water use per hour:

Detergent use per hour:

**Due to concerns of intellectual property, data has been redacted from this chapter. The original data has been peer-reviewed*

Washing machine Year of construction:

Cup washing company C:

Location of wash plant:

Number of cups washed per hour:

Number of crates washed per hour:

Reported loss percentage:

Energy consumption per hour:

Water use per hour:

Detergent use per hour:

Washing machine Year of construction:

Cup washing company D:

Location of wash plant:

Number of cups washed per hour:

Number of crates washed per hour:

Reported loss percentage:

Energy consumption per hour:

Water use per hour:

Detergent use per hour:

Washing machine Year of construction:

Crate Washing

Three out of the four companies are able to wash the crates that are used to transport and store the cups in the same machine as is used for the washing of the cups. One company was not able to wash the crates in the same machine. Crate wash data from another company has been adopted for that situation. The amount of crates that could be washed per hour lies between

**Due to concerns of intellectual property, data has been redacted from this chapter. The original data has been peer-reviewed*

Systems Modelling

As input to the BCT, the environmental impact data is required for each part of two beverage serving systems. In the BCT screen shot on page 60 above, the example impact category is GWP; however, the three other impact categories also need to be included.

Each of the cup types and cup scenarios need to be modelled for input to the BCT as does the crate, washing system and transports. The reason for modelling these parts of the systems separately is described in the above chapter on Systems Losses that explains the background to the BCT.

Cup Manufacturing Impact

All cups that qualify for comparison within this study were modelled and their environmental impact reported below in line with the four environment impact categories.

Soft Cups

The Soft Cups were modelled based on the previously listed recycling and incineration percentage and for National and European manufacturing energy, resulting in 84 Soft Cup models per reported environmental impact category.

These models contain the raw materials, conversion processes, packaging, transports and end-of-life inputs, with the final destination of the Soft Cups being the central point in the Netherlands ready to be used by the festival events.

Transport after use is covered in the chapter below titled Cup Transport Impacts, as this relates to transport within the Netherlands as part of the cup system.

Table 8: GWP per Soft Cup per Recycling Percentage manufactured using National & European Energy Data

SOFT CUP - The Cup							
National Energy & European Energy							
Waste Scenario	Energy	GWP kgCO_2-eq/cup					
		PLA 1	rPET 1	rPET 2	rPET 3	PP 1	PP 2
0% recycled / 100% incinerated	National	0.04409	0.04425	0.03934	0.04398	0.03012	0.02827
25% recycled / 75% incinerated	National	0.04123	0.04079	0.03556	0.04075	0.02712	0.02546
41% recycled / 59% incinerated	National	0.03940	0.03858	0.03314	0.03869	0.02520	0.02366
50% recycled / 50% incinerated	National	0.03836	0.03733	0.03177	0.03753	0.02412	0.02265
75% recycled / 25% incinerated	National	0.03549	0.03387	0.02798	0.03430	0.02112	0.01984
92% recycled / 8% incinerated	National	0.03357	0.03152	0.02543	0.03211	0.01908	0.01793
98% recycled / 2% incinerated	National	0.03285	0.03068	0.02449	0.03134	0.01835	0.01726
0% recycled / 100% incinerated	European	0.04097	0.03357	0.03532	0.03395	0.02828	0.02652
25% recycled / 75% incinerated	European	0.03811	0.03011	0.03154	0.03073	0.02528	0.02372
41% recycled / 59% incinerated	European	0.03628	0.02790	0.02912	0.02866	0.02336	0.02193
50% recycled / 50% incinerated	European	0.03524	0.02664	0.02775	0.02750	0.02228	0.02091
75% recycled / 25% incinerated	European	0.03237	0.02318	0.02396	0.02428	0.01927	0.01810
92% recycled / 8% incinerated	European	0.03041	0.02084	0.02141	0.02209	0.01724	0.01622
98% recycled / 2% incinerated	European	0.02973	0.02000	0.02048	0.02131	0.01651	0.01551

Waste Scenario	Energy	PLA 1	rPET 1	rPET 2	rPET 3	PP 1	PP 2
Table 9: H_2O per Soft Cup per Recycling Percentage manufactured using National & European Energy Data							
SOFT CUP - The Cup							
National Energy & European Energy							
		H_2O m³/cup					
0% recycled / 100% incinerated	National	0.0023400	0.0001400	0.0001400	0.0001400	0.0000820	0.0000783
25% recycled / 75% incinerated	National	0.0023400	0.0001300	0.0001400	0.0001400	0.0000813	0.0000776
41% recycled / 59% incinerated	National	0.0023400	0.0001300	0.0001400	0.0001400	0.0000808	0.0000772
50% recycled / 50% incinerated	National	0.0023400	0.0001300	0.0001400	0.0001300	0.0000806	0.0000770
75% recycled / 25% incinerated	National	0.0023400	0.0001300	0.0001400	0.0001300	0.0000799	0.0000763
92% recycled / 8% incinerated	National	0.0023400	0.0001300	0.0001400	0.0001300	0.0000794	0.0000758
98% recycled / 2% incinerated	National	0.0023400	0.0001300	0.0001300	0.0001300	0.0000792	0.0000757
0% recycled / 100% incinerated	European	0.0023300	0.0001100	0.0001100	0.0001100	0.0000758	0.0000724
25% recycled / 75% incinerated	European	0.0023300	0.0001100	0.0001100	0.0001100	0.0000751	0.0000717
41% recycled / 59% incinerated	European	0.0023300	0.0001100	0.0001100	0.0001100	0.0000746	0.0000713
50% recycled / 50% incinerated	European	0.0023300	0.0001100	0.0001100	0.0001100	0.0000744	0.0000711
75% recycled / 25% incinerated	European	0.0023300	0.0001100	0.0001100	0.0001100	0.0000736	0.0000704
92% recycled / 8% incinerated	European	0.0023300	0.0001100	0.0001100	0.0001100	0.0000732	0.0000699
98% recycled / 2% incinerated	European	0.0023300	0.0001100	0.0001100	0.0001100	0.0000730	0.0000698

Waste Scenario	Energy	PLA 1	rPET 1	rPET 2	rPET 3	PP 1	PP 2
Table 10: CED per Soft Cup per Recycling Percentage manufactured using National & European Energy Data							
SOFT CUP - The Cup							
National Energy & European Energy							
		CED MJ-eq/cup					
0% recycled / 100% incinerated	National	0.72679	0.44867	0.40109	0.50205	0.51173	0.48075
25% recycled / 75% incinerated	National	0.72636	0.44815	0.40052	0.50155	0.51140	0.48044
41% recycled / 59% incinerated	National	0.72609	0.44782	0.40016	0.50124	0.51119	0.48024
50% recycled / 50% incinerated	National	0.72592	0.44762	0.39994	0.50106	0.51107	0.48013
75% recycled / 25% incinerated	National	0.72548	0.44709	0.39936	0.50057	0.51074	0.47982
92% recycled / 8% incinerated	National	0.72521	0.44676	0.39899	0.50024	0.51052	0.47961
98% recycled / 2% incinerated	National	0.72508	0.44661	0.39883	0.50012	0.51044	0.47954
0% recycled / 100% incinerated	European	0.73358	0.39816	0.40974	0.45465	0.51585	0.48467
25% recycled / 75% incinerated	European	0.73314	0.39763	0.40916	0.45416	0.51552	0.48436
41% recycled / 59% incinerated	European	0.73286	0.39729	0.40879	0.45384	0.51531	0.48416
50% recycled / 50% incinerated	European	0.73271	0.39710	0.40858	0.45367	0.51519	0.48405
75% recycled / 25% incinerated	European	0.73227	0.39658	0.40801	0.45318	0.51487	0.48375
92% recycled / 8% incinerated	European	0.73196	0.39621	0.40761	0.45284	0.51464	0.48353
98% recycled / 2% incinerated	European	0.73187	0.39609	0.40747	0.45272	0.51456	0.48346

Table 11: ReCiPe Endpoints per Soft Cup per Recycling Percentage manufactured using National and European Energy Data							
SOFT CUP - The Cup							
National Energy & European Energy							
Waste Scenario	Energy	ReCiPe Total points/cup					
		PLA 1	rPET 1	rPET 2	rPET 3	PP 1	PP 2
0% recycled / 100% incinerated	National	0.00383	0.00369	0.00306	0.00384	0.00288	0.00270
25% recycled / 75% incinerated	National	0.00369	0.00352	0.00287	0.00368	0.00273	0.00256
41% recycled / 59% incinerated	National	0.00360	0.00341	0.00275	0.00358	0.00263	0.00247
50% recycled / 50% incinerated	National	0.00355	0.00335	0.00268	0.00352	0.00258	0.00243
75% recycled / 25% incinerated	National	0.00341	0.00318	0.00250	0.00336	0.00244	0.00229
92% recycled / 8% incinerated	National	0.00332	0.00306	0.00236	0.00326	0.00233	0.00218
98% recycled / 2% incinerated	National	0.00328	0.00302	0.00232	0.00322	0.00230	0.00216
0% recycled / 100% incinerated	European	0.00357	0.00262	0.00272	0.00283	0.00272	0.00255
25% recycled / 75% incinerated	European	0.00342	0.00245	0.00253	0.00267	0.00257	0.00241
41% recycled / 59% incinerated	European	0.00332	0.00234	0.00241	0.00257	0.00247	0.00232
50% recycled / 50% incinerated	European	0.00328	0.00227	0.00234	0.00251	0.00243	0.00228
75% recycled / 25% incinerated	European	0.00314	0.00210	0.00215	0.00235	0.00228	0.00214
92% recycled / 8% incinerated	European	0.00302	0.00199	0.00202	0.00225	0.00217	0.00204
98% recycled / 2% incinerated	European	0.00301	0.00195	0.00198	0.00221	0.00215	0.00201

Reference is made, on page 31, to the fact that raw material is recovered when recycling Soft Cups while other aspects of the cup life cycle are lost, such as conversion process impacts. Based on the Soft Cups that are 98% recycled and are manufactured using European energy, the GWP of the raw materials of a Soft Cup is compared to the non-material portion of the cup life cycle. This can be seen in Figure 27 below, the total of both being the GWP of the specific Soft Cup.

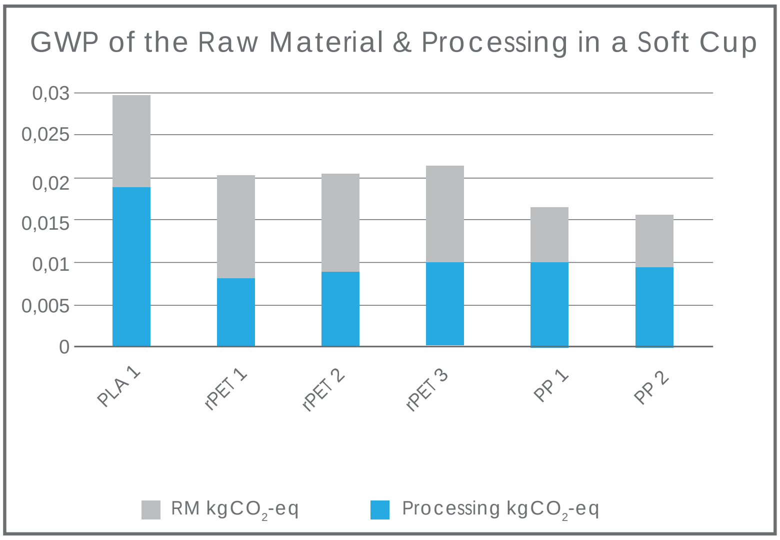


Figure 27: Graph of the major Life Cycle Stages Contribution to the Soft Cup GWP

A significant portion of the Soft Cup GWP is lost every time these single use cups are recycled. The average percentage of the PP Soft Cup GWP that is processing is 39%. For the rPET Soft Cups, this is 57% and for the PLA Soft Cup, it is 36%. It can be seen that while the rPET raw material within the rPET Soft Cups are of a generally lower impact than the PP raw material in the PP Soft Cups, the recycling of the rPET Soft Cups could lead to more lost processing GWP. In the case that these cups are modelled based on manufacturing using their national energy data, the processing part of the rPET 1 cup is 74% of the total GWP of the cup.

The average "Processing", for the equivalent Hard Cups, is 35% of the total GWP of these cups. However, this 35% loss occurs at the end of the useful life of this reusable cup which could have involved many servings.

Recycling retains raw material but loses the other processes within the life cycle of a cup. In the case of a single use cup, this could lead to a far higher impact than for reusable cups that have been used for multiple servings prior to eventually being recycled.

Hard Cups

The Hard Cups were modelled using both national and European energy mix, resulting in 6 models.

These models contain the raw materials, conversion processes, printing, packaging, transports, and end-of-life inputs. The energy within the models is the national energy mix of the country of manufacture (Dutch, French or Spanish). An additional model is made for each cup involving a European energy mix figure to address the sensitivity of process energy within the models. The final destination of the Hard Cups being the central point in the Netherlands ready to be washed at the washing facilities.

Transport within the Hard Cup system is covered in the chapter below titled Cup Transport Impacts.

Table 12: Hard Cup - Environmental Impact Category Data

Hard Cup				
Impact Category	GWP	H_2O	CED	ReCiPe Total
Units	$kgCO_2$-eq	m^3	MJ-eq	points
(H)PP 3 National	0.06995	0.00032	2.78411	0.00992
(H)PP 3 Europe	0.08354	0.00031	2.70531	0.01125
(H)PP 1 National	0.09196	0.00032	2.97456	0.01241
(H)PP 1 Europe	0.09551	0.00035	3.02792	0.01276
(H)PP 2 National	0.11364	0.00036	3.40503	0.01485
(H)PP 2 Europe	0.10445	0.00038	3.44606	0.01419

Crate Manufacturing Impact

For background related to the crate, please refer to the chapter titled Reuse Crates on page 57 above. This crate model contains the raw materials, conversion processes (using German energy), packaging, transports, and end-of-life inputs, for the crate and, for crate C only, a plastic film bag liner, with the final destination of the crate and liner being the central point in the Netherlands ready to be used by the washing companies.

The reason that the crate is given a fixed number of uses is explained in the BCT description on page 60. The input figure for the crate should be the impact of the crate divided by the number of cups it can contain, i.e. the impact of the crate per cup. The 100 uses of the crate is then calculated by the BCT.

The crates are owned by the washing companies and form part of their confidential inventory, hence specific data will not be correlated to the company names within the study. However, Crate A should always be applied for washing at Company A as input for the BCT, and likewise for crates C and D. For company B any of the crates can be used as input to the BCT.

Table 13: Reuse Crate - Environmental Impact Category Data				
Blue Reuse Crate				
Impact Category	GWP	H_2O	CED	ReCiPe Total
Units	$kgCO_2$-eq	m^3	MJ-eq	points
(H)PP 3 National	0.01040	0.000034	0.31345	0.00138
(H)PP 3 Europe	0.01040	0.000034	0.31345	0.00138
(H)PP 1 National	0.02299	0.000075	0.69128	0.00304
(H)PP 1 Europe	0.02299	0.000075	0.69128	0.00304
(H)PP 2 National	0.02428	0.000080	0.73005	0.00321
(H)PP 2 Europe	0.02428	0.000080	0.73005	0.00321

Cup and Crate Washing Impact

For background related to the washing systems please refer to the chapter titled Hard Cup Washing Process above and the associated Appendix E.

The cup and crate washing models contain the datasets Dutch medium voltage electricity, tap water, wastewater, the modelled detergent as described in Appendix E and, where applicable, heat generated using natural gas.

The final figure for input to the BCT is the impact of washing a single cup plus the impact of washing a crate divided by the number of cups within the crate. Exact cup quantities are given for the crates used by three of the washing companies; for the fourth company, a cups/crate assumption is made based on the crate size.

It is reported that the crates in company A are washed by hand and no data was available for this activity. Hence the crate washing impact for company C was adopted for crate washing in company A, this being due to the fact that it is the highest impact crate washing of the three companies washing crates by machine.

Table 14: Cup and Crate Washing - Environmental Impact Category Data				
Cup and Crate Washing System				
Impact Category	GWP	H_2O	CED	ReCiPe Total
Units	$kgCO_2$-eq	m^3	MJ-eq	points
Company A	0.005546	0.000082	0.089922	0.000507
Company B	0.010813	0.000318	0.174647	0.000997
Company C	0.011076	0.000112	0.179182	0.001017
Company D	0.014480	0.000117	0.234058	0.001325

Cup Transport Impact

For background related to the transport systems, please refer to the chapter titled Transport on page 54 above. The transports modelled here relate exclusively to the systems transport and not the initial raw materials and manufactured cup delivery to the Netherlands; specifically, transport to the washer from the festivals and transport from the festival to the recycling or incineration facility.

Hard Cup Transport – Between Festival and Washer

Hard Cups are transported between the festivals and washers within the reuse system.

The average of the distances between the festivals and the closest and second closest washing facility is the distance upon which the following impacts are based.

Table 15: Hard Cup Transport between Venue and Washer - Environmental Impact Category Data

Hard Cup Transport between Festival and Washer				
Impact Category	GWP	H_2O	CED	ReCiPe Total
Units	$kgCO_2$-eq	m^3	MJ-eq	points
(H)PP 3 National	0.00127756	0.00000354	0.02041592	0.00013190
(H)PP 3 Europe	0.00127756	0.00000354	0.02041592	0.00013190
(H)PP 1 National	0.00154371	0.00000428	0.02466906	0.00015938
(H)PP 1 Europe	0.00154371	0.00000428	0.02466906	0.00015938
(H)PP 2 National	0.00182030	0.00000505	0.02908970	0.00018790
(H)PP 2 Europe	0.00182030	0.00000505	0.02908970	0.00018790

Soft & Hard Cup Transport – Between Festival and Recycler or Incinerator

At the end of their useful life, cups that have not been lost and are therefore still in the system will be sent for recycling or incineration.

The average of the distances between the festivals and the closest and second closest recycling, and closest and second closest incineration facility, is the distance upon which the following impacts are based.

For the Hard Cups, the crates are removed and only the cups, at their end of useful life, are transported.

For the Soft Cups, the corrugated boxes are removed and only the cups are transported. It should be noted that the average distance from the festival to the closest and second closest recycling and incineration facility is adopted, with the exception of the PLA cup, for which the distances to the incineration facility remains the same but the distance to the recycling facility is the distance to LoopLife in Belgium.

Table 16: Hard Cup transport to EoL Facility - Environmental Impact Category Data				
Hard Cup Transport to End-of-Life Facility				
Impact Category	GWP	H_2O	CED	ReCiPe Total
Units	$kgCO_2$-eq	m^3	MJ-eq	points
(H)PP 3 National	0.00128171	0.00000356	0.0204823	0.00013233
(H)PP 3 Europe	0.00128171	0.00000356	0.0204823	0.00013233
(H)PP 1 National	0.00140287	0.00000389	0.0224184	0.00014484
(H)PP 1 Europe	0.00140287	0.00000389	0.0224184	0.00014484
(H)PP 2 National	0.0016957	0.00000471	0.0270973	0.00017510
(H)PP 2 Europe	0.0016957	0.00000471	0.0270973	0.00017510

Table 17: Soft Cup transport to EoL Facility - Environmental Impact Category Data				
Soft Cup Transport to End-of-Life Facility				
Impact Category	GWP	H_2O	CED	ReCiPe Total
Units	$kgCO_2$-eq	m^3	MJ-eq	points
PLA 1	0.000337	0.000000935	0.00539	0.0000348
rPET 1	0.000338	0.000000938	0.00540	0.0000349
rPET 2	0.000370	0.000001030	0.00591	0.0000382
rPET 3	0.000315	0.000000874	0.00503	0.0000325
PP 1	0.000237	0.000000658	0.00379	0.0000245
PP 2	0.000222	0.000000616	0.00355	0.0000229

4 Results

4 Results

Topics

Results

While it could be possible to model the results of any number of the potential scenarios mentioned in this study, data related to these specific scenarios was not available. The latest data related to reuse and single use cup scenarios at events is available within the Plastic Promise 2019 study and hence this study was adopted in the results part of this study text.

Plastic Promise 2019

In 2019, Plastic Promise collected data from 78 events as regards the reuse of Hard Cups and the collection and recycling of Soft Cups, see Figure 29.

When a deposit-return system was made available for the Hard Cups, it was recorded that between 80 to 98% of the cups were returned. When a deposit-return system was made available for the Soft Cups, it was recorded that between 41 to 92% of the cups were recycled. In the event that Soft Cups were collected without a deposit-return system, between 0 to 75% of the Soft Cups were recycled.

Using these figures from the 2019 events, this study has been carried out to compare the impact of Hard Cups that are 80 to 98% returned for reuse with Soft Cups that are 0%, 41%, 75% and 92% recycled.

Comparisons are made to identify the breakeven point, being the point at which the Hard Cup system becomes the lower GWP system based on a sensitivity of 5% to account for Soft Cup weight tolerances. When the figure 5000 is reported in the tables below, it relates to a breakeven that exceeds the 5000th serving, which may indicate it will never be achieved.

To aid the reader in identifying whether a breakeven would be realistic, three different colours have been applied to the tables below. Cells marked in green show that a Hard Cup would break even within 0 to 25 servings. Cells marked in yellow show that a Hard Cup would break even between 26 to 74 servings. Cells marked in red show that a Hard Cup would break even after 75 servings or more. The green scenario would be easy and realistically achievable. A yellow scenario is more questionable and for a red scenario, it is unlikely that the Hard Cup would be the better system from an GWP impact point of view.

It should be noted that the choice of these color based, number of servings, bands is subjective. Hence, the actual serving number is displayed within each cell.

	0 – 25 servings
	26 – 74 servings
	75 servings or more

Figure 28: Illustration of colour coding

Figure 29: Plastic Promise 2019 Results

Table 18: Cup systems to be compared as relates to the Plastic Promise 2019 study

Hard Cup	Wash Co.	% Returned
(H)PP 3	A	80
(H)PP 3	A	98
(H)PP 3	B	80
(H)PP 3	B	98
(H)PP 2	A	80
(H)PP 2	A	98
(H)PP 2	B	80
(H)PP 2	B	98
(H)PP 2	C	80
(H)PP 2	C	98
(H)PP 1	D	80
(H)PP 1	D	98

VS

Soft Cup	% Recycled			
PLA 1	0	41	75	92
rPET 1	0	41	75	92
rPET 3	0	41	75	92
rPET 2	0	41	75	92
PP 2	0	41	75	92
PP 1	0	41	75	92

Weight Tolerance Sensitivity at 98% Hard Cups Return

The breakeven point in Table 19 below is based on the lowest weight Soft Cup within the manufacturing weight tolerance, with all cups being manufactured using national energy impact data and with 98% of the Hard Cups being returned.

To aid in reading Table 19, the (H)PP 2 Hard Cups washed at company B are the lower GWP option from the 8th serving when compared to the rPET 1 Soft Cups that are 75% recycled.

Table 19: Hard Cup breakeven – 98% returned vs Lowest Weight Tolerance Soft Cup – National Energy

Hard Cups 98% Returned- National Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups - Lowest Weight Tolerance - National Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	3	3	3	4	3	3	3	4	3	4	4	5	3	3	3	4	4	5	7	8	4	6	8	9
(H)PP 3	B	3	3	4	4	3	4	4	5	3	5	6	8	3	4	4	5	5	8	13	20	6	9	17	29
(H)PP 2	A	4	5	5	6	4	5	6	6	5	6	8	9	4	5	6	6	7	9	13	17	8	11	15	20
(H)PP 2	B	5	6	7	8	5	6	8	9	6	8	12	15	5	6	7	8	10	16	33	76	11	20	52	315
(H)PP 2	C	5	6	7	8	5	6	8	9	6	8	12	16	5	6	8	9	10	16	26	93	12	21	59	1225
(H)PP 1	D	4	5	7	8	4	6	7	9	5	8	13	19	4	6	7	8	10	20	123	5000	12	29	5000	5000

Table 20: Hard Cup breakeven – 98% returned vs Highest Weight Tolerance Soft Cup – National Energy

Hard Cups 98% Returned- National Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups -Highest Weight Tolerance - National Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	2	3	3	3	2	3	3	3	3	3	4	4	2	3	3	3	4	4	6	7	4	5	6	8
(H)PP 3	B	3	3	3	4	3	3	4	4	3	4	5	6	3	3	4	4	5	6	9	13	5	7	11	17
(H)PP 2	A	4	4	5	5	4	4	5	6	4	5	7	8	4	4	5	5	6	8	11	13	7	9	12	15
(H)PP 2	B	4	5	6	6	4	5	6	7	5	7	9	11	4	5	6	7	8	12	21	33	9	14	27	52
(H)PP 2	C	4	5	6	7	4	5	6	7	5	7	9	12	4	5	6	7	8	12	22	36	9	15	29	59
(H)PP 1	D	4	5	5	6	4	5	6	7	5	6	9	12	4	5	6	7	8	13	32	124	9	17	60	5000

The breakeven point in Table 20 above is based on the highest weight Soft Cup within the manufacturing tolerance, with all cups being manufactured using national energy impact data and with 98% of the Hard Cups being returned.

As can be seen in Table 20, when applying the within tolerance higher weight Soft Cups, the Hard Cups break even at a lower number of servings. The actual breakeven figure will be somewhere between these two figures.

Manufacturing Energy Sensitivity at 98% Hard Cup Return

The breakeven point in Table 21 below is based on the lowest weight Soft Cup within the manufacturing tolerance, with all cups being manufactured using European energy impact data and with 98% of the Hard Cups being returned.

The breakeven point in Table 22 below is based on the highest weight Soft Cup within the manufacturing tolerance, with all cups being manufactured using European energy impact data and with 98% of the Hard Cups being returned.

At 98% Hard Cup return, when compared with the PLA and rPET Soft Cups, the Hard Cup system could be considered to be the lower GWP impact option, regardless of the weight tolerance range and the manufacturing energy data type adopted. As regards the PP Soft Cups, the Hard Cups is the lower GWP system when the PP cups recycling rate is 41% or less. If the recycling rate is higher, the PP Soft Cups are only the better option against specific Hard Cup types washed at specific washing companies.

Table 21: Hard Cup breakeven – 98% returned vs Lowest Weight Tolerance Soft Cup – European Energy

Hard Cups 98% Returned- European Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups -Lowest Weight Tolerance - European Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	3	4	4	5	4	5	7	8	4	5	7	8	4	5	7	8	5	7	10	13	6	8	11	15
(H)PP 3	B	4	5	6	6	5	7	12	17	5	7	11	15	5	7	10	14	7	12	24	54	8	14	36	153
(H)PP 2	A	4	5	6	6	5	7	10	12	5	7	9	12	5	7	9	11	7	10	15	20	8	11	18	25
(H)PP 2	B	5	6	8	9	7	11	19	30	6	10	16	26	7	10	16	23	10	18	56	5000	12	24	146	5000
(H)PP 2	C	5	6	8	9	7	11	19	33	7	10	17	28	7	10	16	24	11	20	66	5000	13	26	234	5000
(H)PP 1	D	5	7	9	10	8	13	35	191	7	12	27	88	8	12	25	57	13	34	5000	5000	17	66	5000	5000

Table 22: Hard Cup breakeven – 98% returned vs Highest Weight Tolerance Soft Cup – European Energy

Hard Cups 98% Returned- European Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups -Highest Weight Tolerance - European Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	3	3	4	4	4	5	6	7	3	4	6	7	4	4	6	7	5	6	8	10	5	7	9	11
(H)PP 3	B	3	4	5	5	4	6	9	12	4	6	8	11	4	6	8	10	6	9	16	25	7	10	20	38
(H)PP 2	A	4	4	5	5	5	6	8	10	4	6	8	9	5	6	8	9	6	8	12	15	7	9	14	18
(H)PP 2	B	4	5	6	7	6	8	13	19	5	8	12	17	6	8	12	15	8	13	28	63	9	16	41	185
(H)PP 2	C	4	5	6	7	6	9	14	20	5	8	12	18	6	8	12	16	8	14	30	74	10	17	45	352
(H)PP 1	D	4	5	7	8	6	10	19	36	6	9	16	29	6	9	16	24	10	19	110	5000	12	26	5000	5000

Weight Tolerance Sensitivity at 80% Hard Cups Return

The breakeven point in Table 23 below is based on the lowest weight Soft Cup within the manufacturing tolerance, with all cups being manufactured using national energy impact data and with 80% of the Hard Cups being returned.

The breakeven point in Table 24 below is based on the highest weight Soft Cup within the manufacturing tolerance, with all cups being manufactured using national energy impact data and with 80% of the Hard Cups being returned.

As can be seen in Table 24 below, when applying the within tolerance higher weight Soft Cups, the Hard Cups breakeven at a lower number of servings. The actual breakeven figure will be somewhere between these two figures.

Table 23: Hard Cup breakeven – 80% returned vs Lowest Weight Tolerance Soft Cup – National Energy

Hard Cups 80% Returned- National Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups -Lowest Weight Tolerance - National Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	3	4	5	6	3	4	6	7	4	6	12	22	3	4	6	7	9	25	5000	5000	11	70	5000	5000
(H)PP 3	B	4	6	9	12	4	6	11	18	6	12	5000	5000	4	6	10	16	33	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	A	9	16	40	184	9	18	116	5000	16	743	5000	5000	9	17	78	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	B	18	116	5000	5.000	17	5000	5000	5000	120	5000	5000	5000	18	1041	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	C	19	175	5000	5000	18	5000	5000	5000	184	5000	5000	5000	19	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 1	D	12	38	5000	5000	12	63	5000	5000	38	5000	5000	5000	12	58	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

Table 24: Hard Cup breakeven – 80% returned vs Highest Weight Tolerance Soft Cup – National Energy

Hard Cups 80% Returned- National Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups -Highest Weight Tolerance - National Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	3	3	4	5	3	3	4	5	3	5	8	11	3	3	4	5	6	12	104	5000	7	18	5000	5000
(H)PP 3	B	3	4	6	7	3	5	7	9	4	7	22	5000	3	5	7	9	12	5000	5000	5000	21	5000	5000	5000
(H)PP 2	A	7	10	16	24	6	10	22	53	10	27	5000	5000	7	10	20	39	562	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	B	10	20	140	5.000	10	24	5000	5000	20	5000	5000	5000	10	23	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	C	10	21	234	5000	10	25	5000	5000	21	5000	5000	5000	10	25	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 1	D	7	13	41	5000	7	15	5000	5000	13	5000	5000	5000	7	15	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

Manufacturing Energy Sensitivity at 80% Hard Cup Return

The breakeven point in Table 25 below is based on the lowest weight Soft Cup within the manufacturing tolerance, with all cups being manufactured using European energy impact data and with 80% of the Hard Cups being returned.

The breakeven point in Table 26 below is based on the highest weight Soft Cup within the manufacturing tolerance, with all cups being manufactured using European energy impact data and with 80% of the Hard Cups being returned.

At 80% Hard Cup return, regardless of the weight tolerance or manufacturing energy type, it is evident that the Hard Cup system is not the lower GWP option in 76% of the cases. This is most evident when Soft Cup recycling percentages are high. It could reasonably be said that when only 80% of the Hard Cups are returned, it is the Soft Cup system that is likely to be the lower GWP option.

Table 25: Hard Cup breakeven – 80% returned vs Lowest Weight Tolerance Soft Cup – European Energy

Hard Cups 80% Returned- European Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups -Lowest Weight Tolerance - European Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	5	7	11	15	9	30	5000	5000	8	20	5000	5000	9	23	5000	5000	27	5000	5000	5000	83	5000	5000	5000
(H)PP 3	B	8	14	55	5000	29	5000	5000	5000	17	5000	5000	5000	25	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	A	9	17	70	5000	36	5000	5000	5000	21	5000	5000	5000	32	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	B	21	5000	5000	5.000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	C	22	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 1	D	28	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

Table 26: Hard Cup breakeven – 80% returned vs Highest Weight Tolerance Soft Cup – European Energy

Hard Cups 80% Returned- European Energy		Hard Cup GWP Breakeven Serving No. vs Percentage Recycled Soft Cups -Highest Weight Tolerance - European Energy																							
Hard Cup	Wash Co.	PLA 1				rPET 1				rPET 2				rPET 3				PP 1				PP 2			
		0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%	0%	41%	75%	92%
(H)PP 3	A	4	5	7	9	7	14	679	5000	6	11	71	5000	6	12	55	5000	13	368	5000	5000	20	5000	5000	5000
(H)PP 3	B	5	8	15	27	12	5000	5000	5000	9	60	5000	5000	11	117	5000	5000	717	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	A	7	10	19	35	15	5000	5000	5000	11	77	5000	5000	14	154	5000	5000	1328	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	B	11	26	5000	5.000	178	5000	5000	5000	36	5000	5000	5000	99	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 2	C	11	28	5000	5000	403	5000	5000	5000	41	5000	5000	5000	144	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
(H)PP 1	D	12	40	5000	5000	5000	5000	5000	5000	79	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

Other Impact Categories

The above results are based entirely on GWP, while the study also considers the Water Resource (H_2O), Cumulative Energy Demand (CED) and the weighted ReCiPe Total endpoints.

H_2O

As regards H_2O, there are no circumstances in which the PLA Soft Cup system performs better than the Hard Cup system, PLA being a raw material derived from primary agriculture whose water resource footprint exceeds that of all the Hard Cup systems within the first serving. As regards the PP Soft Cups, the Hard Cup systems are not of a lower water footprint than the PP Soft Cups at the 5000th serving. Hence, the PP Soft Cups are the better option from a water resource perspective.

At 20% Hard Cup loss, when compared to the rPET Soft Cups, the Hard Cups are not the better H_2O option by the 5000th serving, regardless of the percentage recycling of the rPET Soft Cups. At 2% loss, the highest H_2O impact Hard Cups do not reach breakeven by the 5000th serving when compared to the 0% recycled rPET Soft Cups. However, when compared to the lowest H_2O impact Hard Cup system, breakeven is achieved by the 5th serving when compared to the rPET 1 and rPET 2 Soft Cups, assuming these rPET cups are 92% recycled.

CED

As regards CED, at 20% Hard Cup loss, the Hard Cup is not the better option by the 5000th serving when compared to all 0% recycled Soft Cups, except for the PLA Soft Cup. When compared with the lowest CED Hard Cup system, the Hard cup breaks even with the PLA cup at the 49th serving and for the highest CED Hard Cup, it does not breakeven by the 5000th serving.

As regards CED, at 2% Hard Cup loss, the Hard Cup is the better option. Comparing the highest CED Hard Cup and the rPET Soft Cups, the average breakeven is at the 26th serving; for the PP Soft Cups, this is at the 19th serving and for the PLA, this is at the 8th serving. Against the lowest CED Hard Cup, this falls to the 16th, the 12th and the 6th serving respectively.

ReCiPe Endpoints Total

As regards ReCiPe endpoints, at 20% Hard Cup loss, the Hard Cup is not the better option by the 5000th serving when compared to all Soft Cups when they are 0% recycled and the highest ReCiPe endpoint total Hard Cup system is adopted. When comparing the lowest ReCiPe endpoint total Hard Cup system to the 92% recycled Soft Cups, the Hard Cups do not break even by the 5000th serving, with the exception of against the PLA and Polish rPET cups. When the Soft Cups are 0% recycled and compared to the lowest impact Hard Cup system, the Hard Cups break even by the 49th serving, with the exception of against the PP 2 cup against which the Hard Cup does not break even by the 5000th serving. When the Soft Cups are 92% recycled and compared to the lowest impact Hard Cup system, the Hard Cup system is not the better option, except for in comparison with the PLA cup at the 13th serving and the rPET 1 cup at the 23rd serving.

As regards ReCiPe endpoints, at 2% Hard Cup loss, the Hard Cup is the better option, breaking even against all 92% recycled Soft Cups by the 8th serving, based on the lowest ReCiPe endpoint total Hard Cup system. When the highest ReCiPe endpoint total Hard Cup system is adopted, the Hard Cup is the better option, breaking even against all 92% recycled Soft Cups by the 30th serving. If 41% recycled Soft Cups are compared to the lowest and highest impact Hard cups, the breakeven is at the 7th and 19th serving respectively.

In general, when studies are made using the BCT involving GWP, H_2O and ReCiPe impact categories, the same diagonal line can be drawn as seen in Table 27 below. In all cases, the Hard Cups break even at the lowest number of servings when compared to the PLA cups and the highest number of servings when compared to the PP cups.

This line then becomes more "V" shaped when CED is considered, with the higher breakeven numbers associated with the rPET Soft Cups, as can be seen in Table 28 below.

Table 27: Typical Diagonal line achieved in all studies involving GWP, H_2O and ReCiPe Endpoints Total

Servings, *n*	Hard Cup		Soft Cup											
			PLA 1		rPET 1		rPET 2		rPET 3		PP 1		PP 2	
	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings	Overall GWP after n servings	GWP per serving after n servings
1	7,82	0,0782	3,32	0,0332	3,10	0,0310	2,49	0,0249	3,17	0,0317	1,86	0,0186	1.75	0.0175
2	8,77	0,0439	6,64	0,0332	6,20	0,0310	4,97	0,0249	6,33	0,0317	3,72	0,0186	3.50	0.0175
3	9,73	0,0324	9,96	0,0332	9,31	0,0310	7,46	0,0249	9,50	0,0317	5,58	0,0186	5.24	0.0175
4	10,69	0,0267	13,27	0,0332	12,41	0,0310	9,94	0,0249	12,66	0,0317	7,43	0,0186	6.99	0.0175
5	11,64	0,0233	16,59	0,0332	15,51	0,0310	12,43	0,0249	15,83	0,0317	9,29	0,0186	8.74	0.0175
6	12,60	0,0210	19,91	0,0332	18,61	0,0310	14,92	0,0249	18,99	0,0317	11,15	0,0186	10.49	0.0175
7	13,56	0,0194	23,23	0,0332	21,71	0,0310	17,40	0,0249	22,16	0,0317	13,01	0,0186	12.24	0.0175
8	14,52	0,0181	26,55	0,0332	24,81	0,0310	19,89	0,0249	25,32	0,0317	14,87	0,0186	13.99	0.0175
9	15,48	0,0172	29,87	0,0332	27,92	0,0310	22,37	0,0249	28,49	0,0317	16,73	0,0186	15.73	0.0175
10	16,43	0,0164	33,19	0,0332	31,02	0,0310	24,86	0,0249	31,66	0,0317	18,59	0,0186	17.48	0.0175

Table 28: Typical V-shaped line achieved in all studies involving CED

Servings, *n*	Hard Cup		Soft Cup											
			PLA 1		rPET 1		rPET 2		rPET 3		PP 1		PP 2	
	Overall CED after n servings	CED per serving after n servings	Overall CED after n servings	CED per serving after n servings	Overall CED after n servings	CED per serving after n servings	Overall CED after n servings	CED per serving after n servings	Overall CED after n servings	CED per serving after n servings	Overall CED after n servings	CED per serving after n servings	Overall CED after n servings	CED per serving after n servings
1	291,81	2,9181	73,05	0,7305	45,20	0,4520	40,47	0,4047	50,52	0,5052	51,42	0,5142	48.31	0.4831
2	310,68	1,5534	146,09	0,7305	90,40	0,4520	80,95	0,4047	101,03	0,5052	102,85	0,5142	96.62	0.4831
3	329,60	1,0987	219,14	0,7305	135,60	0,4520	121,42	0,4047	151,55	0,5052	154,27	0,5142	144.93	0.4831
4	348,51	0,8713	292,19	0,7305	180,80	0,4520	161,90	0,4047	202,06	0,5052	205,69	0,5142	193.24	0.4831
5	367,43	0,7349	365,24	0,7305	226,01	0,4520	202,37	0,4047	252,58	0,5052	257,12	0,5142	241.55	0.4831
6	386,35	0,6439	438,28	0,7305	271,21	0,4520	242,84	0,4047	303,09	0,5052	308,54	0,5142	289.85	0.4831
7	405,26	0,5789	511,33	0,7305	316,41	0,4520	283,32	0,4047	353,61	0,5052	359,96	0,5142	338.16	0.4831
8	424,18	0,5302	584,38	0,7305	361,61	0,4520	323,79	0,4047	404,12	0,5052	411,38	0,5142	386.47	0.4831
9	443,10	0,4923	657,42	0,7305	406,81	0,4520	364,27	0,4047	454,64	0,5052	462,81	0,5142	434.78	0.4831
10	462,01	0,4620	730,47	0,7305	452,01	0,4520	404,74	0,4047	505,15	0,5052	514,23	0,5142	483.09	0.4831
11	480,93	0,4372	803,52	0,7305	497,21	0,4520	445,21	0,4047	555,67	0,5052	565,65	0,5142	531.40	0.4831
12	499,84	0,4165	876,56	0,7305	542,41	0,4520	485,69	0,4047	606,18	0,5052	617,08	0,5142	579.71	0.4831
13	518,76	0,3990	949,61	0,7305	587,61	0,4520	526,16	0,4047	656,70	0,5052	668,50	0,5142	628.02	0.4831
14	537,68	0,3841	1022,66	0,7305	632,81	0,4520	566,64	0,4047	707,21	0,5052	719,92	0,5142	676.33	0.4831
15	556,59	0,3711	1095,71	0,7305	678,02	0,4520	607,11	0,4047	757,73	0,5052	771,35	0,5142	724.64	0.4831

Plastic Promise 2019 – Results - General Conclusions

Even with the large number of variables and scenarios possible, when comparing this study's beverage serving systems with the Plastic Promise 2019 product reuse, collection and recycling data, there are a number of conclusions that can be drawn:

1. At 20% Hard Cup Loss, there are very few examples of viable serving quantities, across all impact categories, that would indicate that the Hard Cup system is the lower environmental impact scenario compared to the Soft Cup system, based on any level of recycling of these Soft Cups.
2. At 2% Hard Cup Loss, there are few examples of viable serving quantities, across all impact categories, that would indicate that the Hard Cup system is the higher environment impact scenario compared to the Soft Cup system, based on any level of recycling of these Soft Cups.
3. Should a Hard Cup system be adopted, it should be the system with the lowest impact per impact category, in combination with the lowest impact wash, being used in any comparison with the Soft Cup system. Typically, the (H)PP 3 Hard Cup washed at company A performs the best across most impact categories.
4. Should a Soft Cup system be adopted, it should be the system with the lowest impact per impact category being used in any comparison with the Hard Cup system. Typically, the PLA Soft Cup is the highest impact cup and the PP Soft Cups are the lowest impact cups across all impact categories, except CED in which the rPET Soft Cups are of the lowest impact.
5. Should a Soft Cup system be adopted, the cups should be recycled to the highest possible percentage.

The (H)PP 3 Hard Cup washed at company A and collected for reuse to the highest possible level is the Hard Cup approach that should be adopted. When a Soft Cup system approach is to be considered, the PP 2 cup should be adopted based on the highest possible percentage of recycling. If a choice is to be made between these two systems, the Hard Cup system will be the system of generally lower environmental impact.

Relative Influence of the Variables

Soft Cups

The choice of Soft Cup system type makes a considerable difference to the breakeven point with the Hard Cup system. Soft Cups are single use cups and, as such, for 10 beverages, 10 cups are required. Hence, a study of the variables within the cup itself is relevant.

The influencing variables for Soft Cups are the cup material type, the manufacturing of the cup, the cup weight and the level of recycling of the cups. In Table 29 below, the relative impact of the cup raw material compared to the other processes within the manufacturing of the cup is compared.

Different manufacturing countries have different energy impacts. Different raw materials have different yields, producing cups of differing weights for the same like-functionality design. Different raw materials require different and/or additional manufacturing processes.

In Table 30 below, it can be seen that the choice of country of manufacture of a Soft Cup, and the associated energy impact of that country, can significantly change the GWP of a cup. By adopting a European energy impact figure for the manufacturing processes, the GWP of the PP cups decreases by 10%, the German rPET cups by 15%, the PLA by 9% and, most significantly, the average Polish rPET cups by 33%, this being due to the high impact of Polish energy compared to that of the average of Europe.

Table 29: Soft Cup – material, processing, country of origin and GWP at 98% recycled and National Energy

Based on National Manufacturing Energy				
Soft Cups	Cup Weight	Soft Cup GWP Influencing Factors		
		Raw Material	Processing	GWP @ 98% rec
	g	%	%	$kgCO_2eq$
PLA 1	5.55	57.61	42.39	0.03285
rPET 3	6.24	31.94	68.06	0.03134
rPET 1	6.70	26.36	73.64	0.03068
rPET 2	7.33	36.13	63.87	0.02449
PP 1	4.70	54.91	45.09	0.01835
PP 2	4.40	54.67	45.33	0.01726

Table 30: Soft Cup – material, processing, country of origin and GWP at 98% recycled and European Energy

Based on European Manufacturing Energy				
Soft Cups	Cup Weight	Soft Cup GWP Influencing Factors		
		Raw Material	Processing	GWP @ 98% rec
	g	%	%	$kgCO_2eq$
PLA 1	5.55	63.66	36.34	0.02973
rPET 3	6.24	46.97	53.03	0.02131
rPET 2	7.33	4.21	56.79	0.02048
rPET 1	6.70	40.45	59.55	0.02000
PP 1	4.70	61.03	38.97	0.01651
PP 2	4.40	60.82	39.18	0.01551

Hence, it can be stated that the manufacturing of the cups, and specifically the energy impact to do so, is a highly influencing factor, as can be seen for the Polish rPET cups in which a 33% reduction could be achieved by changing the energy source.

Cup weight has an influence but this is often not something that can be changed due to the physical and mechanical properties of the specific raw material. Single use cups are usually manufactured to the lowest functional weight with relatively small weight changes between similar cups made from the same materials. Had the rPET 2 cup been made to the same weight as the PP 2 cup, it would have the lowest GWP impact but the cup would likely be unable to function as a viable beverage cup.

Where weight does play a role is in the amount of material resource used between the systems. To service one million beverages in an average of the Soft Cup weights cup requires 5.8 tons of net material resource. To provide the same number of servings based on a Hard Cup system at no loss would require 0.58 tons of material resource assuming that each Hard Cup was reused 50 times.

Raw material choice has three influences, one being the impact of the raw material granule itself, another being the required cup weight to achieve the function, and the final being the type of processes required to convert raw materials into cups. As can be seen in Figure 30 below, the PLA has a GWP impact that is 50% higher than for the average of the other materials.

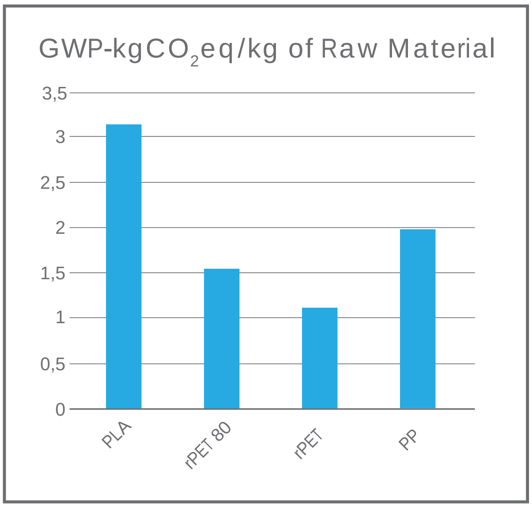


Figure 30: Graph of GWP-kgCO_2eq/kg of raw material

When the graph in Figure 30 above is adjusted for the weight of the cups associated with these raw materials, the PLA still remains at a GWP impact of 50% higher than for the average of the other cups.

Hence, it can be stated that raw material choice for the cups has a high influencing factor, at 50% for the PLA cups, when compared based entirely on the raw material GWP impact. When this is adjusted to include manufacturing impacts, the figure drops to 26% when compared to the average of the other Soft Cups.

The impact of the level of collection and recycling of the Soft Cups when moving from 98% recycled to 0% recycled is an influential variable, as can be seen in Table 31 below, with increases in the Soft Cup GWP of between 25.5 to 39.0% when moving from 98% recycling to 0% recycling.

It can be concluded that raw material type, the type of manufacturing and the country of manufacturing of cups, and the level to which they are recycled have a significant impact on the Soft Cup System, all to a high degree.

Transport to the end-of-life scenario for the Soft Cups is 0.9% of the Soft Cup system when 98% of the Soft Cups are recycled. Transport within the cup manufacturing system, basically the raw material delivery and the final cup delivery to the washer, can be seen in Table 32 below, based on 98% of the Soft Cups being recycled.

Hence, it can be stated that percentage recycling and cup type are variables of significant influence on the GWP of the Soft Cup system whereas transport is a variable of little influence on the GWP of the Soft Cup system.

Table 31: Influence of the percentage of recycling, at the EoL of the Soft Cups on their GWP

Soft Cups	% Increase in GWP when recycling rate drops from 98% to 0%
PLA 1	25.50
rPET 1	30.66
rPET 2	37.13
rPET 3	28.74
PP 1	39.00
PP 2	38.90

Table 32: Transport as a percentage of GWP within the Soft Cup system

Transport of Soft Cup in Total System	
Soft Cups	% GWP
PLA 1	5.12
rPET 1	4.95
rPET 2	2.63
rPET 3	4.77
PP 1	2.39
PP 2	1.99

Hard Cups

While there are differences in GWP between the Hard Cups, which are all made of the same raw material using the same conversion processes, it is the impact of the processes within the Hard Cup system that are the variables of greatest influence, specifically loss percentages and washing company.

To assess these process impacts a version of the BCT was built that separated out the individual process impact at each serving.

In "Table 33: Individual Process Impact Tool Example" on page 85 below, the lowest GWP Hard Cup and Washing system is adopted. In this case, while the cup GWP is high at the early servings and the washing and transport is low, the situation becomes inverted at higher servings based on 98% of the Hard Cups being collected for reuse. It can be seen that the cup GWP becomes under half of the Hard Cup GWP by the 11th serving based on 98% recovery of the Hard Cups but that when only 80% of the cups are recovered, the cup GWP remains at over half of the Hard Cup system GWP up to the 5000th serving.

Were the highest GWP Hard Cup and Washing system to be adopted, the cup GWP becomes under half of the Hard Cup GWP by the 9th serving based on 98% recovery of the Hard Cups. However, when only 80% of the cups are recovered, the cup GWP remains at over half of the Hard Cup system GWP up to the 5000th serving.

Taking a loss percentage between 2 and 20%, i.e. 11%, the Hard Cup GWP remains relatively constant as the rate of change becomes very minor per serving after a number of servings.

Hence, the percentage of collected Hard Cups and the washing company adopted, are the variables of most significant influence. Followed by Cup Type and Transport to and from the event.

Table 33: Individual Process Impact Tool Example

N° of cups in the system:	100	Cup:	GWP $kgCO_2$-eq/cup				Washing company:	GWP $kgCO_2$-eq/cup
% of lost/discarded cups:	2	(H)PP 3 National	0,06995000	0,01040000	0,001277561	0,001281714	Company A	0,005545664
			Hard Cup	Crate	Transport to Wash	Transport EoL		

Servings	Cup	Crate	Washing	Transport between event and washer	End of Life Transport	Total	Difference HC/rotation	% Cup	% Crate	% Washing	% Transport event-washer	% EoL Transport
1	7,00	0,0104	0,5546	0,1278	0,1256	7,81	-	89,53%	0,13%	7,10%	1,64%	1,61%
2	7,13	0,0208	1,1091	0,3807	0,1256	8,77	0,96	81,35%	0,24%	12,65%	4,34%	1,43%
3	7,27	0,0312	1,6637	0,6337	0,1256	9,73	0,96	74,77%	0,32%	17,10%	6,51%	1,29%
4	7,41	0,0416	2,2183	0,8866	0,1256	10,69	0,96	69,38%	0,39%	20,76%	8,30%	1,18%
5	7,55	0,0520	2,7728	1,1396	0,1256	11,64	0,96	64,88%	0,45%	23,81%	9,79%	1,08%
6	7,69	0,0624	3,3274	1,3925	0,1256	12,60	0,96	61,06%	0,50%	26,40%	11,05%	1,00%
7	7,83	0,0728	3,8820	1,6455	0,1256	13,56	0,96	57,77%	0,54%	28,63%	12,13%	0,93%
8	7,97	0,0832	4,4365	1,8985	0,1256	14,52	0,96	54,93%	0,57%	30,56%	13,08%	0,87%
9	8,11	0,0936	4,9911	2,1514	0,1256	15,48	0,96	52,43%	0,60%	32,25%	13,90%	0,81%
10	8,25	0,1040	5,5457	2,4044	0,1256	16,43	0,96	50,23%	0,63%	33,75%	14,63%	0,76%
11	8,39	0,1144	6,1002	2,6573	0,1256	17,39	0,96	48,26%	0,66%	35,08%	15,28%	0,72%
12	8,53	0,1248	6,6548	2,9103	0,1256	18,35	0,96	46,51%	0,68%	36,27%	15,86%	0,68%
13	8,67	0,1352	7,2094	3,1632	0,1256	19,31	0,96	44,93%	0,70%	37,34%	16,38%	0,65%
14	8,81	0,1456	7,7639	3,4162	0,1256	20,27	0,96	43,49%	0,72%	38,31%	16,86%	0,62%
15	8,95	0,1560	8,3185	3,6692	0,1256	21,22	0,96	42,19%	0,74%	39,20%	17,29%	0,59%
16	9,09	0,1664	8,8731	3,9221	0,1256	22,18	0,96	41,00%	0,75%	40,00%	17,68%	0,57%
17	9,23	0,1768	9,4276	4,1751	0,1256	23,14	0,96	39,90%	0,76%	40,74%	18,04%	0,54%
18	9,37	0,1872	9,9822	4,4280	0,1256	24,10	0,96	38,90%	0,78%	41,43%	18,38%	0,52%
19	9,51	0,1976	10,5368	4,6810	0,1256	25,05	0,96	37,97%	0,79%	42,06%	18,68%	0,50%
20	9,65	0,2080	11,0913	4,9339	0,1256	26,01	0,96	37,11%	0,80%	42,64%	18,97%	0,48%

Conclusion of the Relative Influence of the Variables

The relative influence of the variables on the environmental impact of the systems can be summed up in the following figure.

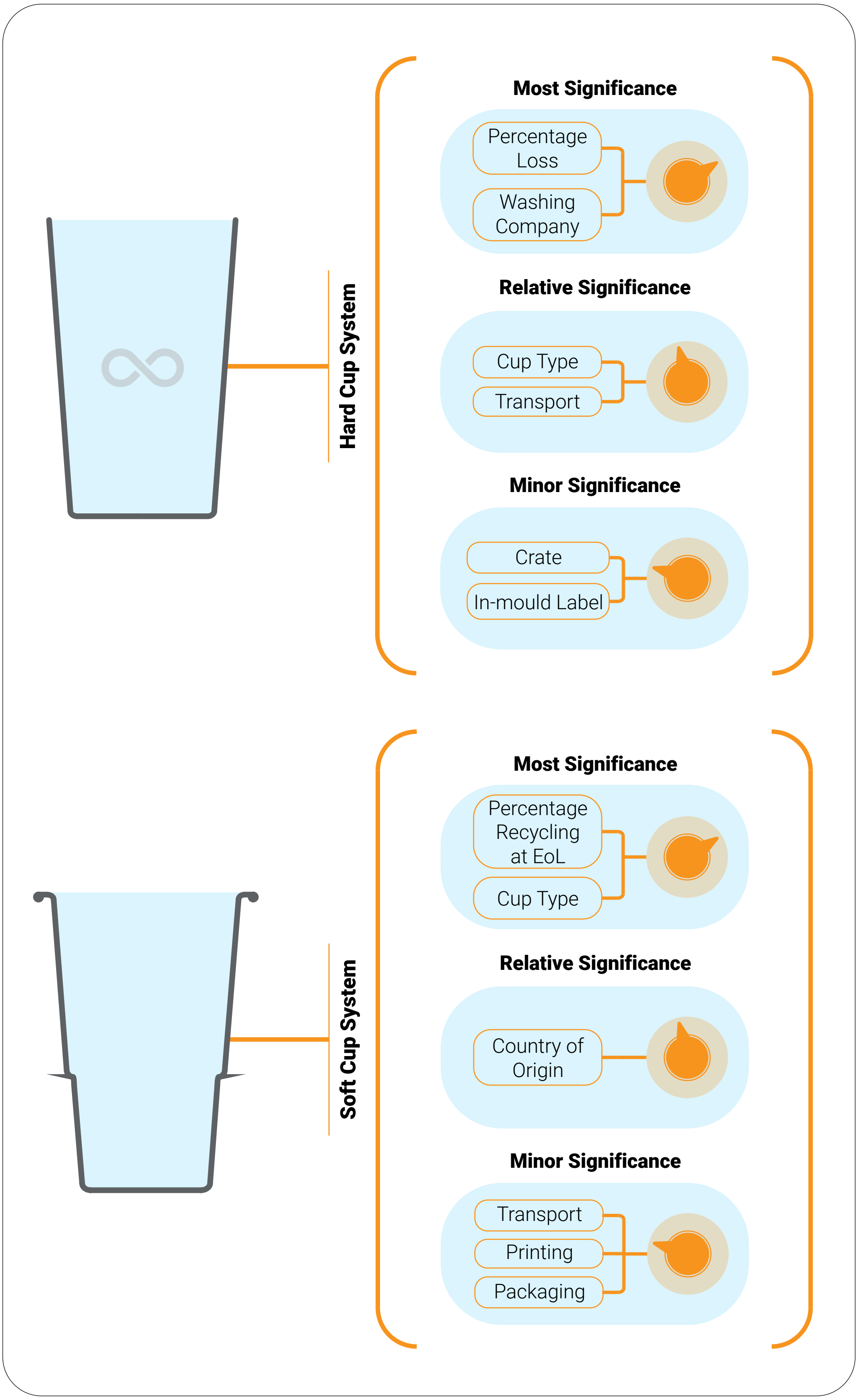


Figure 31: Relative Influence of the Variables on the Impact of the Hard & Soft Cup systems

Interpretation and discussion

It is important to note that the figures in this report have been based throughout on a 100 cup system so that the impacts can be seen as percentages. Actual systems used will be much larger than this. For example, for system of 100 000 cups, the impact figures seen in the report will be multiplied by 1000. Figure differences that appear small in terms of percentage will be much larger in terms of actual figures.

The above losses and recycling percentages identified by Plastic Promise are large in their spread i.e. 80-98% returned Hard Cups, 41-92% recycled Soft Cups based on a deposit return system and 0-75% recycling in sorted waste. To further interpret the results of this study, four example scenarios have been studied. While these choices are subjective, they could also be seen as being possible and realistic.

Example Scenario 1 – The City Summer Festival

A mass open street festival in which Hard and Soft Cup systems are used may lead to higher cup losses. In this scenario, the relatively low cost PP Soft Cups and (H)PP 3 Hard Cups are adopted. It is assumed that the Soft Cups are collected, often mixed with other waste, leading to 50% being recycled. It is assumed that a deposit return system exists for the Hard Cup and losses would be 5%. The remaining Hard Cups are washed at company B.

The Hard Cup system would be the system of lowest impact breaking even with the Soft Cup system from the 12th serving when compared to the PP 2 Soft Cup and the 9th serving when compared to the PP 1 Soft Cup.

Example Scenario 2 – The Pop Festival

A major closed event in which Hard and Soft Cup systems are used, which may lead to a lower cup loss due to the captive audience. In this scenario, the rPET Soft Cup and the (H)PP 2 Hard Cup were adopted. It is assumed that a gratuity is given for returned Soft Cups and that the Hard Cups are part of a deposit return system. The Soft Cups are recycled to 92% and the Hard Cup loss is 3%. The remaining Hard Cups are washed at company C.

The above Hard Cup system would be of a lower impact than the above Soft Cup system, with it breaking even from the 9th serving when compared to the rPET 1 Soft Cup, the 8th serving when compared to the rPET 3 Soft Cup and the 15th serving compared to the rPET 2 Soft Cup.

Example Scenario 3 – The Cultural Event

A closed event in which Hard and Soft Cup systems are used, which may lead to a lower cup loss due to the captive audience. In this scenario, the rPET Soft Cup and the (H)PP 1 Hard Cup were adopted. It is assumed that bins are provided for returned Soft Cups and that the Hard Cups are part of a deposit return system. The Hard Cups are printed with the unique logo and date of the event. The Soft Cups are recycled to 75% and the Hard Cup loss is 20%. The remaining Hard Cups are washed at company D.

The Soft Cup system would be the system of lowest impact.

Example Scenario 4 – Open Country Event

A closed event in which Hard and Soft Cup systems are used, which may lead to a lower cup loss due to the captive audience. In this scenario, the PP Soft Cup and the (H)PP 2 Hard cup were adopted. It is assumed that bins are provided for returned Soft Cups and the Hard Cups are part of a deposit return system. The Hard Cups have a generic print. The Soft Cups are recycled to 75% and that Hard Cup loss is 10%. The remaining Hard Cups are washed at company A.

The Soft Cup system would be the system of lowest impact.

It can be seen that there are many permutations of scenarios and that they will all have their unique impact breakeven point. This suggests that each scenario should be studied prior to its adoption.

5

Conclusions & Recommendations

Topics

Conclusions

With regard to the Central Research Question, the following can be concluded from this study:

1. The assumption that either the Hard Cup or Soft Cup system, as is currently used at Dutch events, will always be the preferred system from an environmental perspective, is incorrect.

2. The point at which one system becomes more efficient than the other system (breakeven point) from an environmental perspective is dependent on the relative impact of the various inputs such as cup types, percentage recycling and cup losses, transports and washing systems impacts, as well as the environmental impact category being studied.

An exception to the above conclusions can be seen when the Water Resource use footprint is considered. In this case, the PP Soft Cup systems are always the better option than the Hard Cup systems at the 100^{th} serving and the Hard Cup system is always better than the PLA Soft Cup system at the 1^{st} serving.

Although various parts of the Hard and Soft Cup systems will be discussed below, it is crucial to think in terms of systems and to continually consider these singular parts in relation to their associated total system. It should also be stated that adaptation of Hard Cup systems requires long term commitment as the potential environmental benefit of the Hard Cup system becomes evident over time.

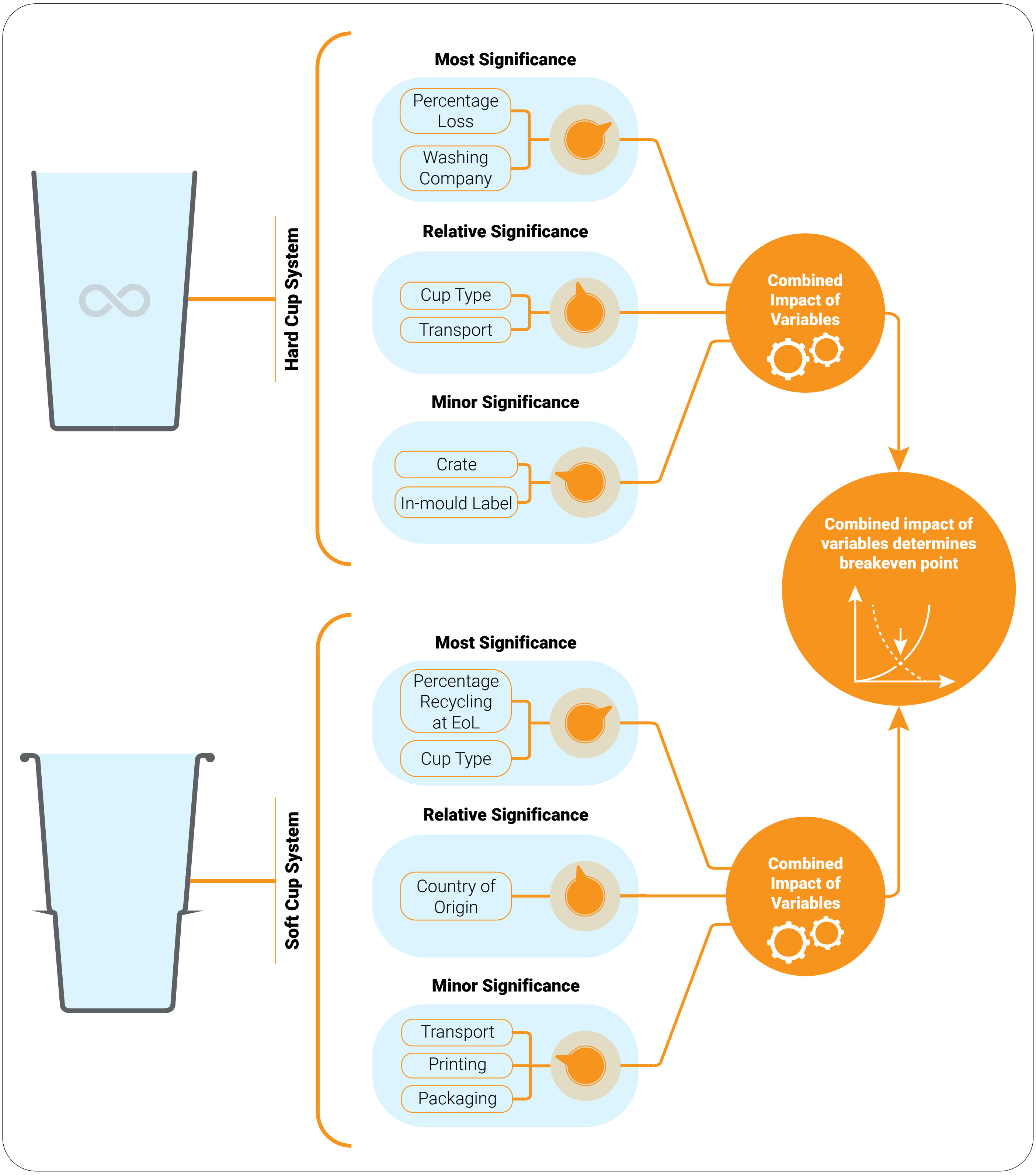


Figure 32: Illustration for the Conclusions

Cup Type

It is evident that cup type is important, both for the Hard Cup and Soft Cup systems, from an environmental perspective. The cups need to be designed specifically to have the lowest environmental impact for their function. The lighter weight reusable (H)PP 3 Hard Cup, manufactured in France, and the PP 2 single use Soft Cups are the most efficient cups within this study. In almost all cases studied, these cups are associated with the lowest impact Hard Cup and Soft Cup systems.

As the number of servings increases, the impact of the Hard Cup system cup impact reduces per serving, while every Soft Cup use requires the full impact of that cup. Hence for the Hard Cup, the cup type becomes less significant as the number of servings increases at low levels of Hard Cup loss.

Soft Cup Recycling

The higher the percentage of the Soft Cups that are recycled, the lower the environmental impact of the single use Soft Cup system. At very low Soft Cup recycling levels, the Hard Cup system is predominantly the lower environmental impact option. This was specifically noted at 0% and 42% Soft Cup recycling, as per the reported lower percentages of recycling of Soft Cups in the Plastic Promise 2019 study.

Hard Cup Loss

The higher the percentage of Hard Cups that are lost, the greater the environmental impact of the reusable Hard Cup system. At certain Hard Cup loss percentages, the Soft Cup clearly becomes the lower impact option, depending on the input variables. This was specifically noted at 20% Hard Cup loss, as per the reported lower percentage returned Hard Cups in the Plastic Promise 2019 study.

A potential conflict exists between the Hard Cup rental business model and the objective of reduce Hard Cup loss, since the event organiser earns ever larger net income from an ever higher percentage of non-returned cups against which a deposit has already been paid. While this income could be seen to motivate the use of the Hard Cup system and help with any additional costs related to operating such a system, it is also dependent on non-returned cups which is counter to the environmental objective of a Hard Cup system.

Soft Cup Recycling vs Hard Cup Loss

It can be concluded that the Hard Cup loss has less effect on a shift in breakeven point than the Soft Cup recycling rate and the choice of Hard Cup washing company. At 0% recycling of the Soft Cups, it is very common for the Hard Cup system to be the better option even at fairly significant Hard Cup loss percentages.

Washing Process

Cup washing processes vary significantly in environmental impact, for example washing company D has a per cup GWP that is 2.6 times higher than that of washing company A. Washing can have a significant impact on breakeven points depending on the cups being compared. Within this study, some washing processes are linked to specific cups and some are contract washers who will wash any Hard Cup.

What can be seen is that a Hard Cup which is washed at a less efficient wash company might not be able to break even with an efficient and recycled Soft Cup. By contrast, when the most efficient wash system is used, the Hard Cups break even at an early stage compared to the rPET and PLA cups. The influence on the breakeven point is significant for the actual wash system in place.

As the number of servings increases, the impact of washing grows in comparison to the reducing Hard Cup impact per serving. Beyond a certain number of servings, the percentage of the Hard Cup system that is washing, increases so marginally as to be seen to be stable.

Transport

Transport within the reuse system makes up a significant percentage of the average reuse system. As the number of servings increases, the impact of transport grows in comparison to the reducing Hard Cup cup impact per serving. As with the washing impact, the transport impact stabilises after a number of servings and shows little growth.

In Figure 33 below, the percentage contribution to the GWP of each of the inputs to the Hard Cup system can be seen for the most efficient Hard Cup system based on the 1st and 50th serving.

(H)PP 3 washed at Company A

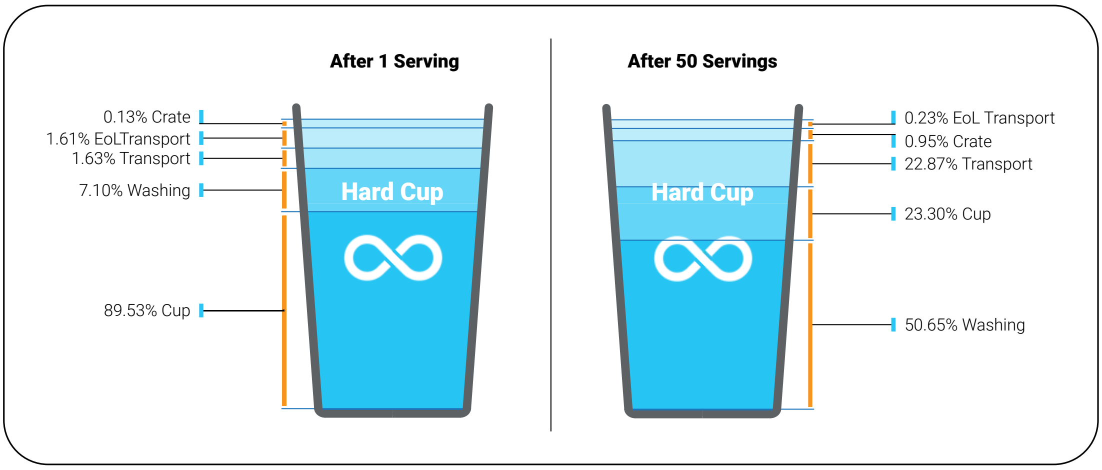


Figure 33: Comparison of 1st and 50th serving for most efficient Hard Cup systems

Recommendations

This chapter will act to guide the event organiser in making choices as regards beverage cup systems available for serving cold beverages.

Hard Cups

While there are scenarios that favour one or other cup system, it is evident that legislation is driving a move to a reusable Hard Cup type system and away from a single use plastic Soft Cup solution, this being evident in the EU Packaging & Packaging Waste Directive 92/64EC and the EU Single Use Plastics Directive EN2019/904. The latter will require Soft Cups to display plastic-content warning markings and these cups will be subject to consumption reduction targets and extended producer responsibility associated charges. The EU Single Use Plastics Directive has been driven by concern for terrestrial and marine plastic litter.

This Hard Cup approach makes sense from a resources perspective unless the level of Hard Cup loss is high, which contributes again to further resource use exceeding that of the Soft Cup system. The average PP Soft Cup weighs 4.55g and the average PP Hard Cup weighs 28.8g, thus, at the Plastic Promise 2019 highest reported loss figure of 20%, rendering the resource amount for the Hard Cup 1.2g heavier per serving. Hence, any Hard Cup system should work to achieve as high a return of used cups as possible.

Considerations as to how this could be achieved could be:

1. A deposit return system that actively charges to a punitive level, forcing attendees of the event to return the cups.

   If this charge is linked to an attendee's credit card or smart phone, it could be possible to approach this charge in the fashion of a car-rental or hotel deposit system, this being linked to a specific identifiable cup. Technology exists for this type of approach and it is being considered for the supply of cups at events.

   The system must make the attendee fully responsible for the cup return.

2. Enough access to reverse vending or return counters needs to be secured throughout the event but especially at the end. Alternatively, easy return systems should be made available after the event. If the attendee cannot easily manage and return their cup, they may bring their own cups, reusable or single use, which could be littered or could render servings unhygienic. Events would have to accept to only serve beverages in the fresh unused reuse Hard Cup chosen for the event.

3. In the case that the cups were to contain a RFID chip or other active track and trace devices, this could act to set off an alarm when the person leaves the event with the cup. Large warning signs could communicate this fact and bins could be made available at the exit. This could be operated with or without a deposit return system.

4. Providing unprinted cups that do not encourage keeping the cup as a souvenir or not keeping the cup because it has an attractive generic design.

5. Printing the cup with the clearly explained deposit return system rules.

The Hard Cups need to be as easy as possible for the attendee to return. This will require the application of "pain or gain" in the return system design. Ideally, the attendee has to feel the cup belongs to the event, as with a ceramic coffee cup in a restaurant. This will relate to the perceived value of the cup versus the deposit return charge.

The Hard Cup type and design has to permit the maximum number of reuses, or servings, over its useful life. To achieve this maximum number of servings, the cup will need to be used over more than just one annual event. An event organiser would logically go for a lightweight Hard Cup, if his decision is based on cost and the impact of the cup over his event only. Hence, this renders the responsibility for the cup type and design that of the party offering the Hard Cup system.

As the number of uses is the defining aspect of the reuse Hard Cup system, it could be important for the party operating the Hard Cup system to prove the number of uses the cups have already undergone. This would have to take account of the quality of the Hard Cups after a large number of uses.

Secondary to the cup type and number of uses, the cup washing system impact needs to be considered. As 95% of the cup washing GWP relates to the energy required to operate the washing machinery, it could be wise to check the energy source of the cup washing company. Additionally, this study shows a large difference in the quantity of cups washed per hour, which also contributes significantly to the washing impact.

Hence the event organiser should ask the party operating the Hard Cup system:

1. Regarding the cups that you will supply for my event, what is the average number of uses they have already had?
2. How many cups do you wash per hour and what is the source of your cup washing energy?
3. What is the non-returned cup charge?

Smart phone apps, track-and-trace, reverse vending, algorithms and the platform economy will all contribute to the optimisation of reuse systems to organise, manage and return the maximum number of cups. They will also contribute to a much clearer understanding of the environmental impact of an actual reuse system.

However, given the current financial model for cup reuse, it is questionable as to the level of motivation of the parties to invest in such systems that reduce their income from cup loss. On the other hand, it has been noted that a highly durable cup that is designed for the maximum number of servings and a minimum percentage loss, with a relatively high impact per cup, could still be the better option after the extended number of uses.

Questions are asked as to the cleanliness of reusable cups compared to single use cups; this issue may be of even greater concern given the current pandemic. The event organiser should ask for the appropriate audit based certification related to the washer's system as regards their resultant cup cleanliness.

The results of this study show that, even with the activity of transporting and washing between servings, this still renders the Hard Cup the lower environmental impact option in low loss scenarios.

Soft Cups

While the future is likely to be defined by aspirations for well-designed Hard Cup systems with low loss rate and efficient washing services, it should be recognised that the lack of necessary infrastructure and/or consumer willingness for change of behaviour may render the implementation of such systems impossible in the current situation.

Should an event organiser wish to adopt a Soft Cup system, they, as with the Hard Cup system, should put in place systems to recover the maximum amount of these cups in a clean waste stream to achieve a maximum recycling level. This may also be achieved using a deposit-return system in which returned cups are simply replaced with a new cup at each serving or the deposit after the last serving has been consumed.

Unlike with the Hard Cup system, where the cup needs to be durable for a maximum number of uses, the Soft Cup requires to be of the lowest weight design and material type to meet the function based on a single use. In this study, the Soft Cups researched were manufactured from three material types. The lowest environmental impact Soft Cups, in almost all cases, were the PP Soft Cups. Soft Cups made from PP are typically lighter in weight than other cup types and the manufacturing of cups from PP is a relatively lower impact process compared to manufacturing using the other material types.

This recommendation seems contradictory to the circularity principles whereby the use of recycled materials within close loop systems is encouraged. As the only recycled plastic type in a cup-to-cup recycling system currently available for food contact is rPET, it has been promoted by Plastic Promise as a preferred Soft Cup option. However, the study clearly shows that a rPET based Soft Cup system does not result in the lowest environmental impact compared to other Soft Cup systems. In order to achieve the full circular potential at the lowest environmental impact, a development of a closed loop cup-to-cup recycling system for PP Soft Cups is recommended. This recommendation is in line with the ongoing activities of the Food2Food PP recycling working group.

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Peer review

This study has been subjected to a peer review which will be supplied in Appendix F

Disclaimer

The LCA Centre general terms and conditions are applicable.

Abbreviations

Abbreviation	Definition
BCT	Breakeven Calculation Tool
CED	Cumulative Energy Demand
CFU	Colony forming unit
CO_2	Carbon Dioxide
CO_2eq	Carbon Dioxide equivalent
DC	Distribution Centre
EU	European Union
FTIR	Fourier transform infrared spectroscopy
g	Gram
GIGO	Garbage In Garbage Out
GLO	Global
GWP	Global Warming Potential
GWPC	Cup Global Warming Potential
GWPCr	Crate Global Warming Potential Per Cup
GWPEoL	End-of-Life Transport Global Warming Potential
GWPT	Transport Global Warming Potential
GWPW	Washing Global Warming Potential
HC	Hard Cup
H_2O	Water
ISO	International Organization for Standardization
JRC	Joint Research Centre
KIDV	Kennisinstituut Duurzaam Verpakken
kg	Kilogramme
km	Kilometre
kWh	Kilowatt-hour
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Analysis
LDPE	Low Density Polyethylene
m^3	Meters cubed
MJ	Mega Joules
ml	Millilitre
OVAM	Openbare Vlaamse Afvalstoffenmaatschappij
PC	Polycarbonate
PDF	Portable Document Format
PE	Polyethylene
PET	Polyethylene Terepthalate
PLA	Polylactid acid
PP	Polypropylene
PS	Polystyrene
ROW	Rest Of World
rPET	Recycled Polyethylene Terephthalate
RWS	Rijkswaterstaat
SC	Soft Cup
SDG	Sustainable Development Goal
XRF	X-ray Fluorescence

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6 Appendices

Appendix A

Methodology

The methods used within this study are explained below, commencing with a basic introduction to Life Cycle Assessment.

Life Cycle Assessment (LCA)

Definition of Life Cycle Assessment

"Life Cycle Assessment is a tool to assess the environmental impacts and resources used throughout a product's life cycle, i.e., from raw material acquisition, via production and use phases, to waste management" (Finnveden, G., et al., 2009).

LCA is a method that quantifies environmental stressors, such as resource use and emissions, that occur over the life cycle of anthropogenic systems and translates these stressors into metrics of environmental interferences for a number of mutually exclusive and collectively exhaustive "impact categories", such as climate change, eutrophication, and eco-toxicity (Bjorn, A., et al., 2015, p. vii).

Life Cycle Assessment Standardised Procedure

A description of the standardised ISO LCA procedure is given to define the framework and the four stages within an LCA study. The ISO standards provide guidance on procedures, but not on the method required for these procedural steps to be taken.

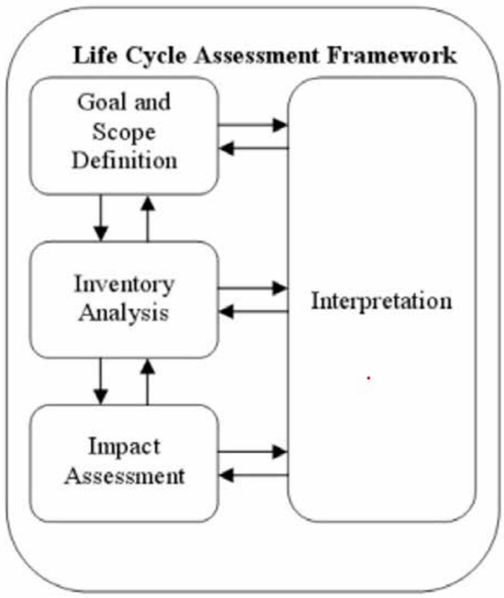

Figure 34: ISO 14040 (2006) LCA Framework and the Links with the Four Stages

An ISO standardised LCA consists of four stages as follows:

1. Goal and Scope Stage

The first stage is the definition of the Goal and Scope. This defines the purpose of the study and how it will be performed.

1. The Goal definition describes the objective of the study, the intended use of the results, and the audience.
2. The Scope definition describes the methodological approach to be used within the study, the definition of the product under study, and the system boundaries of that studied product system. The Scope defines the methodological framework for the next two stages, these being the life cycle inventory analysis and impact assessment stages.

2. Inventory Analysis

In the Inventory Analysis stage, the processes within the product system are studied with the objective of quantifying the input and output data for each process, this being the inventory data.

- Economic inventory data include the amount of resources, materials and energy needed to manufacture a product.
- Environmental inventory data include all extracted natural resources which are input into the process and all emissions and waste released or output to the environment.

3. Impact Assessment

At the Impact Assessment stage, the above defined Inventory data is converted into data related to their contribution to environmental impact in the chosen, scope defined, impact categories.

- Classification - assigns the environmental inventory data to the selected impact categories.
- Characterisation - calculates the contribution of each environmental input or output to an impact category, based on characterisation models.

4. Interpretation

The Interpretation stage involves evaluating the inventory data and impact results from the previous stages as defined in the goal and scope, drawing conclusions and recommendations.

It also addresses the reliability of the LCA results. Sensitivity and uncertainty analysis is introduced.

While the ISO standard provides detailed guidance on procedures, it does not define the LCA methods to be used, leaving the LCA operative to choose from a range of methodological approaches. Some national standards and guidelines, with their own interpretation of approach and method, provide methodological guidance (Baumann, H., & Tillman, A. M., 2004), (Sonnemann, G., et al., 2011), (Guinée, J. B., et al., 2002).

The ambiguity relating to the ISO LCA standards is a subject of various papers (Ekvall, T., et al., 2001), (Guinée, J. B., et al., 2010), (Weidema, B., 2014), (Zamagni, A., et al., 2008). This is important as the standardisation of LCA has not led to a situation in which study results for the same product are always identical; in many cases they can be different or conflicting (Finnveden, G., & Ekvall, T. 1998), (Lazarevic, D., 2015), (von Falkenstein, et al., 2010), (Weiss, M., et al., 2012), (Wenzel, H., et al., 2006). These differences in LCA results for the same product can be related to uncertainties in data, methodological choices and assumptions (Brandao, M., et al., 2012).

However, when used to compare different products of like functionality, LCA results require to be robust and trustworthy (Finnveden, G., et al., 1998), (Geisler, G., et al., 2005), (Guinée, J., et al., 2002), (Ingwersen, W. W., et al., 2012).

LCA – Uncertainties and Factors influencing their Result

Due to the effect of the influence of LCA procedural and choice factors on the results of LCA studies, they are considered.

Impact Assessment Method

Of initial consideration is the choice of impact assessment method as this has influence over the results of an LCA study (Dreyer, L. C., et al., 2003).

Commonly used impact assessment methods are CML2001 (Guinée, J.B., et al., 2002), Eco-indicator (Goedkoop, M., et al., 2001), ReCiPe (Goedkoop, M., et al., 2009), Impact 2002+ (Jolliet et al., 2003), and ILCD Midpoint 2011+ (EC-JRC, 2010).

The impact assessment methods used in studies such as this one typically involve CML2001, Cumulative Energy Demand, Water Resource and/or ReCiPe, as is described later in this section.

Weighting

In LCA studies that require a single figure result derived from trade-offs and aggregation across LCIA impacts, weighting techniques are adopted (Bare, J. C., et al., 2000). LCIA impact, midpoint, indicators are considered to be of lower uncertainty than the endpoint indicators common to LCA. The approach to aggregation and the trade-off choices and methodologies, in deriving a single figure result to an LCA study, will impact the result between these LCA approaches.

Allocation

A further consideration relates to the allocation of environmental burden when a process produces multiple products, a common problem in LCA (Reap, J., et al., 2008), (Russell, A., et al., 2005).

Allocation is of concern when accounting for recycling, which is both a materials production process as well as a waste management option. A range of methods regarding the allocation of burden in recycling exists (Ekvall, T., et al., 2001), (Ekvall, T., et al., 1997), (Guinée, J. B., et al., 2002), (Ligthart, T. N., et al., 2012), (Newell, S. A., et al., 1998).

Their application can also result in differences in LCA results for the same product (Azapagic, A., et al., 1999), (Cederstrand, P., et al., 2014), (Ekvall, T., et al., 2001), (Weidema, B. P., et al., 2010).

Uncertainty

Uncertainty is inherent in LCA studies and must also be considered. Uncertainty should be explicitly and transparently addressed in LCA studies, especially if they are to inform decision makers (Bennett, N. D., et al., 2013), (Jakeman, A. J., et al., 2006).

In the ISO 14044 procedure (ISO, 2006b), it is stated that uncertainty analysis must be adopted, being seen as integral to LCA (Ciroth, A., et al., 2004), (Finnveden, G., et al., 2009), (Heijungs, R., et al., 2004), (Notten, P., et al., 2003).

Process Datasets

An increasing number of datasets are becoming available covering the same or similar processes, such as those available from Ecoinvent. LCA results can differ based on the choice of dataset adopted for a process, this being addressed using sensitivity analysis (Peereboom, E. C., et al., 1998).

Forensic LCA

Forensic LCA (Campbell, A. 2019) functions to increase the accuracy of product economic inventory data, in the inventory analysis stage, for input to LCA. This is especially important if the product manufacturing stakeholder is not willing or available to give component and processing data. It functions to reduce the chance of GIGO (garbage in – garbage out) in product comparative LCA studies.

Forensic LCA requires the use of laboratory instrumentation to assess like-functionality in defining product compliance to the functional unit and to facilitate forensic techniques to identify material component composition and processing. It also requires to be carried out exclusively by packaging technologists who can interpret the findings in a technologically relevant manner, as the lack of product technological relevance has been a major criticism of LCA.

Forensic LCA is an approach unique to The LCA Centre and is fully described in their book on the subject (ISBN: 978-94-6380-571-1).

Global Warming Potential

Global warming potential (GWP) is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide and is expressed as a single factor of carbon dioxide (whose GWP is standardised to 1). The time horizon associated with the GWP within this study is 100-years.

Water Resource

Water Resource is a generic term used to describe human activity involving water resources as well as the total amount of water used during the process. This water is from the Biosphere as well as the Technosphere, as well as wastewater to the Technosphere and Biosphere, as can be seen in Figure 35 below:

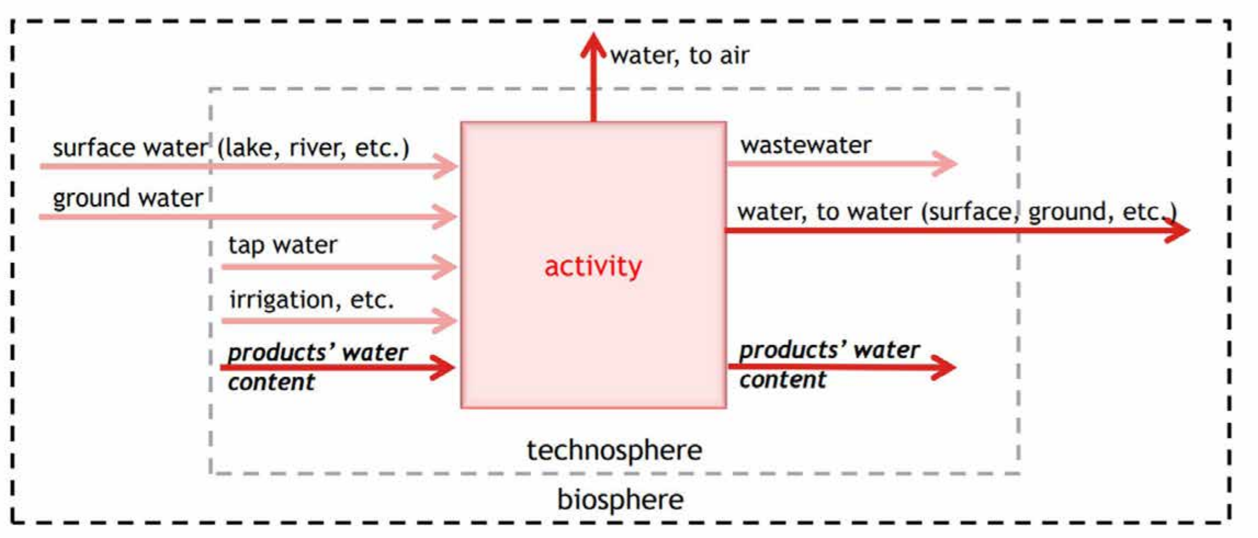

Figure 35: Activities related to the Water resource impact factor

Cumulative Energy Demand

Cumulative Energy Requirements Analysis aims to investigate the energy use throughout the life cycle of a good or a service. This includes the direct uses as well as the indirect or grey consumption of energy due to the use of, e.g. construction materials or raw materials. This method was developed in the early seventies and has a long tradition (Boustead & Hancock 1979; Pimentel 1973).

According to Verein Deutscher Ingenieure (1997) "the data on the cumulative energy demand ... form an important base in order to point out the priorities of energy saving potentials in their complex relationship between design, production, use and disposal". However, the cumulative energy demand (CED) is also widely used as a screening indicator for environmental impacts.

Furthermore, CED-values can be used to compare the results of a detailed LCA study to others where only primary energy demand is reported. Finally, CED-results can be used for plausibility checks because it is quite easy to judge on the basis of the CED whether or not major errors have been made.

Cumulative energy analysis can be a good 'entry point' into life cycle thinking. But it does not replace an assessment with the help of comprehensive impact assessment methods. If more detailed information on the actual environmental burdens and especially on process-specific emissions are available - and the Ecoinvent database provides such information - more reliable results are available with such methods. Thus, Kasser & Pöll (1999:9) e.g. write that the CED "makes only sense in combination with other methods".

Different concepts for determining the primary energy requirement exist. For CED calculations one may chose the lower or the upper heating value of primary energy carriers where the latter includes the evaporation energy of the water present in the flue gas. Furthermore, one may distinguish between energy requirements of renewable and non-renewable resources.

Due to the existence of diverging concepts and the unclear basis for the characterisation of the different primary energy carriers, the CED-indicator is split up into eight categories for the Ecoinvent database and no aggregated value is presented. Common to all categories is the thesis that all energy carriers have an intrinsic value. This intrinsic value is determined by the amount of energy withdrawn from nature. However, the intrinsic value of energy resources expressed in MJ-Equivalents need not be comparable across the subcategories.

The user may adjust and combine these categories as intended for own calculations. Wastes, which are used for energy purposes are dealt with a cut-off approach. Thus, they are not accounted for in the CED values. Their energy content and thus the demand is allocated to the primary use.

Impact assessment method cumulative energy demand implemented in Ecoinvent includes the following subcategories:

- non-renewable resources being fossil hard coal, lignite, crude oil, natural gas, coal mining off-gas, peat, nuclear, uranium, primary forest wood and biomass from primary forests
- renewable resources being biomass wood, food products, biomass from agriculture, e.g. straw, wind energy, solar energy (used for heat & electricity), geothermal energy, water run-of-river hydro power, reservoir hydro power

Unless otherwise indicated the CED figure reported is the aggregated value of the eight categories described above.

ReCiPe Methodology - Version 2016

ReCiPe (Goedkoop, M., et al., 2009) is a method for the impact assessment in LCA. Using characterisation factors, LCIA translates emissions and resource extractions into a limited number of environmental impact scores. The primary objective of the ReCiPe method is to transform lists of Life Cycle Inventory results into a limited number of indicator scores. These indicator scores express the relative severity on an environmental impact category.

The ReCiPe method combines both midpoint and endpoint modelling with 18 midpoint categories, notably climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication, human toxicity, photochemical oxidant formation, particulate matter formation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, ionizing radiation, agricultural land occupation, urban land occupation, natural land transformation, water depletion, mineral resource depletion and fossil fuel depletion. At the endpoint level there are 3 categories, notably damage to human health, damage to ecosystem diversity and damage to resources availability.

ReCiPe uses a series of effects that together can create a certain level of damage, for example to human health or ecosystems, as the basis for its modelling. An example of this is climate change for which it is known that a number of substances increase the radiative forcing, preventing heat from being radiated out into space from Earth. As a result, more energy is trapped and temperature increases, leading to changes in habitats for living organisms, and the possibility that species may become extinct.

The overall structure of the ReCiPe method can be seen below in Figure 36, showing the impact categories and pathways covered by the methodology, from life cycle inventory to a final single endpoint score. The diagram shows five columns: the result of the Life Cycle Inventory, the environmental mechanisms they contribute to, the midpoints, the translation to environmental damage and the endpoint scores.

The ReCiPe method groups different sources of uncertainty and different choices into a limited number of perspectives or scenarios. In this study, the hierarchist (H) perspective model will be adopted which is based on the most common policy principles with regards to time frame and other issues. In the hierarchist perspective, the 100-year time frame is the most frequently used. The hierarchist model is often considered to be the default model.

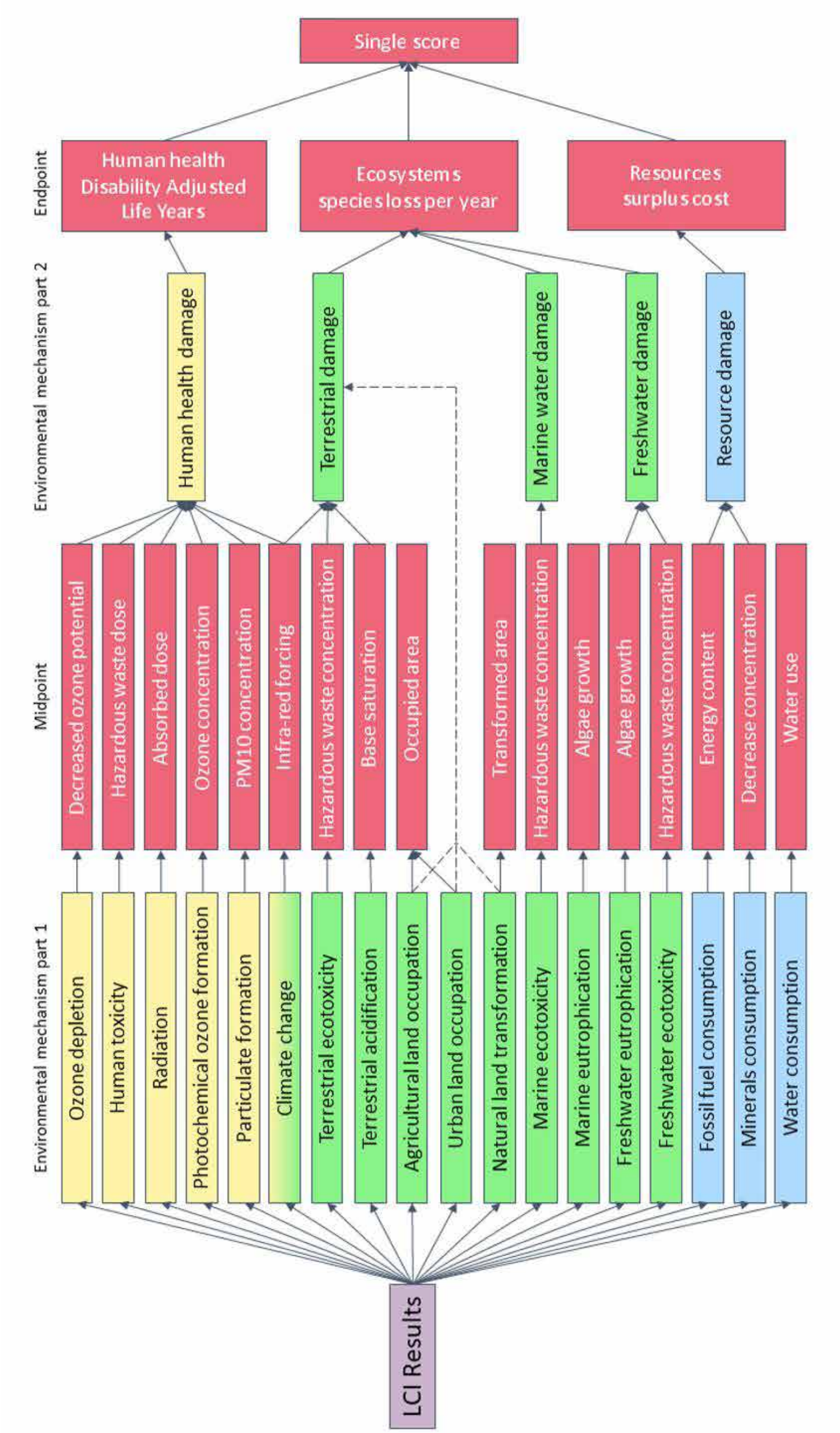

Figure 36: Relationship: LCI Parameters (left), Midpoint Indicator (middle) & Endpoint Indicator (right) in ReCiPe

ReCiPe determines indicators at two levels:

Table 34: First level - Eighteen Midpoint Indicators	
ReCiPe (H) Midpoint	
Impact Category	Reference Unit
Ozone depletion	kg CFC-11-Eq
Human toxicity	kg 1,4-DCB-Eq
Ionizing radiation	kg U235-Eq
Photochemical oxidant formation	kg NMVOC
Particulate matter formation	kg PM10-Eq
Climate change	kg CO_2-Eq
Terrestrial ecotoxicity	kg 1,4-DCB-Eq
Terrestrial acidification	kg SO_2-Eq
Agricultural land occupation	m^2a
Urban land occupation	m^2a
Natural land transformation	m^2
Marine ecotoxicity	kg 1,4-DCB-Eq
Marine eutrophication	kg N-Eq
Freshwater eutrophication	kg P-Eq
Freshwater ecotoxicity	kg 1,4-DCB-Eq
Fossil depletion	kg oil-Eq
Metal depletion	kg Fe-Eq
Water depletion	m^3

Midpoint indicators are considered to be links in the cause-effect chain of an impact category at which characterisation factors or indicators can be derived to reflect the relative importance of emissions or extractions (Bare, J. C., et al., 2000).

Table 35: Second Level - Three Endpoint Total Indicators	
Human Health	Ozone Depletion
Human Health	Human Toxicity
Human Health	Ionizing Radiation
Human Health	Photochemical Oxidant Formation
Human Health	Particulate Matter Formation
Human Health	Climate Change
Human Health - total	
Ecosystem Quality	Terrestrial Ecotoxicity
Ecosystem Quality	Terrestrial Acidification
Ecosystem Quality	Marine Ecotoxicity
Ecosystem Quality	Freshwater Eutrophication
Ecosystem Quality	Freshwater Ecotoxicity
Ecosystem Quality - total	
Resources	Fossil Depletion
Resources	Metal Depletion
Resources - total	
Total - Total	Total of the Endpoint Totals

Endpoint characterisation indicators are calculated to reflect differences between stressors at an endpoint in a cause-effect, such as measures of biodiversity change (Bare, J. C., et al., 2000).

An explanation of the individual LCIA categories and their associated equivalent units can be seen in Table 36 below:

Overview of the midpoint categories, indicators and characterisation factors

Impact category Name	Abbr.	Indicator Name	Unit**	Characterisation factor Name	Unit*	Abbr.
Climate change	CC	Infra-red radiative forcing	Wxyr/m²	Global warming potential	kg (CO_2 to air)	GWP
Ozone depletion	OD	Stratospheric ozone concentration	ppt##xyr	Ozone depletion potential	kg (CFC-11^5 to air)	ODP
Terrestrial acidification	TA	Base saturation	yrxm²	Terrestrial acidification potential	kg (SO_2 to air)	TAP
Freshwater eutrophication	FE	Phosphorus concentration	yrxkg/m³	Freshwater eutrophication potential	kg (P to freshwater)	FEP
Marine eutrophication	ME	Nitrogen concentration	yrxkg/m³	Marine eutrophication potential	kg (N to freshwater)	MEP
Human toxicity	HT	Hazard-weighted dose	-	Human toxicity potential	kg (14DCB to urban air)	HTP
Photochemical oxidant formation	POF	Photochemical ozone concentration	kg	Photochemical oxidant formation potential	kg (NMVOC^6 to air)	POFP
Particulate matter formation	PMF	PM_{10} intake	kg	Particulate matter formation potential	kg(PM_{10} to air)	PMFP
Terrestrial ecotoxicity	TET	Hazard-weighted concentration	m²xyr	Terrestrial ecotoxicity potential	kg (14DCB to industrial soil)	TETP
Freshwater ecotoxicity	FET	Hazard-weighted concentration	m²xyr	Freshwater ecotoxicity potential	kg (14DCB to freshwater)	FETP
Marine ecotoxocity	MET	Hazard-weighted concentration	m²xyr	Marine ecotoxocity potential	kg (14-DCB^7 to marine water)	METP
Ionising radiation	IR	Aborbed dose	manxSv	Ionising radiation potential	kg (U^{235} to air)	IRP
Agricultural land occupation	ALO	Occupation	m²xyr	Agricultural land occupation potential	m²xyr (agricultural land)	ALOP
Urban land occupation	ULO	Occupation	m²xyr	Urban land occupation potential	m²xyr (uban land)	ULOP
Natural land tranformation	NLT	Transformation	m²	Natural land tranformation potential	m² (natural land)	NLTP
Water depletion	WD	Amount of water	m³	Water depletion potential	m³ (water)	WDP
Mineral resource depletion	MRD	Grade decrease	kg^{-1}	Mineral depletion potential	kg (Fe)	MDP
Fossil resource depletion	FD	Lower heating value	MJ	Fossil depletion potential	kg (oil#)	FDP

**The unit of the indicator here is the unit of the physical or chemical phenomenon modelled. InReCiPe2008, these results are expressed relative to a reference intervention in a concrete LCA study.*

***The unit of the impact category here is the unit of the indicator result, thus expressed relative to a reference intervention in a concrete LCA study*

 # The precise reference extraction is "oil, crude, feedstock, 42MJ per kg in ground".

The unit ppt refers to units of equivalent chlorine.

Table 36: LCIA categories and their associated equivalent units

Appendix B

Product category considerations

The cups in the 250 ml Soft and Hard Cup range, see Table 37 below, were submitted by the study members for comparison and are seen by the parties to be of like functionality. Functional equivalency is important when making a comparative environmental claim between product.

Table 37: Soft and Hard Cups in the Study Intake Form	
SOFT CUPS	
Cup Ref. No.	Fill Line
PLA 1	250 ml
rPET 1	250 ml
rPET 2	250 ml
rPET 3	250 ml
PP 1	250 ml
PP 2	250 ml
PP 3	200 ml
HARD CUPS	
Cup Ref. No.	Fill Line
(H)PP 1	250ml
(H)PP 2	250 ml
(H)PP 3	250 ml

Cup Capacity

The PP 3 Soft Cup is used by 4'Daagse and is reported as being a 200 ml (20cl fill line marking); all other cups are 250 ml in accordance with the study functional unit. The PP 3 rim fill is 270ml which would seem very close to the 250 ml functional unit capacity; all other cups have rim fills above 300ml. The PP 3 cup is equivalent in height to many of the other cups but it is generally narrower than the other cups, and "visibly" smaller than the other cups. Figure 37 below, in the photo on the left, shows the PP 3 cup with 250 ml of contents; the fill is to just under the rim making the cup difficult to carry without spilling and there is no room for a head of foam on the drink. The photo on the right in Figure 37 below shows an rPET cup filled with 250 ml of water, showing plenty of room for head foam and increase in level due to carrying compression of the wall. The photo on the left in Figure 37 below shows a PP 3 cup filled with 250 ml of water, showing no space for head foam and increase in level due to carrying compression of the wall. The latter cup was not taken up within this study.

Figure 37: Verification of the 250ml carrying capacity of the cups

Due to the reduced capacity that does not meet the Functional Unit description, the PP 3 cup has been dropped from the study.

The (H)PP 1 Hard Cup used by Elevation Events is reported as a 200 ml cup with only 7.5mm of head space above 250 ml of beverage, with a rim fill capacity of 280ml. All other (H)PP 1 users report a 250 ml cup which has a measure rim fill of 360ml. The difference in fill level can be clearly seen in Figure 38 below.

For this study, the 250 ml (H)PP 1 cup will be adopted, along with the 250 ml (H)PP 2 and the 250ml (H)PP 3 cups.

Figure 38: The 200 and 250 ml (H)PP 1 Hard Cups filled with 250 ml of water

Cup Weight

A maximum number of the submitted cups were weighted and divided by the number of cups. Knowing that these cups are subject to weight tolerance, the identified weight was then compared to the nearest reported weight related to the cup reported on public websites, this being the most likely intended weight of the cup manufacturer.

For example, one of the Soft Cups weighed in at 6.55g/cup and was then identified on two websites as being sold as a 6.7g cup. This 2.2% weight difference is within a typical tolerance for this type of cup. The weight of 6.7g will then be adopted in the model of the cup.

Cup Strength

The strength of the three Hard Cups is evidently very similar. These reuse cups are obviously of a higher strength than Soft Cup so as to permit their multiple reuses without damage to the cup.

In the case of the Soft Cup, there is a greater spread of different strengths. It should also be noted that PP cups are inherently softer, and the wall displaces easily under pressure. All filled Soft Cups were subject to horizontal compression testing at the finger position (15mm below the rim), using the cup compression tester seen in Figure 39 below. The average pressure to displace the diameter of the cup by 5mm was 1.47N for the PP cups and 3.51N for the polyester cups.

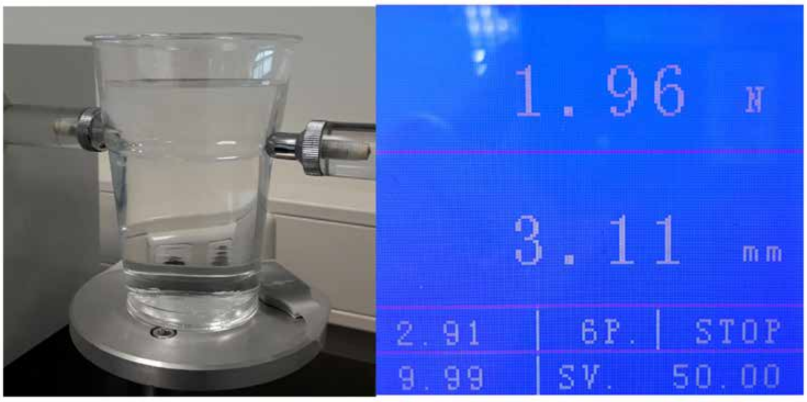

Figure 39: Cup Compression Tests instrumentation

Due to this large difference in Soft Cup weights it is possible that other functionality issues could exist. Any additional functionality has not been tested by The LCA Centre and the choice of the cups for comparison remains that of the study parties.

Cup Print

A further function that qualifies the cups for comparison is the fact they are either reported as being printed or can be printed, this being for both the Soft and Hard Cups. This study assumes that all the cups are printed. It should be noted that should unprinted cups be used and modelled, this would lead to a reduction in environmental impact of the cups. For example, a reduction in GWP of 6.04% for PP 1 and 6.43% for PP 2, based on national energy and the cups being 98% recycled.

The EU Single Use Plastics Directive EN2019/904 will require that single use beverage cups have a plastic content warning marking on them. This marking could be based on a print. Providing further justification, for all such cups, to be assumed to be printed within this study.

It should be noted that the choice of print on the cups, to qualify for comparison, may also influence other aspects of their function, such as their eventual end-of-life scenario. Of concern regarding printing is the possibility that printed cups may be more likely to be taken as a souvenir leading to cup losses within the system. Insights from the (H)PP 2 manufacturer regarding printing are:

1. Printing on the Hard Cup, indicating what to do with the cup and how much the deposit is, increases the chance of the cups being returned

2. Unprinted Hard Cups are less well treated by the public (low value perception)

Specific venue name and date based prints on Hard Cups will render the cup unusable at other events or the same event a year later. This may shorten the useful life of a reuse cup. Likewise, if a similar print run is applied to the Soft Cups and not all the cups are used, these could lead to unusable cups and potential disposal without use. It is also possible that minimum print runs on Hard Cups could lead to more cups than servings.

It could be concluded that the printing on the cup could lead to increased losses from the system and as such should be considered during the design phase.

Cup Disposal

The study assumes that all cups can be recycled and or incinerated at the end of their useful life. This assumption was studied, and recyclers and incinerators are available to handle waste cups, including PLA cup recycling (Looplife Belgium).

In the above chapter, titled Scenarios, reference is made to factors that could influence litter. Littering is a cup disposal route that should be discouraged through the cup and system design. It can be assumed that a percentage of the non-returned cups may end up as litter. Single use Soft Cups may have a higher propensity to be littered. Litter is not modelled within this study.

Cup Cleanliness

No used and washed Hard Cups were received from the events, thus these could not be studied for their cleanliness in comparison with Soft Cups. The LCA Centre has previously carried out such studies involving bacteria, and these were used to provide information about the hygienic status of a product.

Appendix C

In the subchapters dedicated to the raw material and processing of PLA and rPET into Soft Cups, a number references were used that are reported separately within this appendix.

rPET

A variety of technical publications were referred to as regards the nature and processing of rPET. Notably:

https://www.ptonline.com/knowledgecenter/plastics-drying/resin-types/crystalline-vs-amorphous-pet

https://www.ptonline.com/knowledgecenter/plastics-drying/drying-questions/pet-drying

https://plasticsrecycling.org/images/apr/2018-APR-Recycled-Resin-Report.pdf

https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=4245#PD

https://core.ac.uk/download/pdf/38087728.pdf

https://www.wrap.org.uk/sites/files/wrap/rPET%20Quality%20Report.pdf

http://www.lifeplus-lightpet.com/materiale/ActionC1-LCAanalysisUsing100virginPET.pdf

PLA

Natureworks, the manufacturer of the PLA granule adopted for this study, have a sizable library of Technical Document resources, as can be seen at https://www.natureworksllc.com/Resources

Within this study reference was made to:

https://www.natureworksllc.com/~/media/Files/NatureWorks/Technical-Documents/Processing-Guides/ProcessingGuide_Crystallizing-and-Drying_pdf.pdf

Appendix D

Calculating the overall Global Warming Potential (GWP)of a cup reuse system

To calculate the overall GWP of a single use Soft Cup system, the number of cups used is simply multiplied by the GWP per cup. For example, for a 100 Soft Cup system, after 3 rotations 300 cups will have been used for 300 servings and so the overall GWP for the system (up to this point) would be 300 x GWP/cup. This is based on the presumption that all Soft Cups are used only once and then recycled or incinerated.

To calculate the overall GWP of a reuse Hard Cup system so that a breakeven point between a Soft Cup system and a Hard Cup system can be found, the BCT is used to compare the two systems. The formulas for the BCT are set out below. It should be noted that a rotation is made up of one wash, transport to/from the washing facility and one use. In addition, and most importantly, the formulas given provide the cumulative GWP of the HC system up to and including the rotation input into the formula. For example, if n = 5 is input into the formula, it will give the cumulative GWP of the first five rotations and not just the 5th rotation. It is also presumed that at the end of the number of rotations input, all cups will leave the system, even where this is unlikely, i.e. after just a few rotations, as this is the only way to find the rotation, if it exists, where the reuse system has a lower GWP than single use.

(i) Cup usage calculation to use with the cup GWP (GWPC)

For a 100 cup Hard Cup system with, say, a 2% loss per rotation, the system works as follows:

1. 100 cups are prewashed and transported to the event.
2. 100 cups serve 100 drinks, 2 cups are lost, the remaining 98 cups are sent to be washed.
3. 2 new cups join the system, all 100 cups are washed and returned to the event.
4. Repeat 2) and 3).

The flowchart in Figure 40 below shows the number of cups required for both the Hard Cup (HC) and the Soft Cup (SC) systems from 1 to 5 rotations:

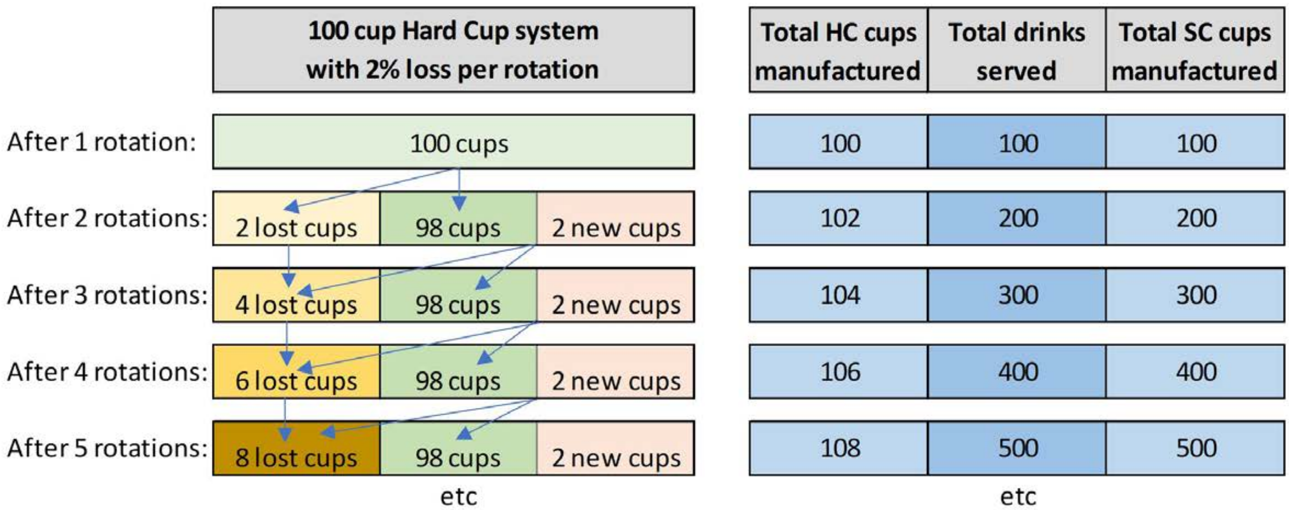

Figure 40: 100 cup Hard Cup system with 2% loss versus 100 Soft Cups, 5 rotations

The number of cups required for the first five rotations is:

1 rotation: 100

2 rotations: 100 + 2

3 rotations: 100 + 4

4 rotations: 100 + 6

5 rotations: 100 + 8

Hence, it can be seen that the formula for the number of Hard Cups required to service a 100 cup Hard Cup system, with a 2% loss per rotation, after n rotations is:

$$100 + 2 \times (n - 1)$$

Similarly, for a 100 cup Hard Cup system with 5% loss per rotation:

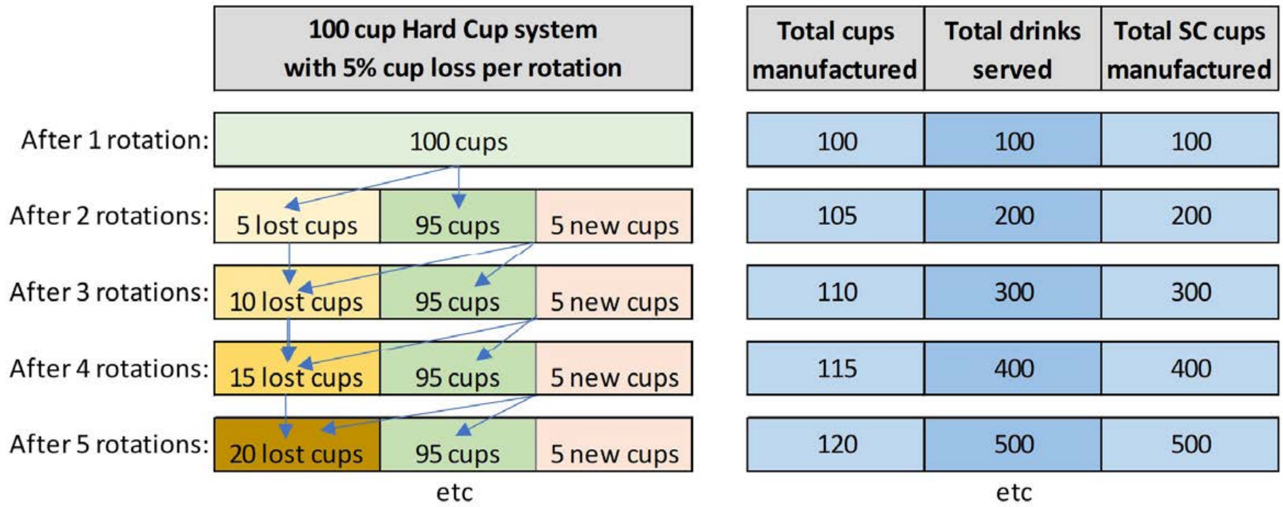

Figure 41: 100 cup Hard Cup system with 5% loss versus 100 Soft Cups, 5 rotations

Hence, the formula for the number of Hard Cups required to service a 100 cup Hard Cup system, with a 5% loss per rotation, after n rotations is:

$$100 + 5 \times (n - 1)$$

From these two examples we can see that the formula for 100 cups with x% loss after n rotations is:

$$100 + x(n - 1)$$

The formula for 100 cups can be adapted for a system of y cups with x% loss after n rotations:

$$\frac{y}{100}\left(100 + x(n - 1)\right)$$

Hence, the formula to calculate the cup GWP for a system of y cups with x% loss after n rotations is:

$$GWPC\left(\frac{y}{100}(100 + x(n-1))\right)$$

where GWPC is the global warming potential of one cup.

(ii) Crate usage calculation to use with the crate GWP per cup (GWPCr)

The cups are delivered to the event in crates. As for the cup, the crate, from manufacture to delivery at the event, has its own GWP. The GWP for the crate could be calculated in the same way as the cups, ie presuming that after a given rotation, the crate is lost to the system. However, in reality the crates have their own life span.

If the cups are taken out of circulation early for some reason, thus ending the current reuse system, the crates will just be used with another similar reuse system. As such, a different approach is required as otherwise an unrealistically high GWP for the crate would occur in the lower rotations. Therefore, the crate GWP is divided by an estimated number of crate uses (100 uses in this study) and this is then used for each rotation. For the cumulative crate GWP, ie after n rotations, the per rotation crate GWP is simply multiplied by n.

Hence, the formula to calculate the crate per cup GWP for a system of y cups with x% loss per rotation after n rotations, presuming 100 uses of the crate, is:

$$\frac{GWPCr}{100}(ny)$$

where GWPCr is the global warming potential of the crate per cup.

The washing and the transport of the cups now need to be considered. The flowchart in Figure 42 below shows the washing and transport required for the first three rotations of a 100 cup system with 2% loss per rotation. Unlike Figure 40 and Figure 41, here the washing and transport per rotation is shown, rather than the total after a number of rotations:

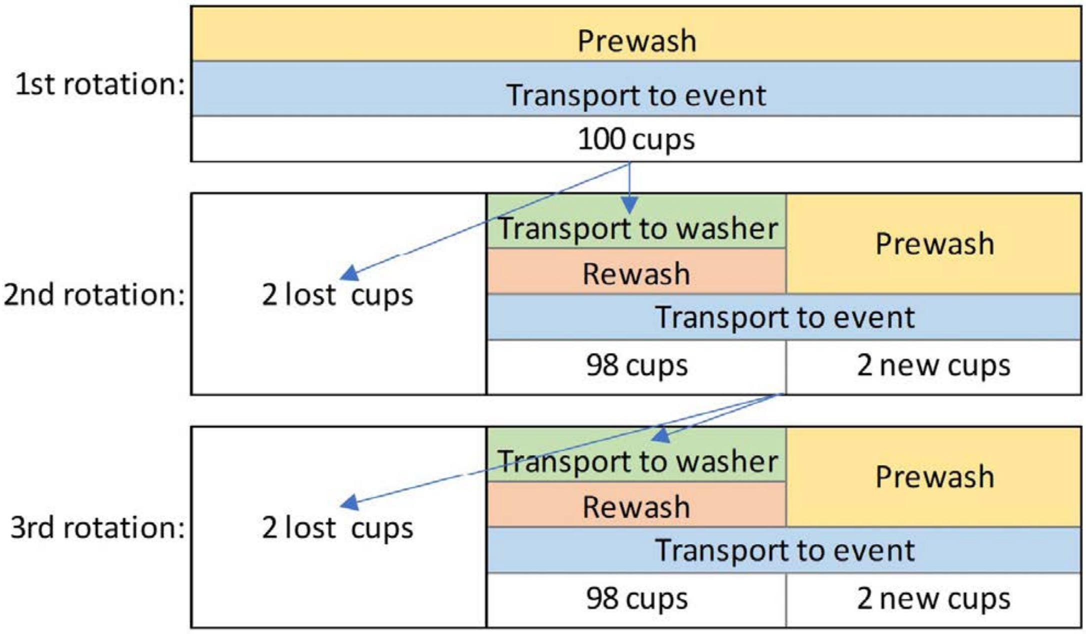

Figure 42: First 3 rotations showing washing and transport for a 100 cup system with 2% loss per rotation

(iii) Cup washing calculation to use with the washing GWP (GWPW)

It can be seen from Figure 42 above that all cups to be used in each rotation are either prewashed (the new cups) or rewashed (the cups that have remained in the system) prior to that rotation so the number of cups simply needs to be multiplied by the number of rotations and then multiplied by the washing GWP. In this example, 100 cups are either washed or prewashed prior to every rotation so after, say, 3 rotations, there have been 300 washes.

Hence, the formula to calculate the washing GWP for y cups with x% loss per rotation after n rotations is:

$$GWPW(ny)$$

where GWPW is the global warming potential of the washing of a cup.

(iv) Transport to/from washing facility calculation to use with the transport GWP (GWPT)

From Figure above, it can be seen that in a 100 cup Hard Cup system with 2% loss, the following will happen with regard to transport:

Before the 1st use: 100 cups will be transported to the event.

Before the 2nd use: 98 cups will be transported to the washer then (after washing)

100 cups will be returned to the event.

Before all subsequent uses: Repeat 'Before the 2nd use'.

Hence, after 3 rotations, for example, 3 x 100 single journeys and 2 x 98 journeys will have been made. This gives a general formula for the number of single journeys in a 100 cup Hard Cup system with x% loss after n rotations as:

$$n \times 100 + (n-1)(100-x)$$

The formula for 100 cups can be adapted for a system of y cups with x% loss after n rotations:

$$\frac{y}{100}(100n + (100-x)(n-1))$$

Hence, the formula to calculate the transport GWP for y cups with x% loss per rotation after n rotations is:

$$GWPT\left(\frac{y}{100}(100n + (100-x)(n-1))\right)$$

where GWPT is the global warming potential of a single journey between the washing facility and the event.

(v) End-of-life transport to a recycling facility calculation to use with the end-of-life transport GWP (GWPEoL)

This is a one-off calculation for the final transportation of the cups to the recycler. As such, it is independent of the number of rotations. However, the cups lost in the final rotation will not be transported to the recycler, hence the number of cups required for this formula are those left after x% are lost which (from (iv) above) is:

$$\frac{y}{100}(100-x)$$

Hence, the formula to calculate the end-of-life transport to a recycler GWP for y cups with x% loss per rotation after n rotations is:

$$GWPEoL\left(\frac{y}{100}(100 - x)\right)$$

Hence, the overall cumulative formula for a system of y cups with x% loss per rotation after n rotations is:

$$GWPC\left(\frac{y}{100}(100 + x(n-1))\right) + \frac{GWPCr}{100}(ny) + GWPW(ny) + GWPT\left(\frac{y}{100}(100n + (100 - x)(n-1))\right) + GWPEoL\left(\frac{y}{100}(100 - x)\right)$$

Appendix E

Washing systems and data*

Osmosis water

The use of osmosis water was reported, being a treated water from which all the salt and other minerals have been removed so as not to damage the machine or cup. The use of osmosis water will reduce the risk of dry water stains on the plastic cups. Osmosis water is typically produced onsite using a reverse osmosis water treatment system. The efficiency of typical osmosis water treatment systems is 40%, so for 200 litres of water, 500 litres of fresh water is required. Some companies did not declare the use of osmosis water. However, it is likely that they would use water that has passed a water softener. When it is not reported, the assumption that they are not using osmosis water has been modelled. For the production of softened water, no specific inputs have been modelled.

Hot water/ hot-fill

At the start of the day, the washing machines are often filled with hot water so that they reach the optimum wash temperature much faster and can be used almost immediately. The extra energy required for heating this water which is used at the start up in an external boiler is included in the study. Some companies within this study use electrical heated boilers and some companies use gas boilers. During the day, the machine will be filled with cold (osmosis) water which will first be partly heated with a heat recovery system and later heated within the machines' boilers. Some of the companies also hot fill their machines during the day. This is accounted for in the calculation models.

Electricity

All washing companies use electricity from the local grid. All the washing companies are located in the Netherlands. All washing machines use 400 Volt electricity (krachtstroom in Dutch) as is deducted from several technical datasheets from brands like Meiko, Hobart and Rhima. Within the LCA, this is called medium voltage electricity.

Detergents

The cup washing companies all reported details regarding their use of detergents to wash the cups. They all use a rinse aid at the end and one or two main wash detergents. All companies use liquid detergents. The typical dosing rate for the main wash detergent lies between and gram per litre of water. For the rinse aid, the dosing rate lies between and gram per litre. Some wash companies use a separate bleach detergent to remove stains and with others this is already included in the main wash detergent.

For the modelling of the detergent, a literature study has been performed and it has been chosen to model the detergent composition based on information from a JRC report. (Arendorf, et al., 2014) This is the Joint Research Centre from the European Commission. In 2014, they published the preliminary report called: Revision of European EU Ecolabel – Criteria for Detergents for Dishwashers.

Diswasher detergents are complex formulations with ingredients that can be categorised as alkalis, surfactants, bleaching agents, builders, and auxiliary agents. More information on dishwashing detergents can be found in the JRC study.

**Due to concerns of intellectual property, data has been redacted from this chapter. The original data has been peer-reviewed*

The following detergent composition has been used within this study:

Table 38: LCIA datasets used to model the Detergent		
Flow	**Amount**	**Ecoinvent v3.5 process**
soda ash, dense	43%	Market for soda ash, dense | soda ash, dense | Cutoff, U - GLO
citric acid	30%	Citric acid production | citric acid | Cutoff, S - RoW
layered sodium silicate, SKS-6, powder	10%	Layered sodium silicate production, SKS-6, powder | layered sodium silicate, SKS-6, powder | Cutoff, S - RoW
sodium percarbonate, powder	7%	Sodium percarbonate production, powder | sodium percarbonate, powder | Cutoff, S - RoW
polycarboxylates, 40% active substance	6%	Polycarboxylates production, 40% active substance | polycarboxylates, 40% active substance | Cutoff, S - RoW
ethylenediamine	2%	Ethylenediamine production | ethylenediamine | Cutoff, U - RoW
fatty alcohol sulfate	2%	Market for fatty alcohol sulfate | fatty alcohol sulfate | Cutoff, U - GLO
Total	100%	

Detergent manufacturing

For the manufacturing of the detergent, data from the same JRC study (Arendorf, et al., 2014) has been used. According to the JRC study, most raw materials used in detergents are sourced from Asia, therefore the Ecoinvent Global (GLO) or Rest of World (RoW) figures have been used instead of European figures. However, differences would be almost insignificant. The detergent itself will most likely be manufactured in Europe so European energy figures are used. According to the JRC study, the manufacturing of 1kg of detergent costs approximately 2.035 MJ of electricity, which is 0.565 kWh. This figure has therefore been used. Transport of raw materials to Europe from Asia with sea freight and some lorry transport is included in the dataset. The data in Table 39 has been used in the detergent manufacturing model:

Table 39: Data for Detergent Manufacturing Model			
Flow	**Amount**	**Unit**	**Ecoinvent v3.5 process**
Transport, freight, lorry >32 metric ton, EURO5	250	kg*km	Transport, freight, lorry >32 metric ton, EURO5 | transport, freight, lorry >32 metric ton, EURO5 | Cutoff, U - RoW
Transport, freight, sea, transoceanic ship	15000	kg*km	Transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | Cutoff, U - GLO
Electricity, medium voltage	2.035	MJ	Market group for electricity, medium voltage | electricity, medium voltage | Cutoff, U - Europe without Switzerland

Detergent packaging

Exact inventory data regarding the detergent packaging type is unknown. All wash companies use liquid detergents which are typically supplied in 10 litre bag in box packaging or even larger jerrycans up to 25 litres. For this study, it was assumed that the 10 litre bag in box type packaging is used. See Figure 43 below of Rhima Pro Wash as an example. A bag in box packaging is generally made from corrugated board which has been printed, die-cut and glued together into a box. The bags used inside the box will most likely be multi-layered PA/PE bags with HDPE or PP spouts.

Figure 43: Example of washing detergent packaging

Wastewater

All machines produce wastewater which is generally drained through the sewer. It will contain dirt and detergent but is not seen as heavily polluted water. The detergents and rinse aids that are used are the same as the ones used in dishwashers installed in restaurants and bars. For wastewater, the dataset below has been used:

market for wastewater, average | wastewater, average | cut-off, U - Europe without Switzerland

Excluded from the washing process study:

- Building
- Energy use for the building (heating/lighting)
- The washing machine itself and its end of life
- Washing crates or washing pins
- Warehouse
- Forklift truck use
- Linen /paper towels
- Use of Maintenance products
- Items that need periodic replacement

Appendix F

Notes from two peer reviews and one commentary party are given as examples below. There were several rounds of communication and notes received from the peer reviewers as the versions of the study report advanced.

Peer Review - Prof. dr. ir. Roland ten Klooster

Review of: A Study of the Festival Cup systems as commissioned by Rijkswaterstaat in cooperation with Plastic Promise, executed by the LCA Centre.

Studied document TLC 20-041, dated 24 August 2020.

Review comments

The document has been studied on issues related to my business field, packaging design. The focus has been put on facts related to the cups that are used, like the weight, the production processes and related issues like scrap, waste, energy etc. Another important issue relates to the scenario's that are used. Many scenario's are possible looking at the use of reusable, refillable cups. A discussion with the researchers has been done about the functional unit and the knowledge and insight of festivals were refillable cups are used. The functional unit is a drink at a festival from a hygienic cup. The last notification is important because hygiene is often not taken up in comparisons between one-way and reusable items, while one-way items score better on this issue. Another conclusion is that at this moment there is not much research material available about festivals with refillable cups. A lot of scenario's have been formulated about the use of refillable cups. In this research the one with the highest expected energy use has been chosen. It is assumed that a cup is washed in an industrial washing process after one time use. This gives the same level of hygiene. To get a wider view a look has been taken at the results if a cup would be used several time while being flushed with cold water on the spot before it is washed industrially.

Conclusion

The study has been executed on base of scenario's that give insight in breakeven points of the amount of use of refillable cups compared to the use of one-way cups with the same hygiene level, in a way that can be defined as realistic and reliable. The conclusions can be used to set strategies for future use of refillable cups.

Prof. dr. ir. Roland ten Klooster

30 August 2020

Peer Review – Dr. Leigh Holloway

Review Notes for:

A Study of the Festival Cup systems as commissioned by Rijkswaterstaat in cooperation with Plastic Promise – round 2

Date of Report: 1 Sept 2020 (NB version 2 of the report was supplied on 24 August 2020)

Date of review: 26 August 2020

Compiled by: Dr Leigh Holloway, Eco3 Ltd.

Overall Comments

Following the submission of review notes for V1 of the report on the 19th of August 2020, the authors have made alterations and amendments and issued a revised version for further review.

This second round of review note applies to V2 of the report.

Notes on methodology, data, assumptions etc. remain as outlined in the previous review and many of the issues have been addressed in this new version of the report.

The important editorial notes / issues have also been addressed.

This review covers a limited number of further editorial issues and the overall presentation of results only.

Editorial Notes

General – all tables / graphs and diagrams need formal numbering and titles to help the user understand what they are showing.

Line 221 (and all other occurrences) – Abbreviation of Soft Cups and Hard Cups should be SCs and HCs, no apostrophe should be used.

Line 256 - Hard Cups will all be recycled at end of life and Soft cups are recycled by varying degrees. Is the 100% recycling of hard cups a sound assumption?

Line 300 – refers to the 'above results'. The preceding sections were more a discussion of observations or assumptions and not results. So considered replacing the word 'results'

Line 505 and 506 – on what basis is this recommendation made? GWP? Other impacts?

Line 525 – not clear what this table is showing. (See earlier comment about titles on tables etc.)

Line 617 – Assumption on Hard Cups lost from system having been 'removed' and a cut-off applied. Is this the same for soft cups as it is not listed in the assumptions if it is?

Line 630 – 'Scenarios' Explain that these are comments on the way the systems work and what variables will affect the overall impact / efficiency of a given system. This will ensure that this section is not considered to bell all the different scenarios that have been calculated as part of the report.

Line 889 – 100% rPET – it this a valid / reasonable assumption. Any data to back this up as the text says 'assumed'.

Line 916 – clarify that 'Nebraska' is the state in the USA and not a company name. Perhaps clarify NatureWork's facility in Nebraska if this is the case?

Line 1000 onwards – In-Mould Labelling. Where is this model explained in terms of waster etc?

Line 1058 onwards – Packaging. Are the details of the packaging used (weights, materials etc) given anywhere in the report? If so, this should be referenced. If not, a summary should be shown somewhere.

Line 1277 – Cup Loss Modelling Tool. This section then discusses a re-use assessment tool (RAT). Are these the same thing? If so, make sure a single term is used.

Line 1296 – not clear what this table is showing. A breakeven point is discussed but the table is a list of percentages that relate to the breakeven point. Does this mean (for example) the breakeven point on the reusable v PLA 1 is 4 uses and for the PP 2 is 20 uses? Some explanation is needed to help the reader interpret this.

Line 1308 onwards – Hard Cup Washing Process. Lot of info discussed here. Perhaps a summary table showing average water, energy etc / no cups washed (say per 100 or 1000). Table could go right at the end of the section on page 54.

Line 1529 – is this best termed ‘other processes’ or ‘other life cycle stages’?

Presentation of Results

The results are still very detailed and some of the tables are a little difficult to interpret. However, it is clearer than in the latest version. It might just take some time for the reader to fully understand.

To help show a ‘real life’ single case perhaps 2 ‘defined’ examples could be shown in tables / graphs. For example, at a given loss rate and a given EoL recycling rate the overall GWP of each alternative.

The modelling tool developed to carry out the comparison of the different scenarios has not yet been made available and therefore could not be checked.

(As relates to this last point – Leigh received the BCT tool – his comments were “I’ve also been through the excel tool and tried to understand everything. It’s a very comprehensive and complicated tool! From what I can see it almost all looks OK but I do have one question on one part that I don’t understand”, this question having been further addressed.)

Summary

The study is performed in a way that mirrors the requirements of ISO 14040:2006 and ISO 14044:2006. The data used as well as the calculation approach and the result presentation correspond to the goals of the study (however see subsequent notes on results presentation) .

The explanations concerning assumptions and results are sufficient overall but a small number need a little. Conclusions and recommendations are included, which outline the most important influence factors in a reasonable and transparent way.

Non-Peer Review Guidance Notes – Natuur & Milieu

Although a full peer review was not carried out by Natuur & Milieu, they did provide basic comment after a brief read through of the earliest version of the study report. These being from Lieke van Adrichem - Project Leader Food and Circular Economy and Jelmer Vierstra - Senior Program Leader Circular Economy.

The notes from both parties were submitted in emails as follows:

Dear Alan and others,

Thank you very much for this interesting study. Unfortunately I do not have the time on such short notice to do a full review. So based on the summary and introduction here are my most important remarks:

1. I understand the assumption of incineration of all non-recycled soft cups from a methodological perspective, but I consider this an omission and a possible weak point that might lead to discussion if not addressed. I think a part of the non-returned soft-cups will end up in litter (especially in outdoor and less controlled environments like for instance Vierdaagse Feesten). I recommend to add some sentences on that possibility and the fact that this makes the environmental performance of reuse systems relatively better, although this cannot be quantified. Litter is a big thing in societal debate and therefor a big driver for change.
2. There are several factors that influence the environmental performance of the respective systems. Some of these factors are external that an organisation has to deal with, but a lot of these factors can be influenced. Therefore there is also a 'potential' environmental performance if the proper choices are made. Are the conclusions that you draw based on actual scenario's on or potential scenario's?
3. The 'recommendations chapter' is merely a list of attention points. Perhaps this can be added with real recommendations for festival organisers, governments etc. on standardisation and legislation etc.

Yours sincerely,

Jelmer Vierstra
Senior Program Leader Circular Economy
Natuur & Milieu

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Dear all,

I managed to squeeze in a couple of hours this week in my last week before mat leave to look at the report. I am uncomfortable to be named a peer reviewer in the report after only looking at it for a few hours while it's a highly technical 90 page report that also isn't finished yet with key parts missing (like the Interpretation and Discussion section- which would probably be of most interest to me to review). As it's my last day today at Natuur & Milieu I unfortunately can't be of more help than what I provide in this e-mail.
Maybe Jelmer can find the time next week to formulate a response that could be used in the report but I haven't spoken to him due to his vacation.

Nevertheless I have gathered some feedback for you which will hopefully help you out in improving the report, they are in order of where they occur in the report:

1) In the introduction you state 'this study will take into account the exact products, processes, etc.' while on the same page (and throughout the report) you state that it is a generic study and not a specific study. I find this contradictory.
2) It is unclear after reading the report how the central research question relates to current practices. On page 6 I was inclined to think after reading the sentence 'a preferred option from the environmental point of view' → as opposed to what? Only each other or vs the status quo? On page 9 in the goal definition it's formulated slightly differently which makes it clear what is researched in this report. However, it is still unclear to me after reading the report how the recyclable soft cups compare to 'real life' festival single use cups that are not separately collected (or whether they are the same thing already?). Basically – the link to real life situations.
3) Generally page 7 is confusing , you'd expect a list of the cups itself there. And at various points, before the actual list of producers, various producers are already name-dropped which makes it a confusing read.
4) Page 10 'the use of generic LCIA data was required since no specific data is available for all the cup component parts and the reuse system' – was it partly available and chosen to apply generic data to all anyway? Or was none available?
5) Page 11: 'various assumptions have had to be made where information was not forthcoming' → I'd expect a list of the key assumptions here or a sentence stating that all assumptions will be clearly labelled/explained.
6) Page 11-13:
    a. this is weirdly specific for explaining why 1 type of cup is dismissed in the study (while also confusingly is found in tables later on after you've concluded here that it is not included in the study, e.g. page 18).
    b. On page 13 a hard cup is not dismissed while it has the same deviation in cup capacity – why is this?
    c. The order isn't consistent (it would make more sense to discuss the rejection of a cup after you've introduced the whole list of soft cups, rather than '1 soft cup dismissed, then table of hard cups, inclusion of a deviating capacity for hard cup, then table of all soft cups')
7) Page 13: cup print – the way it's written seems contradictory on whether or not printing makes it more or less likely to cause loss. Better to write 'there's pros and cons to printing in relation to possible loss from the system'
8) Page 13: cup disposal: what about litter/zwerfafval? And is it assumed based on separated collection of the soft cups or in unseparated/general waste?
9) Page 25: The transport between washing companies is based on a crate with a film bag liner for hard cups, and nothing else for soft cups as it is unknown. It probably won't make a big difference in the overall calculations but it's a bit unfair on the hard cups to have an additional impact calculated while the soft cups go free.
10) Page 27: End of life scenarios: I'm missing litter/zwerfafval. Even if you can't calculate the effects of this, it is important to note the possible outcome of both hard and soft cups to be lost outside of the system due to littering. Particularly as single use soft cups are commonly found littered.
11) Page 27: why is the collected and recycled percentage chosen to be the same for each scenario? What is closest to 'likely scenarios'?
12) Page 43 (but basically applicable for the whole report): how many rotations are to be expected on average anyway for a hard cup before they wear off (slijtage)?
13) Page 49: Osmosis water (and also the other variables on washing): do any of these have an impact on how many rotations a cup can last?
14) Page 52: is it correct that facility B uses up SO much more water than the others in comparison to their number of cups washed per hour?
15) Page 57/58: I don't understand what you're trying to say with the bit on the percentage of GWP of a cup that is not the direct material to be recycled – and then the rPET cup coming out as much worse (or better? the text is cryptic) for the percentage of soft cup GWP that is lost every time a cup is recycled. What does it mean?
16) Page 77: I don't understand the table on soft cup recycling vs hard cup loss, and the text underneath only makes it more confusing.
17) Page 77: generally about the conclusion: same as for the research questions, I'm still not sure about the context of these hard and soft cups in comparison to what's already happening at festivals in practice. And whether they all choose 1 system per festival or that they co-exist (the tables for hard cups and soft cups are structured differently for which it isn't easy to see which festivals use hard cups and which use soft cups or which use both).
18) Page 78: very major insight in GWP of the washing facilities using onshore wind turbines – I'd be really interested to know why such companies (which are eco-minded) aren't already using green electricity?

Hopefully this is of use to you! If you have any further questions on this and generally about the role of Natuur & Milieu in peer reviewing this, please contact Jelmer who will be back from vacation on the 24th.

Best of luck finishing the report,

Kind regards,

Lieke van Adrichem
Projectleider Voedsel & Circulaire Economie
Aanwezig op maandag en donderdag

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