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Public Private Partnership project: Wrap or waste

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This study was carried out by Wageningen Food & Biobased Research, subsidised and commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality via Topsector Agri & Food and funded by Ferrero, Friesland-Campina, Kraft-Heinz, Royal Smilde, Upfield, STV, KIDV, CBL, FNLI, GFH and NRK.

Wageningen Food & Biobased Research
Wageningen, July 2023

Public

Report 2454
DOI: 10.18174/634052

WFBR Project number: 6234192300
BAPS number: BO-64-001-022
Version: Final
Reviewer: Karin Molenveld
Approved by: Jan Jetten
Carried out by: Wageningen Food & Biobased Research
Subsidised by: the Dutch Ministry of Agriculture, Nature and Food Quality via Topsector Agri & Food
Funded by: Ferrero, Friesland-Campina, Kraft-Heinz, Royal Smilde, Upfield, STV, KIDV, CBL, FNLI, GFH, NRK
This report is: Public



The research that is documented in this report was conducted in an objective way by researchers who act impartial with respect to the client(s) and sponsor(s). This report can be downloaded for free at https://doi.org/10.18174/634052 or at www.wur.eu/wfbr (under publications).



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# Samenvatting

Het publiek-private-samenwerkingsproject 'Verpakkingen versus Verliezen' heeft als doel om de duurzaamheid van verpakte levensmiddelen te onderzoeken, waarbij de nadruk ligt op het kwantificeren van de relatie tussen het gebruik van verpakkingen aan de ene kant en het behoud van kwaliteit en beperking van voedselverliezen aan de andere kant. Ten gevolge van nieuwe wetgeving die het gebruik van kunststof verpakkingen aan banden legt, is er behoefte aan het in kaart brengen van de effecten op de duurzaamheid van het gebruik van alternatieve verpakkingen. Het veranderen van verpakkingsmethoden heeft effect op de productkwaliteit, de keten en ook op de gebruikte verpakkingsmaterialen. Wageningen Food and Biobased Research (WFBR) verzamelt in dit project via praktijkcasussen van specifieke product-verpakkingscombinaties kwantitatieve data en ontwikkelt hiermee tools die bedrijven concrete handvatten geven om duurzame verpakkingskeuzes te kunnen maken.

De casus beschreven in dit rapport richt zich op portieverpakkingen van levensmiddelen. Deze kleine levensmiddelverpakkingen worden thans gebruikt bij tal van horeca gelegenheden en bevatten producten die variëren van mayonaise, jam, pindakaas tot margarine en boter. Typische productgewichten zijn 10 a 20 gram. Het meest gebruikte verpakkingstype is een diepgetrokken plastic schaaltje met een plastic topfolie. De Europese richtlijn voor eenmalig bruikbare kunststofartikelen ("SUP" richtlijn EU2019/904) verbiedt per 1 januari 2024 het gebruik van deze verpakkingen bij food service faciliteiten, kleine hotels en B&B's indien deze op locatie worden genuttigd.

Meerdere alternatieve levensmiddelverpakkingen zijn voorgesteld, waaronder kleine eenmalige verpakkingen gemaakt van alternatieve materialen en een herbruikbaar alternatief. Deze studie verkent de effecten die deze alternatieven waarschijnlijk gaan hebben op meerdere dimensies van duurzaamheid met behulp van de MuDiSa tool die door de WFBR ontwikkeld is om specifiek de duurzaamheid van verpakte producten te beoordelen.
De studie laat duidelijk zien dat er geen ideaal alternatief bestaat in alle dimensies van duurzaamheid. Er is geen oplossing met zowel een lage koolstofvoetafdruk, maximale circulariteit als een geringe kans op de vorming van zwerfafval.

- Het aluminium-gebaseerde alternatief heeft een grote koolstofvoetafdruk, middelmatige materiaal circulariteitsindicator en een middelmatige kans op de vorming van zwerfafval. Echter door gerecycled aluminium toe te passen en de recycling van de aluminium verpakkingen te verbeteren kan de koolstofvoetafdruk worden verlaagd en de circulariteit verhoogd.
- Het flexibele kunststofsachet heeft een lagere koolstofvoetafdruk, lage materiaal circulariteitsindicator en een grotere kans op de vorming van zwerfafval.
- Het papier-gebaseerde kuipje heeft een hogere koolstofvoetafdruk, middelmatige materiaal circulariteitsindicator en een geringere kans op de vorming van zwerfafval.
- Het herbruikbare alternatief met glazen bordjes heeft een veel hogere koolstofvoetafdruk, een maximale materiaal circulariteitsindicator en als het zwerfafval wordt kan het scherpe scherven opleveren die een risico op zich vormen. De hoge koolstofvoetafdruk van het herbruikbare alternatief wordt vooral veroorzaakt door het hoge gebruik aan elektriciteit bij het wassen van de schaaltjes en het verwachte hoge niveau van voedselverlies.

In het kort betekent dit dat er geen beste oplossing is, en ondernemers de minst slechte oplossing zullen moeten kiezen, welke inherent context afhankelijk is (ten aanzien van het soort product en gebruikssituaties).

WBFR laat met de resultaten van deze case zien dat het mogelijk is om op basis van de verzamelde data en de ontwikkelde MuDiSa tool verschillende verpakkingsscenario's te vergelijken en door te rekenen op duurzaamheidsaspecten. De resultaten van deze analyse tonen een genuanceerd beeld; geen van de alternatieve verpakkingen is ideaal in alle dimensies van duurzaamheid. Het is aan het management van de betrokken bedrijven om met behulp van deze resultaten voor hun bedrijf en keten te bepalen welke keuze het meest passende alternatief is.

# Summary

The public-private-partnership project “Wrap or Waste” aims to investigate the sustainability of packed food products. This project focusses to quantify the relationship between the use of packages on one hand and the preservation of product quality and the control of food losses on the other hand. As a consequence of new legislation that restricts the use of plastic packages, there is growing need to explore the impacts of the use of alternative packages on sustainability. Changing packaging methods affects product quality, the product supply chain and the packaging materials themselves. A number of case studies were carried out within this project addressing specific product-packaging combinations. Based on these specific product-packaging combinations studies, Wageningen Food and Biobased Research (WFBR) collected quantitative data and developed tools that provide concrete answers that can help companies in their packaging choices.

The case study described in this report deals with portion packages of food products. These small food packages are currently widely used in various food service facilities and contain products varying from mayonnaise, jam, peanut butter to margarine and butter. Typically amounts of contained food product are 10 to 20 grams. The most commonly used packaging type is a thermoformed plastic tray with a plastic top-lid. The European single-use plastic directive will effectively ban the use of these packages when consumed in at food-service restaurants, small hotels, bed & breakfasts, etc.

Multiple alternative food packages, including small single-use packages from different materials and a reusable alternative were selected for the case study. This study explores the impacts that these alternatives are likely to have on multiple dimensions of sustainability using the so-called MuDiSa tool. The study clearly shows that none of the alternatives is ideal; there is no packaging solution that combines a low carbon footprint, maximal circularity with no chance of littering.

- The aluminium based alternative has a high carbon foot print, mediocre material circularity indicator and mediocre littering chance, but by using recycled content and improving the recycling the carbon footprint is could be lowered and the circularity increased.
- The flexible plastic pouch has a low carbon footprint, low material circularity indicator and a high chance of littering.
- The paper-based tub has a higher carbon footprint, mediocre material circularity indicator and a reduced chance of littering.
- The reusable alternative with small glass plates results in a much higher carbon footprint, a maximal level of circularity and when it is littered and breaks it forms sharp shards that impose a risk on their own. The high carbon footprint of the reuse case is predominantly caused by the large amount of electrical energy required to clean the plates and by the expected higher levels of non-consumed food product.

In short this implies that there is no alternative the best in all dimensions of sustainability. Entrepreneurs will have to select the least worst solution, which will inherently be context-dependant (relates to the type of product and the situation in which it is used).

With the results from this case, WFBR shows that the developed MuDiSa tool can be used to compare different packaging scenarios on sustainability parameters, combining the potential effects of changes in packaging on product loss, recycling and littering. From these results a well-balanced picture emerges. None of the studied alternative packages/solutions is optimal in all dimensions of sustainability. The management of the incumbent organisation can use these results for their company and supply chain to select the most suitable alternative.

# 1 Introduction

## 1.1 General introduction Wrap or waste

This report is part of a public-private partnership project "Wrap or waste". This project aims to quantify the relationship between packaging and alternative techniques on the one hand, and the preservation of product quality on the other hand, thereby helping the industry make optimal, well-founded and sustainable choices. The use of plastic packages gives rise to growing concerns, urging fast moving good industries to reassess their packaging strategies. Changing packaging methods, however, affects product quality, the product supply chain and the packaging materials themselves. Via case studies on specific product-packaging combinations, quantitative data was collected and tools were developed that help to provide concrete answers that companies can use for their packaging choices.

In 2020 this project started with the consortium of Dutch organisations that are described in Figure 1. They are active in the fields of food waste, they develop knowledge on sustainable packaging and/or they represent companies active in the food and packaging sector. Wageningen Food & Biobased Research (WFBR) is the research partner and overall project coordinator. Private companies are joining with specific cases. All partners contribute financially and in kind. The project is co-funded by the Dutch Ministry of Agriculture, Nature and Food Quality via Topsector Agri & Food.

**Consortium Wrap or Waste:**

- Samen tegen Voedselverspilling (STV)
- Kennisinstituut Duurzaam Verpakken (KIDV)
- Federatie Nederlandse Levensmiddelen Industrie FNLI
- NRK Verpakkingen
- Centraal bureau levensmiddelenhandel (CBL)
- GroentenFruit Huis (GFH)
- Wageningen Food & Biobased Research (WFBR)

***Figure 1: Consortium partners Wrap or Waste.***

This report describes the results of one of the case studies: Single-use portion packages by five companies that apply these packages, namely: Ferrero, Friesland-Campina, Kraft-Heinz, Royal Smilde, Upfield and their sectorial organisation FNLI. WFBR performed this study independently and objectively, using input information shared by the participating companies.

By integrating the data from various cases a generic toolbox is created that will be useful for other companies. This toolbox is the main deliverable of this project and is delivered at the end of the project. In a final report the toolbox is described.

## 1.2 Single-use plastic legislation

In 2018 the European Commission published a European strategy for plastics in a circular economy [1] in which it announced policies to accelerate the recycling of plastic waste, to stop leakage of plastics in the natural environment and to ban the plastic objects that are most commonly found on the European beaches. In the same year, the packaging and packaging waste directive was revised [2] in which the recycling target for plastic waste was raised from 22.5 to 50% (to be attained in 2025). In 2019, the European Commission published the Single-Use Plastics (SUP) directive [3]. This directive aims to reduce the use of single-use plastic articles, promote the use of reusable alternatives and ban the use of specific plastic articles that are commonly found on European beaches. In article 4 of the SUP directive member states are obliged to reduce the annual consumption of plastic food containers used to package food products that are consumed directly from the package without further preparation in 2026 as compared to 2022. This part of the SUP directive only relates to rigid plastic articles and not to flexible plastic packages. Furthermore, multi-packs are also excluded, at least when they are sold to the final consumer at the point of sale as multi-packages and not individually as

single-portion packages. In 2021 the commission published a guidance document to define the underlying concepts of “plastic”, “single-use”, “direct consumption”, “food preparation”, “a single portion”, “rigid plastic article”, etc. [4]. The European SUP directive was converted into a Dutch law in 2022, named Ministeriële regeling kunststofproducten voor eenmalig gebruik [5]. In article 2.2 of this law, food service companies that deliver food products or provide food products at take away locations are only allowed to sell their food products in single-use plastic food containers to consumers in case a tax is paid. This tax is paid for each single-use plastic item sold. Furthermore, food service companies that serve food on locations (dine-in) are no longer allowed to use single-use plastic packages and have to serve the food products on reusable tableware / packages. Two exemptions are made. First of all, institutions such as hospitals, nursing homes and prisons are still allowed to use single-use plastics. Furthermore, food-service locations that prove that they recycle 75-90% of the single-use plastics to a food-grade recycled plastic are also exempted.
Other member states simultaneously published their national legislations, that at first glance appear to be the same, but at closer inspection revealed major differences. For example, a paper based food container with an internal coating to make the container water and grease resistant that is deemed recyclable is not considered a SUP in Germany, but is considered a SUP in the Netherlands.

Currently, Dutch food producers and food service companies are awaiting clarifications on the exact interpretation of the law. For instance, what the precise definition of eating on-the-go and eating in (distance from the food service outlet). Nevertheless, some articles of the Dutch law will be in force form July 1st 2023 (SUP tax for SUPs sold at take away venues) and others will be in force from the January 1st 2024 (ban to use SUP for food that is consumed on location).

In the meantime, the European Commission has proposed to revise the packaging and packaging waste directive and to upgrade it to a regulation [6]. This proposal has been published in November 2022 and is now being discussed. This so-called PPWR is expected to be a formal regulation in 2025 in case the negotiation runs smoothly. Should the proposal become a regulation, it will affect the portion packages as well, since in the current proposal all single-use plastic packages are banned, also those based on flexible plastics.

This study will compare the impacts of the current plastic-based portion package with three portion packages made from alternative materials and a reusable system. Hence, this report explores the likely consequences of the law on the sustainability of the food products sold in portion packages. This study by no means intends to deliver an evaluation or interpretation of this Dutch law.

## 1.3 Portion packages

Multiple foods are currently sold in small portion packages, such as sauces & condiments (mayonnaise, ketchup), jam, margarine, butter, peanut butter, hazelnut paste, apple spread, etc. These food packages are used in various markets, such as catering, small hotels, bed & breakfasts, lunchrooms, fast-food restaurants, etc. The portion size is typically 10 to 20 grams. These portion packages are mostly used in smaller businesses. In larger hotels, lunchrooms and restaurants with sufficient turnover it is more economical to serve these products in large bowls and dishes or to use dispensers. With the focus point of the market for these portion packages being the smaller enterprises, it is a very heterogeneous market in which the turnover rate varies greatly from a few packages a week to a dozen per day.
These food products have an extended shelf life in their packages varying between 3 weeks and several years. The most perishable food products need to refrigerated as well (margarine, butter, salad spreads). Unpacked, the shelf life of these food products is one day or a few days at most. Furthermore, the most perishable food products such as butter and margarine have to be consumed within one hour when they are kept unpacked and unrefrigerated [19].

## 1.4 This report

This report is organized as follows:

- In this first chapter, an introduction is given to the overall project and corresponding tool for sustainability assessment. Also, the specific case of portion-packages is introduced.
- Chapter 2 describes the objective, scope and general approach of the study.
- Chapter 3 discusses the methodology.
- Chapter 4 reports on the margarine loss measured in portion packages.
- Chapter 5 describes the Life Cycle Inventory for the case, so describes the data collection and research methods. This results in data that will be used in the sustainability assessment.
- Chapter 6 presents the results of the sustainability assessment.
- In Chapter 7 the outcomes are discussed and in chapter 8 is the study concluded.

# 2 Goal and scope case

## 2.1 Objective and scope

This case study explores the sustainability of alternative packaging methods for portion-packaged food products that might be implemented in a response to the Dutch SUP-legislation. Since there are so many different portion-packaged food products used in so many different markets, the scope of this study was narrowed down to 10 gram portion-packages of margarine sold predominantly in canteens, lunchrooms, bed & breakfasts, hotels, etc.
This can be considered a model case for all related portion packages such as those with butter, jam, peanut butter, hazelnut paste, ketchup, mayonnaise and so on. The sustainability of the portioned food packages is expressed with multiple dimensions of sustainability, including the global warming potential, recycling and circularity indicators.
The first objective of this case study is to explore the environmental impacts of portioned packaged margarine and butter, by studying the sustainability of alternative packaging methods. The second objective is discuss the likely consequences for the broader category of portion packaged food products.
This study does not assess the SUP legislation itself nor does it intend to verify if the central objective of the SUP legislation (reduction of littering) will be achieved.

## 2.2 Approach

To assess the sustainability of the packaging alternatives/scenarios, the following approach was taken. First the amount of non-consumed margarine in currently used portion-packs was measured. Also attempts were undertaken to find data on the amount of margarine that is not-consumed in a reuse scenario. Next, this data together with the technical description of the margarine packages is used to assess the sustainability of the margarine portion packages and the alternatives with a dedicated tool named MuDiSa.

# 3 Methods

## 3.1 Tool for sustainability assessment

Within the public-private partnership project "Wrap or waste" WFBR developed the sustainability analysis tool MuDiSa to assess various dimensions of sustainability and circularity of the packaged products. Traditionally, life cycle assessment (LCA)-based tools are focussed on the environmental and human impact assessments including different impact categories but ignore the relevant dimensions of sustainability that relate to circularity, recyclability and littering. With this tool it is possible to cover more relevant dimensions of sustainability of packaged food products in comparison to other LCA-based tools.

The tool uses foreground and background data to execute the calculations. The foreground data is entered by the user and encompasses packaging specific and food specific data that is specific to the studied case. The background data relates to emission factors of production of the materials and products, processes and end-of-life treatment processes. The entered foreground data is also known as the life cycle inventory (LCI). Scenarios can be studied by varying the type and combination of the product, packaging and the end-of-life scenarios. The data which are necessary for the calculation of the environmental impact and the indicators are:

- Type of product
- Packaging volume
- Food losses [%]
- Packaging components: weight, material, production method
- Amount of loops (in case of reusable packaging)
- Packaging waste scenario
- Binary operators for indicators of recyclability: Recyclable (yes/no), Circular recyclable (yes/no), with respect to the Dutch waste management system.
- Binary operators to establish the littering potential: The use-indicator (in home/out of home) is yes when the packaged food product is likely to be consumed out-of-home and sup-indicator (yes/no) is yes when the article is listed in EU Single Use Plastics directive [3].

Based on these data, the tool calculates and evaluates the contribution of the life cycle stages of product (in this case margarine butter) and packaging to the global warming potential over a period of 100 years (GWP-100) in terms of carbon dioxide equivalents. Namely, the calculated emission of greenhouse gases is split in five life stage contributions:

1) Emissions due to the production of the food product
2) Emissions due to packaging (material and production process)
3) Emissions caused by the reuse process (applicable only for reusable packaging)
4) Emissions due to the end-of-life treatment of food product loss and packaging
5) Avoided emissions due to the use of recycled materials or recovered energy from incineration process or produced compost as a fertilizer

The global warming potential is calculated with a system perspective in mind. This is markedly different from all the other indicators that are calculated from a product perspective.

Additionally, several indicators are calculated to assess the overall sustainability and circularity of the packaged products. These indicators fill the gap of the environmental impacts that can currently not be calculated with a basic LCA method, such as the potential contribution to litter and the recyclability. Across all the calculated indicators, the following three are found relevant for this study:

1) Recyclability Indicator (RI): It is used to identify the recyclability of the packaging material within mechanical recycling processes and to quantify the mass fraction of the packaging that ends up in the recycled material. It is expressed in a percentage, where 100% implies that the portion package is fully recyclable, while 0% means the package cannot be recycled.
2) Recycling Chain Indicator (RCI): It expresses the recycling chain efficiency for a specific type of packaging. It is calculated by multiplying the collection, sorting and recycling efficiency of

the primary material which is converted into a secondary material. In case each packaging is made of several components, this indicator is calculated separately for each component and the sum of all components gives the total value.

3) Material Circularity Indicator (MCI): This indicator was developed by the Ellen Mac Arthur Foundation and is expressed in percentage [7]. This indicator has a lower limit of 10% unlike other indicators where the lower limit is 0%. So, a 100% score signifies that the portion package is fully circular, while 10% signifies the package being fully linear. The MCI indicator takes into account recycling processes (both mechanical and organic), recycling efficiencies, reuse/life-span and material origin. A subfactor within the MCI named 'Utility factor' was set to 1. This subfactor describes both the life span of the product and the amount of loops a reusable product is used. Since the single-use packages are used only once the utility factor is 1. Compared to the other indicators, MCI is the most complete, taking diverse information into account.

## 3.2 Goal, methods and scope

The goal of this study is to execute a sustainability analysis of conventional margarine portion packages (also named mini tubs) in comparison to multiple alterative scenarios. These alternative scenarios relate to the use of different packaging materials that could potentially not be regarded as a SUP and to a reuse system in which the margarine is supplied to the catering facility in large wholesale packages and the margarine is scooped out on reusable glass plates from which it is sold to consumers.

The analysis followed an attributional approach with system expansion using average processes for the background system. This approach includes both direct environmental impacts from processes and avoided impacts or "credits" related to the production of secondary products through recycling processes, energy recovery from incineration of food or packaging, and production of compost through the industrial composting of food products.

Each different type of margarine mini tub packaging of the selected end-of-life scenario was modelled and evaluated individually. Finally, the environmental performance of the margarine packaging in all scenarios were compared to each other with respect to multiple sustainability criteria. The environmental performance is scored using the MuDiSa tool for sustainability assessment.

The scope of this sustainability assessment is formed by the system boundaries. These run from the production of the packaging and food to the end-of-life management of the packaging and the lost food product. The sustainability assessment includes greenhouse gas emissions, a recycling indicator, a material circularity indicator and a recycling chain indicator. The functional unit for this assessment is 1000 kg consumed foods and the results are presented in kg $CO_2$ equivalents per kg of consumed foods. The scores of the environmental performance indicators are compared with each other and a sensitivity analysis is performed on the crucial sensitive parameter: the percentage of food loss/residues remaining on the packages from the consumers.

## 3.3 Methodological issues

The share of non-consumed margarine/butter is entered as the food loss rate in the MuDiSa tool, since only this approach allows for comparison between single-use and reuse systems on common ground. The functional unit is 1 kg consumed margarine/butter and this remains constant for all cases with this approach.

*Sensitivity analysis for aluminium portion packages*
It is well-known that the carbon foot print of the aluminium packages will be largely influenced by the recycling parameters. To better understand these influences a sensitivity analysis is performed in which these factors are systematically varied. The following scenarios are distinguished for the aluminium packages:

- Al-In: Aluminium packages made from 100% new alloy that are incinerated after use and a share of the aluminium is retrieved from the bottom ashes.
- Al-Rc: Aluminium packages made from 100% new alloy that are collected with lightweight packaging waste, sorted at sorting facilities with current low sorting fates (22% to the non-Ferrous metal sortd product (NF)) and recycled.
- Al-RcF: Aluminium packages made from 100% new alloy that are collected with lightweight packaging waste, sorted at advanced sorting facilities with Eddy Current separators over the fine sieve fraction (which raises the sorting fates for small aluminium objects to 76%[21]) and recycled.
- Al-Rc2: Aluminium packages made with 80% recycled content that are collected with lightweight packaging waste, sorted at sorting facilities with current low sorting fates (22% to NF) and recycled.
- Al-Rc2F: Aluminium packages made with 80% recycled content that are collected with lightweight packaging waste, sorted at advanced sorting facilities with Eddy Current separators over the fine sieve fraction (which raises the sorting fates for small aluminium objects to 76%[21]) and recycled.

## 3.4 Margarine/Butter loss in portion packages

The amount of margarine/butter that is not consumed but discarded with the thermoformed mini-tubs was quantified by analysing the catering waste of company canteens twice. The butter and margarine tubs were taken out of the canteen waste. The gross weight of the butter and margarine mini-tubs ($m_{gross}$) was recorded. The residues of butter and margarine were removed and the emptied packages were washed with dish-washing detergent and dried overnight in an oven at 100°C. In the morning the net weight of the butter and margarine mini-tubs was measured ($m_{net}$). From the weight difference the remaining margarine / butter weight was deduced. This weight was divided by the number of mini-tubs retrieved (n) and related to the original product weight (OPW = 10 gram) to render the share of margarine that was not consumed ($S_{nc}$).

$$S_{nc} = \frac{(m_{gross} - m_{net})}{(n \times OPW)} \ [\%]$$

# 4 Margarine/Butter loss

## 4.1 Margarine/Butter loss in currently applied portion packages

Catering waste of two institutional canteens was sorted on June 19th 2023 and June 21st 2023. Both batches of canteen waste were delivered in 1100 litre roll containers. This canteen waste was sorted for a different project and during the sorting process all margarine and butter mini-tubs were kept separate for this project.

During the first sorting run ten complete margarine-butter tubs were found in the canteen waste of which three were further analysed. These were weighted, emptied, cleaned and dried to measure the weight of the components and the weight of the contained margarine. The average weight of these tubs, top-films and the contained margarine is given Table 1. This analysis reconfirmed that the original product weight (OPW) was indeed 10.00 gram.

***Table 1: Weight of margarine/butter and the packaging components of three full mini-tubs retrieved from the canteen waste.***

| Component | Total weight, [g] | Weight per package, [g] |
|---|---|---|
| Margarine/butter | 30.00 | 10.00 |
| Thermoformed tray | 1.91 | 0.64 |
| Top-film | 0.41 | 0.13 |
| Total | 32.32 | 10.77 |

The first batch of canteen waste contained 10 complete margarine tubs, 26 mini-tubs with some margarine / butter residues inside with a top-film partially adhered, 36 mini-tubs with some margarine / butter residues inside without a top-film and 3 loose top-films. The packages were weighted, washed, dried and weighted again to determine the share on non-consumed margarine / butter in these portion-packages. This amounted to 27%. A picture of the retrieved margarine and butter portion packs from the first batch of canteen waste is given in Figure 2.

The second batch of canteen waste contained slightly less margarine and butter portion packs. No complete untouched portion packs were found and 19 partially emptied margarine / butter packs with the top-film attached and 16 without the top-film attached and one loose top-lid. The share of non-consumed margarine or butter was calculated to be 18% for this batch of canteen waste. The data of the first and second batch is summarised in Table 2. From this data an average share of non-consumed margarine or butter from these portion packs of 23 ± 6% was found.

***Table 2: The gathered data from the sorting analysis of two batches of canteen waste and the derived shares of non-consumed margarine / butter from these portion packs.***

| Parameter | First batch | Second batch | Overall |
|---|---|---|---|
| $m_{gross}$ | 247.94 g | 88.62 g | |
| $m_{net}$ | 54.54 g | 25.87 g | |
| n | 72 | 35 | |
| $S_{nc}$ | 27% | 18% | 23 ± 6% |

***Figure 2: The margarine and butter portion packages retrieved from the first batch of canteen waste, left the used tubs without top lids, middle the partially emptied tubs with a top lid and right the complete portion packs.***

## 4.2 Margarine loss in the alternative packages

There was no experience at the participating companies with alternative margarine and butter portion-packages and hence it was assumed that the share of non-consumed margarine/butter for mini-tubs of different materials would be equal to the share of non-consumed margarine in the currently applied mini-tubs. Possibly this is different for the alternative flexible pouch, since it will be emptied differently by the consumer, but since the data is lacking, we also for this alternative package the same share of non-consumed margarine was used.

The Dutch association of catering companies (Veneca) was contacted in June 2023 with the intention to gather insights in the level of food waste for margarine/butter that is offered on reusable plates in catering companies. A letter was written to the members on Veneca, with a request for information of members that operate such a reuse system, or alternatively a request for analysing their waste to determine the amount of margarine loss. There was no single member that had experience with margarine on reusable plates and hence also no insights to be shared. Hence, we had to conclude that there is no reliable data on the level of food loss for the reuse case. However, we can argue that the share of non-consumed butter is likely to be larger for the reuse case than for the currently applied mini-tub. In the reuse case most canteens will prepare scoops of margarine on glass plates in advance. Plates that are not sold, will have to be discarded as according to the Hygiene code for Horeca it is not allowed to sell unpackaged margarine at a later stage [19]. Discarding will involve the removal of the unsold margarine from the reusable glass plate (with a paper towel) and discarding the margarine with organic waste. Subsequently, the glass plates are washed to remove the last residues of margarine. Additionally, the scoops of margarine will be manually produced by staff of the canteen, which will result in more variation in the offered portion size than the machine-based filling and could hence result in a larger share of non-consumed margarine. The amount of margarine on the fraction of unsold plates will add to the non-consumed margarine on used plates to render higher expected overall levels of food loss.

# 5 Life Cycle Inventory

The life cycle inventory encompasses the necessary data derived, from participating companies, literature information and technical documentation (e.g. Ecoivent). The food loss data is described separately in chapter 4.

## 5.1 Selection of the packages

The consortium chose the current portion package of Upfield for margarine as the current reference package. Furthermore, three alternative portion packages scenarios were chosen and one reuse case scenario, see Table 3. Taking into account the currently available packaging options, these alternative scenarios were the most suitable for this study. The portion-package made from aluminium is formally not a SUP, since it is not a rigid plastic package, but for some food products a coating is required. Coatings on aluminium are resin based and whether the presence of a resin-based coating on the inside of a metal package qualifies the package a SUP is unclear. Beverage cans (that are also metal packages with a resin-based coating) are clearly excluded in the EU SUP directive. But the Dutch law text qualifies an object that contains any plastic structural component as a SUP. So, the legal semantics is unresolved, yet. Likewise the paper based tub with an internal coating is clearly regarded in the Dutch law as a SUP, but is not regarded as a SUP in Germany, according to Dutch entrepreneurs. The flexible pouch is obviously a flexible package and margarine is a food product that is not directly consumed on the go, as some preparation is still required and therefore a flexible pouch for margarine is not considered a SUP. However, in the proposed PPWR such flexible plastic package might be forbidden. Hence, all alternative portion packages might not meet the legal requirements and be banned from the Dutch market.

***Table 3: Selected packaging types for small portions of margarine scenarios in this study***

| Code | Packaging type | Source of data |
|---|---|---|
| Cu | Current package: thermoformed PET tub with a metallised PET top film | Upfield |
| Al | Aluminium tub with a metallised PE top-film | Suppliers of Friesland Campina & Royal Smilde |
| Fl | Flexible pouch made from BOPET/PE multi-layered film | Upfield |
| PA | Paper-based tub with an interior PLA coating and a PLA-cellophane top-film | Joint Imagination |
| REUSE | PP based wholesale tub with 2 kg margarine combined with reusable glass plates that are used on location | Tub: Upfield<br>Glass: WFBR |

Dispensers were not chosen as alternatives. Most companies have experience with them and regard these only as potential solutions for large hotels and specific food products for which food safety issues are easier to resolve.

## 5.2 Description of the packaging systems

The material composition of reference mini tub, which is a PET tub with metallised PET film, and the alternative mini tubs packages was obtained mainly from the industrial partners involved in this study. Assumptions were made when necessary based on current market trends or the literature review. Table 4 presents the material composition of each packaging type including the production process of the tubs which is a part of the foreground data of the tool. The margarine content of all portion packages was chosen to be 10.00 grams. The food loss/residues data was derived from the data in chapter 4 and was 23% for all the different mini tubs types. For the reuse-case the level of food loss is unknown, but likely to be higher than for the portion-packages and hence scenarios with 23%, 33%, 43% etc. food loss are studied.

***Table 4: Material composition of the packaging systems for 10 grams of margarine and their production method.***

| Code | Tub | Other | Production process* | Source |
|---|---|---|---|---|
| Cu | 0.73 g PET | 0.082 g Metallised PET film lid | Extrusion plastic sheet and thermoforming | Upfield |
| Al | 0.9 g Aluminium | 0.082 g Metallised PE film lid | Sheet rolling of aluminium and deep drawing of steel | Friesland Campina & Royal Smilde |
| AlR2 | 0.9 g Aluminium with 80% recycled content | 0.082 g Metallised PE film lid | Sheet rolling of aluminium and deep drawing of steel | Based on Royal Smilde |
| Fl | 0.064 g BOPET & 0.036 PE in a multi-layered film | | Extrusion plastic film | Upfield |
| PA | 2.2 g moulded paper | 0.01 g PBAT inside coating | Pulp moulding & coating | Joint imagination |
| | | 0.013 g biobased top film (90% Cellophane, 10% PBAT) | Cellophane production and coating | |
| REUSE | 53 g PP wholesale packaging for 2 kg of margarine | 22 gr PP lid | Injection moulding of PP | assumption |
| | 50 gr glass plate | | Glass blowing | |

** 1) The production process of the different mini tubs is assumed based on the average production process of similar packaged on market, 2) Not all production processes were present in the background database and then the most similar process was chosen.*

The background data on GWP emissions of production and End-of-Life management processes were extracted from a range or sources, mainly from the ecoinventv2.2 and the European Life Cycle Database (ELCD), life cycle inventory (LCI) databases and from literature. The data can be found in Annex 1 along with the adjustments and assumptions that were made to fulfil the goal of this study.

## 5.3 Definition of the scenarios

The environmental impact of different types of margarine portion packs is studied for various end-of-life treatment scenarios of both the contained food residues and the packaging material. The collection for incineration is the base end-of-life option for all portion packages, except for the reuse scenario. Additionally, mechanical recycling through separate collection of lightweight packaging is chosen as end-of-life scenario for current PET, aluminium and for the PP wholesale packaging of the reuse scenario. Within this tool such a mechanical recycling scenario implies that it is assumed that all these packages are separately collected and that the regular sorting and recycling losses that are common for this specific type of packaging in the Dutch waste management system are accounted for. Hence, the scenario in which the mini tubs are intended to be separately collected with lightweight packaging waste, implies that indeed all mini tubs are collected with LWP, but due to sorting and recycling losses still some of these mini tubs are incinerated. The reusable scenario consist of two different packages; a wholesale package to transport the margarine from the producer to the catering facility and reusable glass plates used within the location. In the reuse scenario, the PP wholesale package is collected for mechanical recycling and we assume that there will be no food losses related to this wholesale package. The reusable glass plate is estimated to be used 500 times within the restaurant, washed in a dishwasher after each use and after 500 loops it is assumed to be collected for recycling. Furthermore, we assume that during each use loop a share of the margarine is not consumed and that this is set in the base scenario at 23% (equal to the amount in the single-use portion packs). This number doesn’t consider the margarine that is lost due to the glass plates that have been prepared in advance but were not sold. The impact of these additional food losses are studied in a separate scenario study in which the level of non-consumed margarine is increased in steps of 10%; 23%, 33%, 43% and so on. The margarine that is not consumed on the glass plates is assumed to be removed from the glass plates with paper kitchen towels collected with the organic canteen waste and send to industrial composting.

The list of exploratory baseline scenario's is provided in Table 5.

***Table 5: End of life scenarios studied within this case study. Only in the case of the reuse scenario the share of non-consumed margarine is treated in a different End-of-life process, for the other scenarios it is the same for the package.***

| Code | Packaging type | End-of-Life |
|---|---|---|
| Cu-In | Thermoformed PET tub with a metallised PET top film | Incineration |
| Cu-Rc | Thermoformed PET tub with a metallised PET top film | Recycling |
| Al-In | Aluminium tub with a metallised PE top-film | Incineration |
| Al-Rc | Aluminium tub with a metallised PE top-film and 22% sorted to the NF product in LWP sorting facilities | Recycling |
| Al-RcF | Aluminium tub with a metallised PE top-film and 76% sorted to the NF product in LWP sorting facilities | Recycling |
| Al-Rc2 | Aluminium tub made with 40% recycled content and a metallised PE top-film and 22% sorted to the NF product in LWP sorting facilities | Recycling |
| Al-Rc2F | Aluminium tub made with 40% recycled content and a metallised PE top-film and 76% sorted to the NF product in LWP sorting facilities | Recycling |
| Fl-In | Flexible pouch made from BOPET/PE multi-layered film | Incineration |
| PA-In | Paper-based tub with an interior PLA coating and a PLA-cellophane top-film | Incineration |
| REUSE | PP based wholesale tub with 2 kg margarine combined with reusable glass plates that are used on location | Tub: recycling<br>Glass: recycling<br>Lost margarine: composting |

# 6 Results

First the greenhouse gas emissions results of the current portion package and the alternatives are presented in section 6.1, then the impact of larger food waste rates in the reuse case is shown in section 6.2. The scores of the other indicators are given in section 6.3 and subsequently two sensitivity analysis are presented in section 6.4 and 6.5.

## 6.1 Greenhouse gas emissions (GWP-100)

The global warming potential over 100 years (GWP-100) of the studied scenarios is shown in Figure 3, both in terms of the total emissions (indicated with the yellow dots) and with the various contributing factors (depicted in the various coloured parts of the bars). As for most food packages, the production of the food itself (here the margarine/butter) is the largest contributing factor for all scenarios (shown by the light grey bars).

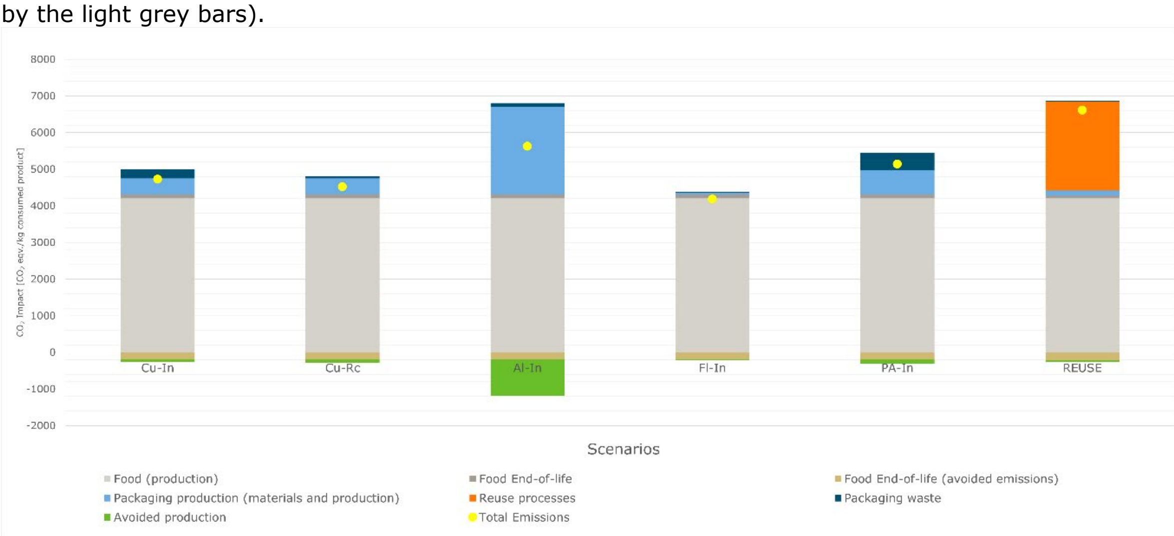


***Figure 3: The global warming potential over 100 years of the scenarios for 10 gram portions of margarine sold in different packages and with different end-of-life options.***

Since the emissions related to the food are the same in all scenarios, a better comparison between the scenarios is provided by focussing only on the emissions that relate to the packages and the reuse process, see Figure 4.

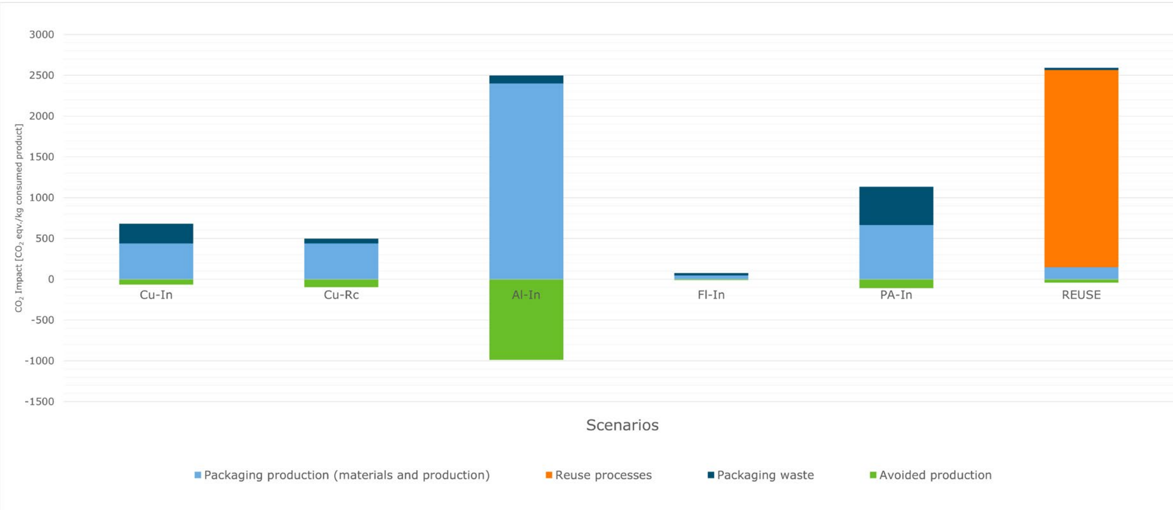


***Figure 4: The greenhouse gas emissions related to the packages and the reuse processes only, for the different scenarios.***

There are substantial differences in greenhouse gas emissions between the various scenarios. The current portion-package that is incinerated (Cu-In) creates mediocre amounts of greenhouse gases. In case the current portion package is recycled after use (Cu-Rc) the emission is slightly reduced. The aluminium packages that are incinerated (Al-In) generate much more $CO_2$ emissions which relates to the energy intensive production of new aluminium. The flexible pouch (Fl) creates really low greenhouse emissions, which can be explained by the low packaging weights. The paper-based tub (PA-In) creates more emissions than the current package, since it is heavier and has to be incinerated after use. The reusable system (REUSE) creates very high emissions and is comparable to the high emissions of the aluminium package that is incinerated (Al-In), due to the large amounts of loops that required to serve 1 kg margarine in 10 gram portions and the associated large amount of energy required to clean all the glass plates for all these loops. This reuse scenario does not take the expected higher levels of food loss into account that are likely to occur in the reuse systems, this is explored in the next section.

## 6.2 Reuse scenarios with higher levels of food loss

As explained in section 4.2 there is no experience with the presentation of margarine/butter on reusable glass plates in canteens and the level of food waste (not consumed margarine) in the reuse case is not known. But given the common work processes, most company canteens prepare the lunch in morning. This would imply that in such canteens scoops of margarine would be placed on the glass plates before the lunch break. The scoops on plates that are not sold, need to be discarded after lunch time as organic waste. The total food loss will therefore be the sum of the amount that is currently also not consumed and the unsold, but prepared amounts and will therefore be likely higher than the current level of food waste of roughly 23%. The effect of these higher expected levels of food waste on the greenhouse gas emissions are shown in Figure 5.

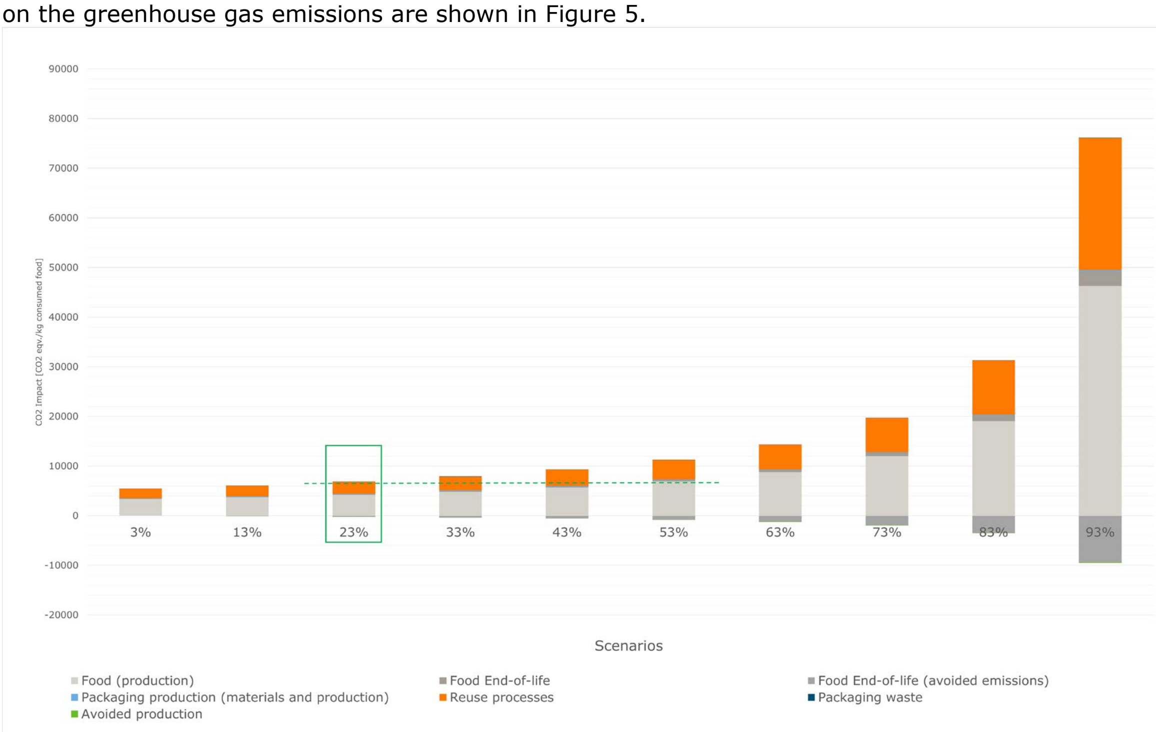


***Figure 5: The impact of the level of food waste on the emission of greenhouse gases for the reuse case. The base case is indicated with the green box and a dashed vertical line is an auxiliary line to assist in the comparison.***

A little bit more margarine-loss causes the greenhouse gas emissions to rise significantly. To make that more explicit, we compared the worst scenario of the current package (Cu-In) with reuse scenarios that show the most likely increases in margarine loss (from 23% for Cu-In to 33%, 43% and 53%), see Figure 6. Hence a small increase in margarine loss in the reuse scenario causes a large increase in the difference with the base-line scenario. In case the margarine loss will only be 10%

higher in the reuse case already 58% more greenhouse gases will be emitted in comparison with the current package that is incinerated.

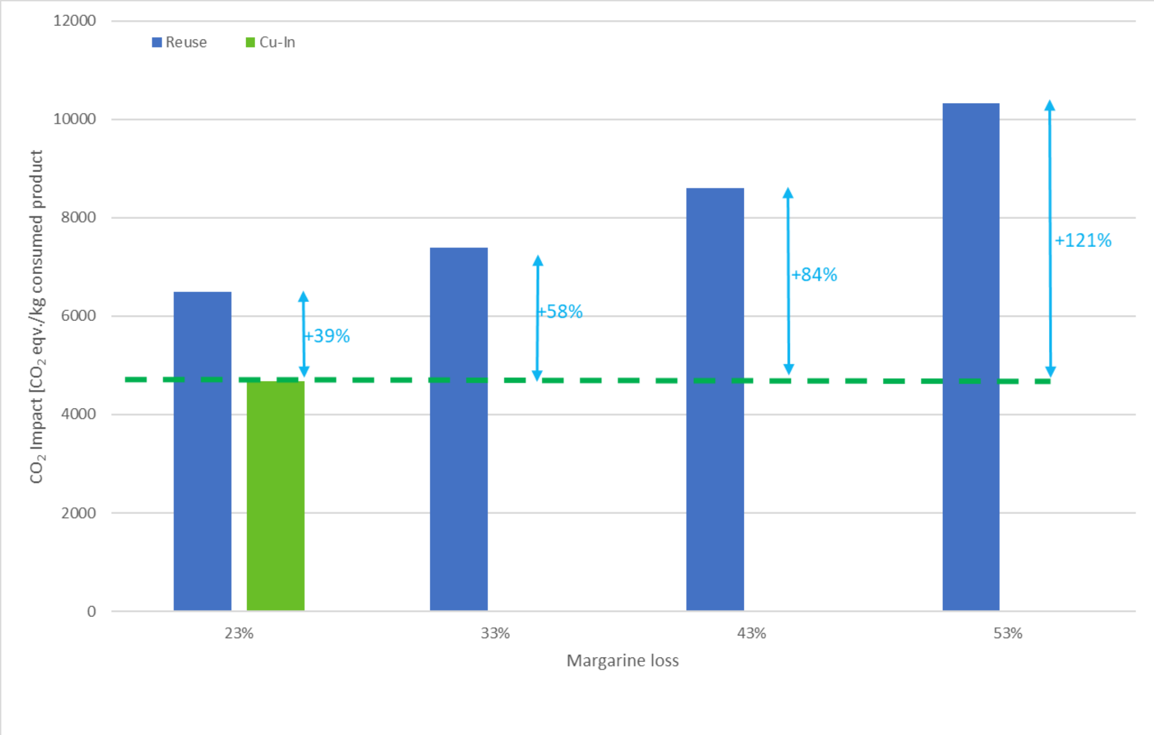


***Figure 6: Comparison of the total emissions of the base scenario (Cu-In: current PET package that is incinerated after use) with the reuse scenarios with slight elevated margarine losses.***

## 6.3 Recycling indicators

The recyclability, actual recycling and material circularity are different dimensions of sustainability, that are expressed with three different indicators; the recyclability indicator, the recycling chain indicator and the material circularity indicator, respectively. These indicators are shown in Figure 7 for all scenarios. Since in the reuse scenario two types of packaging are used and their indicators cannot be combined in one single indicator, the indicators are shown separately (Reuse glass and PP Rc).

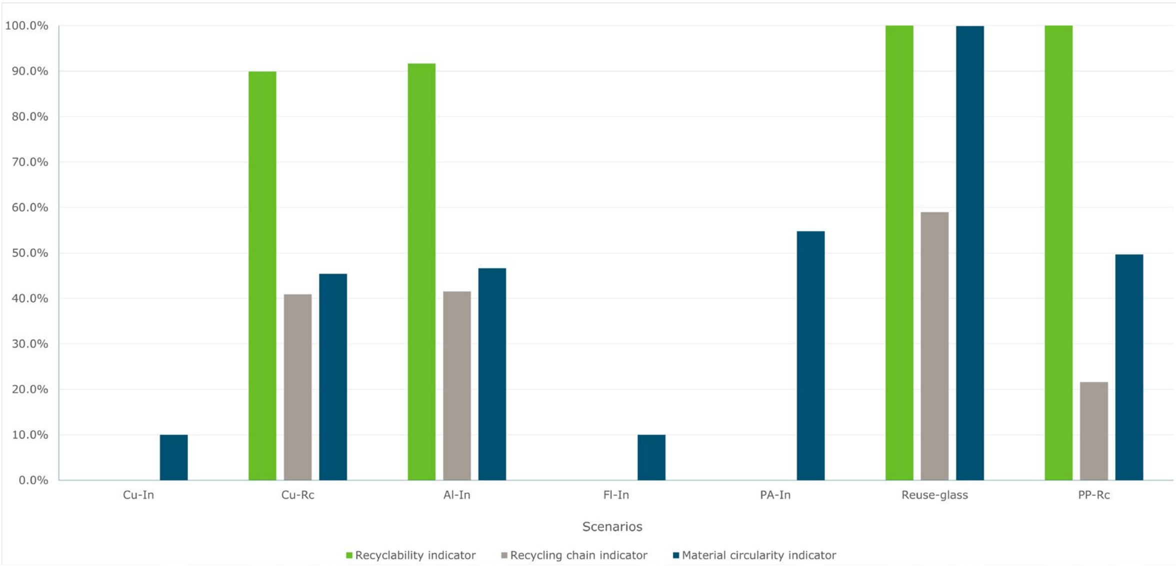


***Figure 7: The recyclability indicator, recycling chain indicator and the material circularity indicator for the scenarios.***

The current package that is incinerated (Cu-In) obviously has the lowest values for all three indicators, since it is not recycled at all. When the current package is being collected for recycling all indicators rise. For this package there is a large difference between the recyclability indicator and the recycling chain indicator, which relates to the small size of this package. In theory it can be recycled but in reality only a small share is recycled. The latter indicator is calculated with standard parameters per packaging category, which doesn't take the white colour of this package into account, yet. Since, coloured and opaque PET are removed both at the sorting facility and the recycling facility, the recycling chain indicator should actually be even lower, close to 0%. The material circularity indicator is even higher as these PET mini-tubs can be recycled, although again this indicator is an overestimation due to the white colour of these PET mini tubs.
Similarly, the aluminium mini-tub that is incinerated (Al-In) is highly recyclable and recycled to a lesser extent, which is reflected in a high recyclability indicator and slightly a lower recycling chain indicator and material circularity indicator.
The flexible pouch is not recyclable and hence has the lowest values for the three indicators. The paper-based tub that is incinerated after use is not recyclable, but is made from biobased feedstock and therefore still has a mediocre material circularity indicator.
The reusable glass plates are recyclable and hence have a high recyclability indicator. But not all glass plates are collected for recycling after use and the recycling chain indicator is lower. The material circularity indicator is maximal, since these plates are recycled and can be made with recycled content. The PP wholesale tub is recyclable (high recyclability and material circularity indicator), but not always collected for recycling (lower recycling chain indicator).

*Litter prevention*
The littering potential of the mini-tubs has not been assessed with the litter prevention indicator of the tool, since it does not take factors into account that are relevant in the markets these portion packages are used. Most of these portion-packages are used in canteens that are closed in-door locations. In these locations the chance that these portion packages will be littered is negligible. However, a small fraction of these packages will be used on out-door locations such as terraces. These out-door locations have specific risks in relation to littering, these are explained qualitatively in Table 6. The flexible pouches are more susceptible to wind gusts and hence can contribute more to the formation of litter. The reusable glass plates are not more likely to form more litter, but in case they do and the fall from a table and shatter in shards the risks for wounding create another dimension to the issue of littering.

***Table 6: Qualitatively assessed chance that litter is formed for the five types of portion packages.***

| Portion package | Indoor food service location | Outdoor food service location |
|---|---|---|
| Current (PET) | Negligible | Mediocre chance of forming litter due to out-door use |
| Aluminium | Negligible | Mediocre chance of forming litter due to out-door use |
| Flexible pouch | Negligible | Slightly larger chance to form litter due to the low weight and the susceptibility for wind gusts |
| Paper-based | Negligible | Mediocre chance of forming litter due to out-door use, but will disintegrate and biodegrade quickly in the natural environment |
| Reusable glass plates | Negligible | Mediocre chance of forming litter due to out-door use, but the sharp shards formed pose an additional risk |

## 6.4 Sensitivity analysis for aluminium portion packages

The base scenario for aluminium portion packages in which these mini-tubs are incinerated contributes largely to the greenhouse gas emissions and is hence not a very favourable scenario for these aluminium based packages. Therefore, we also studied the greenhouse gas emissions of various scenarios in which the portion packages are recycled (Rc) with the current sorting efficiencies (Rc), are recycled with more advanced sorting efficiencies (RcF) and in case 80% recycled content is used to make the portion packages (2).

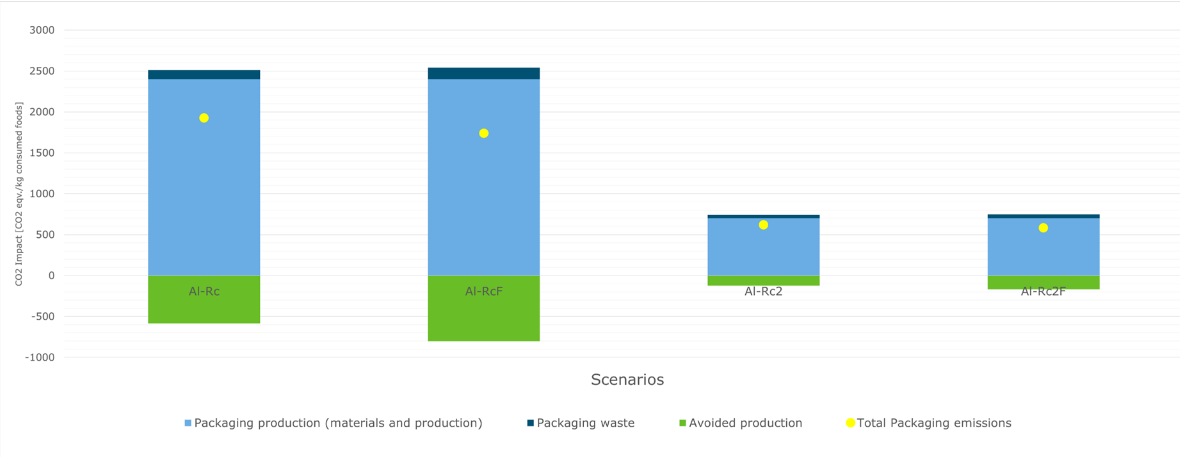


***Figure 8: The packaging related greenhouse gas emissions of various scenarios for the aluminium based portion packages.***

The recycling scenario for the aluminium packages (Al-Rc) doesn't reduce the emissions in comparison to the base scenario (Al-In) in which the aluminium portion packs are incinerated. This is caused by the few Eddy current separators in sorting facilities that currently are placed over the fine sorting fractions, which results in small share of small aluminium packages (~22%) ending-up in the non-Ferrous metal fraction. Even when all sorting facilities are fitted with more Eddy current separators and consequently more small aluminium packages are positively sorted to the non-Ferrous metal fraction (~76%) as is the case in the F (Future) scenario, then still the greenhouse gas emissions hardly reduce. This, however strongly relates how recycled material is credited within the LCA-based tool. Only, when the aluminium packages are produced from 80% recycled content and are recycled (AlRc2 / AlRcF), the emissions will drop significantly to levels that are in the same order of magnitude as the current PET based package.
The material circularity indicator of the same scenarios for aluminium packages are shown in Figure 9, clearly showing that the scenario in which most packages are recycled and recycled content is used in new packages renders the highest score. The MCI doesn't reach 100% since not all aluminium can be recycled due to sorting and recycling losses and the packages cannot be produced from 100% recycled content.

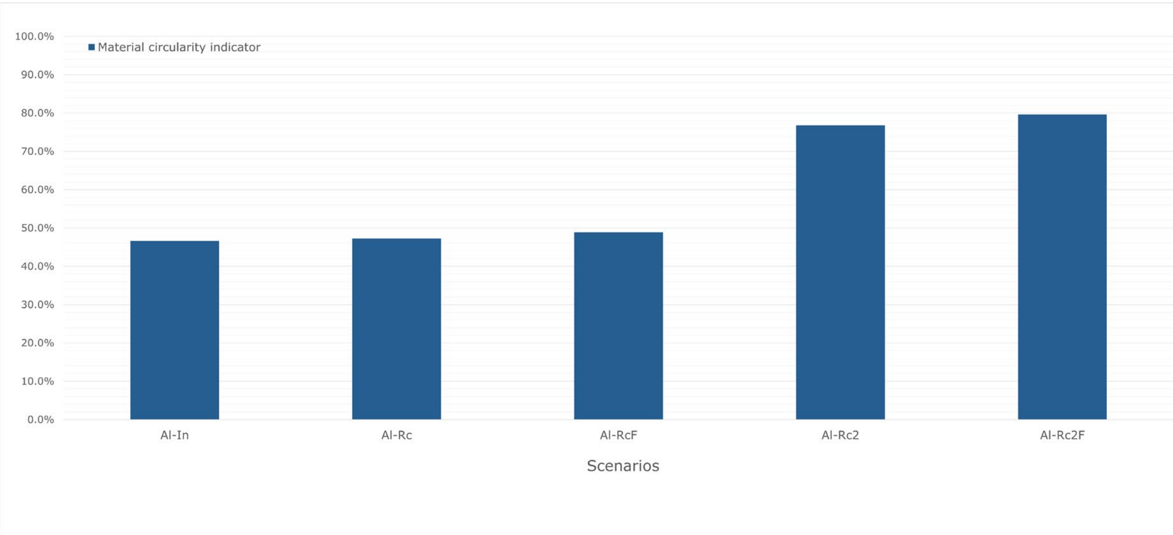


***Figure 9: Material circularity indicator of various scenarios with aluminium based portion packages.***

## 6.5 Sensitivity analysis for reusable plates

From Figure 4 it is clear that the reusable packaging scenario has a large carbon footprint, which (apart from anticipated additional food loss, as explored in Figure 5 and Figure 6) relates largely to "reuse processes". Within these reuse processes the electricity use contributes the most. In the base REUSE scenario we took the electricity use, water use and detergent use of a modern, energy-efficient domestic dishwashing machine, see Annex 1. To analyse, whether the use of professional catering dishwashing equipment would reduce these impacts, we conducted a scenario study with two additional types of the dishwashing machine:

- REUSE: the base scenario with a domestic dishwashing machine,
- REUSE-P: the professional catering dishwashing machine of Hobart,
- REUSE-PII: the semi-professional catering dishwashing machine with a separate dryer, both of Hobart.

The technical data (voltage, current, process time, capacity, water use and detergent use) were taken from a technical datasheet of Hobart [20] and the data is summarised in Annex 1. Unexpectedly, the carbon footprints of the reuse scenarios with the semi-professional and the professional dishwashing machine are even larger, which is caused by their higher electricity use, see Figure 10.
In reality the various catering companies will use a mixture of domestic, semi-professional and professional dishwashing machines and therefore, the calculations provided in section 6.1 and 6.2 of the greenhouse gas emissions of the reuse scenario are an underestimation of the emissions that can be expected for a realistic reuse case.

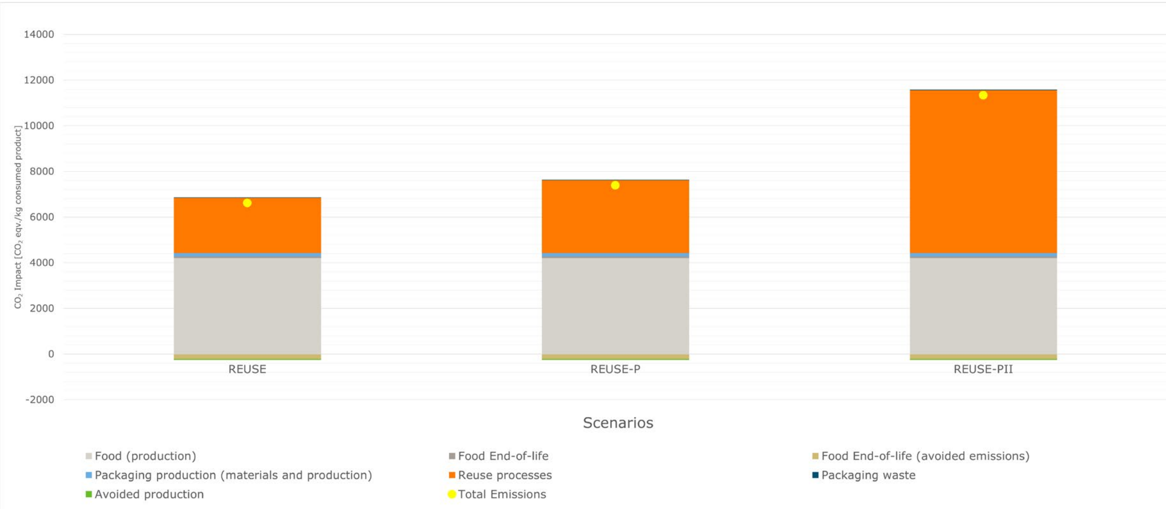


***Figure 10: Greenhouse gas emissions of the three reuse scenarios with different dishwashing machines.***

# 7 Discussion

## 7.1 Uncertainties

This analysis has been performed with the available data. For some production processes background data was lacking and data from slightly similar processes had to be taken. Furthermore, the food loss data was limited (eg. catering waste only measured twice) and it was all that could be gathered within the limitations of this project. To cope with these shortcomings a sensitive analysis was added for the reuse scenario. When in the future more data becomes available by measuring more residues in portion packages and reusable packages the results will change slightly. Nonetheless, this analysis has also revealed that the food loss rate does not have the largest impact on the sustainability dimensions. For the aluminium based portion packages this was predominantly the applied level of recycled content and the presence of sorting and recycling infrastructure, see section 6.4. And for the reusable alternative this was the emissions related to the electricity use of the dishwasher (see section 6.5), which will reduce if in the future our electricity mix will encompass more renewables. Hence, the results are strongly context dependant and when the context develops, the results will change accordingly.

Likewise also the results for the reuse case will be dependent on multiple factors. In the reuse case large amounts of electrical energy are used, consequentially dominating the calculated carbon footprints. When in the future we do manage to decouple from fossil-based energy sources, this contribution to the carbon foot print will lower, making the reuse case more environmentally sound. Another important factor in the reuse case is the share of non-consumed margarine. This share will depend strongly on the work processes in the food service venue. When a small facility is considered with a high personnel to client ratio (for instance a small B&B), then the staff can prepare a scoop of margarine upon order and the food waste will only the share of the provided product that is not consumed. In venues with a low staff to client ratio, such as for instance most company canteens, the products are prepared beforehand, and all unsold products will need to be discarded. This implies that the food loss in the food service facilities is context specific and hence also the sustainability assessment. Given the fact that most food service venues have a low staff to client ratio and in general suffer from a shortage of staff, the chance that the food loss will be elevated is substantial. The precise number is currently unknown and future studies will have to evaluate this in more detail.

Finally, it cannot exclude the possibility that in the future new alternative solutions will emerge such as food safe dispensing machines, that could provide better (more ideal) solutions for specific markets.

## 7.2 Overall assessment: no ideal solution

All portion packages have pros and cons in legal compliance and the different dimensions of sustainability. There is, however, no alternative that is perfect in all dimensions of sustainability and legal compliance. Every choice that is made renders trade-offs. This is explained below.

**Current PET based portion package**

- ☒ Legally no longer allowed from 1st of January 2024 in the Netherlands
- ☐ Moderate carbon footprint which can be reduced by recycling
- ☐ Mediocre MCI when recycled, but circularity can be raised by using recycled content
- ☑ Negligible chance of littering when used indoors
- ☒ When littered it results persistent planetary pollution

**Aluminium based portion package**

- ☑ Legally allowed in most European countries. In the Netherlands some legal semantics still need to be resolved in relation to the meaning of the terminology “structural component”
- ☒ High carbon footprint which can be reduced substantially by using recycled content
- ☐ Mediocre MCI, but circularity can be raised by using recycled content and recycling
- ☑ Negligible chance of littering when used indoors
- ☒ When littered it results persistent planetary pollution

**Flexible plastic pouch portion package**

- ☑ Legally allowed; a food product that is not consumed directly and is packaged in a flexible package is not a SUP
- ☑ Low carbon footprint
- ☒ Minimal MCI, fully linear, not circularity
- ☑ Negligible chance of littering when used indoors, but slightly raised chance outdoors
- ☒ When littered it results persistent planetary pollution

**Paper-based portion package**

- ☒ Legally not allowed in the Netherlands, as the water-resistant coating used, is regarded as a structural component in the Netherlands, whereas it is allowed in Germany
- ☑ Low carbon footprint
- ☐ Mediocre MCI, based on biobased feedstock, but not recyclable
- ☑ Negligible chance of littering when used indoors
- ☑ When littered it will disintegrate and biodegrade and not form persistent planetary pollution

**Reusable glass plates as portion package and wholesale PP package**

- ☑ Legally allowed
- ☒ High carbon footprint
- ☑ Glass plate is fully circular, wholesale PP package has a mediocre MCI
- ☑ Negligible chance of littering when used indoors
- ☒ When littered it can form glass shards that form a safety risk

## 7.3 Known alternatives in relation to food products

In this study case margarine/butter was selected as model product for the portion packaged food products, but other food products may fit specific packaging alternatives better, due their product properties (viscosity, acidity) and/or the presence of existing examples of the alternatives on the market. Products with a low viscosity like sauces are more suited for flexible pouches and these are also currently available on our markets. More solid products like hard butter is currently also sold in metallised paper wrappers, etc. This is further elaborated in Table 7.

***Table 7: Matrix of portion packages and alternatives that are currently on the market.***

| Product | Cu | Al | Fl | PA | REUSE | Other |
|---|---|---|---|---|---|---|
| Margarine | X | | | | | |
| Butter | X | | | | | Wrap |
| Salad spreads | X | | | | | |
| Jam | X | X | | | | Glass mini jar |
| Peanut butter | X | X | | | | Glass mini jar |
| Hazelnut spread | X | | | | | Glass mini jar |
| Mayonnaise | X | | X | | | |
| Ketchup | X | | X | | | |
| Soy sauce | X | | X | | | |

Known alternatives are relatively easy solutions for producers as both the market parties and consumers are already accustomed to them. It can also serve as a first-order approximation of the expected transition response of the incumbent industries, as companies that already market sauces in flexible pouches are more likely to use this solution for their rigid portion packages. It also clarifies that there are no known alternatives for margarine and salad spreads.

## 7.4 Business and behavioural aspects

A change-over to alternative portion-packages has substantial consequences for the producing and distributing industries. New packages have to be developed and tested for shelf life and food safety after which often new packaging machines have to be ordered, which typically take 1-2 years from purchase to delivery and installed. The overall process can take 2 to 3 years. These new machines need to be amortised in 15-20 years within the current business models. This also implies that once chosen, the alternatives should be able to be used for multiple decades. Given the multiple revisions in legislations that we are currently experiencing, this is no longer guaranteed, which automatically makes the incumbent entrepreneurs hesitant to act. Therefore, from the producers perspective, it is highly desirable that the government presents a vision on packaging use in the future to allow businesses to prepare themselves for these changes. Such a long-term vision would allow incumbent entrepreneurs to plan transitions on forehand. When this vision is materialised in new packaging waste laws, it would be advisable for the government to set realistic transition periods.

The SUP legislation will cause the packages to change and in relation to the portion packages this will affect the behaviour of civilians and a long list of entrepreneurs (hotel keepers, B&B owners, lunchroom holders, etc.). In some combinations of products & markets these changes can be executed with relative ease, because they are already used to it; sauce tubs in snack bars can be replaced by flexible pouches. But the change from single-use to reuse requires fundamental behavioural changes from entrepreneurs and civilians. Currently, there is nobody taking the lead to prepare entrepreneurs for new work processes and civilians for consumption behaviour. This puts the transition to a reuse system at risk and that not only the intended policy targets are not achieved, but collateral damage may be inflicted in terms of more greenhouse gas emissions, food safety incidents and bankruptcies.

# 8 Conclusions

Food products in single-use portion packages are currently widely used in various food service venues, small hotels, Bed &Breakfasts, lunchrooms, canteens, etc. for various food products (mayonnaise, ketchup, jam, peanut butter, hazelnut spread, margarine, butter, etc.). Most of these portion packaged food packages are rigid plastic packages. The single-use plastic directive and the derived national legislations aim to limit the use of these plastic portion packages with the intention to minimise the littering of the planet with persistent plastic pollution. As a consequence, rigid plastic portion-packages will be forbidden in the Netherlands from January the 1st 2024 for consumption on location. The incumbent Dutch industries involved in this case study asked for an assessment of the impacts that potential portion package alternatives are likely to have on multiple dimensions of sustainability.

This analysis has shown that all possible alternative solutions have pros and cons. There is no solution that has a minimal carbon footprint, a maximal material circularity indicator and no chance of contributing to the formation of litter. Consequently, it is matter of navigating trade-offs.
In these trade-offs food companies not only have to consider the legal compliance, environmental impacts, business costs but also consumer acceptance. Flexible plastic pouches are suitable candidates for portion-packaged sauces, because consumers are already used to them. This alternative, however, will not solve the issue of littering and does also not fit the vision of a circular economy.

For multiple other food products the aluminium based packages appear to be a potential solution, although for application in the Netherlands it is not clear yet if this option can comply with the Dutch legislation. At the moment there is still discussion on legal semantics and the interpretation of the law text needs to be resolved. One additional remark should be done, these packages have large carbon footprints and these can only be reduced by using recycled content and recycling the packages after use. So, this package can only be a credible alternative in case also changes are effectuated in the aluminium industry and in the waste management industry. The reusable alternative will result in a much larger carbon footprint, that is partially caused by the electrical energy used by dishwashers and by the larger expected food losses. In most canteens, plates with the portions of food will be prepared before the peak hours of clients and the non-sold unpackaged food will have to be discarded. If in the future energy sources could be decoupled from fossil-based energy sources, the contribution of electrical use to the carbon footprint will lower.

In short, the food industry will have to select the least worst solution, which will inherently be context-dependant (type of product and the situation in which it is used). Also future developments for instance in waste management and energy transition will impact the sustainability of the different studied alternatives.

# Abbreviations

| | |
|---|---|
| Al | Aluminium portion package |
| Cu | Current (in relation to packaging types) |
| F | Future (in relation to scenarios) |
| Fl | Flexible portion package |
| GWP | Global warming potential |
| In | Incineration (part of scenario name tags) |
| LCA | Life cycle analysis |
| LCI | Life cycle inventory |
| LWP | Lightweight packaging waste |
| MCI | Material circularity indicator |
| MuDiSa | Multi-dimensional sustainability assessment |
| NF | Non-Ferrous metals |
| OPW | Original product weight |
| Pa | Paper-based portion package |
| PPWR | Packaging and packaging waste regulation |
| Rc | Recycling (part of scenario name tags) |
| RCI | Recycling chain indicator |
| RI | Recyclability indicator |
| SUP | Single-use plastics |

# Literature

1. Commission E. A European Strategy for Plastics in a Circular Economy. Brussels, 2018:18.
2. COUNCIL. DIRECTIVE (EU) 2018/852 amending Directive 94/62/EC on packaging and packaging waste. Official Journal of the European Union 2018;**L 150 / 141**:14
3. COUNCIL. DIRECTIVE (EU) 2019/904 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the reduction of the impact of certain plastic products on the environment. Official Journal of the European Union 2019;**L 155/1**:1-19
4. Commission European. Commission guidelines on single-use plastic products in accordance with Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. Official Journal of the European Union 2021;**C 216/1**:46
5. Rijks Waterstaat DSvIe. Regeling kunststofproducten voor eenmalig gebruik. In: Nederlanden Kd, ed. The Hague: Staatscourant, 2022:45.
6. Commission European. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC. Brussels: European Commission, 2022:118.
7. Foundation EllenMacArthur. Circularity indicators - an approach to measuring circularity. Cowen: Ellen MacArthur Foundation, 2019:64.
8. Liao X, Gerichhausen MJW, Bengoa X, et al. Large-scale regionalised LCA shows that plant-based fat spreads have a lower climate, land occupation and water scarcity impact than dairy butter. The International Journal of Life Cycle Assessment 2020;**25**(6):1043-58 doi: 10.1007/s11367-019-01703-w.
9. Turner DA, Williams ID, Kemp S. Greenhouse gas emission factors for recycling of source-segregated waste materials. Resources, Conservation and Recycling 2015;**105**:186-97 doi: 10.1016/j.resconrec.2015.10.026.
10. Kim MH, Song, H.B., Song, Y., Jeong, I.T., Kim, J.W. Evaluation of food waste disposal options in terms of global warming and energy recovery: Korea. International Journal of Energy and Environmental Engineering 2013;**4**:12 doi: 10.1186/2251-6832-4-1.
11. Saer A, Lansing S, Davitt NH, Graves RE. Life cycle assessment of a food waste composting system: environmental impact hotspots. Journal of Cleaner Production 2013;**52**:234-44 doi: 10.1016/j.jclepro.2013.03.022.
12. Brouwer MT, Thoden van Velzen EU, Augustinus A, Soethoudt H, De Meester S, Ragaert K. Predictive model for the Dutch post-consumer plastic packaging recycling system and implications for the circular economy. Waste Manag 2018;**71**:62-85 doi: 10.1016/j.wasman.2017.10.034.
13. Brouwer M, Picuno C, Thoden van Velzen EU, Kuchta K, De Meester S, Ragaert K. The impact of collection portfolio expansion on key performance indicators of the Dutch recycling system for Post-Consumer Plastic Packaging Waste, a comparison between 2014 and 2017. Waste Manag 2019;**100**:112-21 doi: 10.1016/j.wasman.2019.09.012.
14. Thoden van Velzen EU, Jansen M, Brouwer MT, Feil A, Molenveld K, Pretz T. Efficiency of recycling post-consumer plastic packages. PPS32. Lyon, 2017. doi: 10.1063/1.5016785
15. Thoden van Velzen EU, Brouwer MT, Feil A. Collection behaviour of lightweight packaging waste by individual households and implications for the analysis of collection schemes. Waste Manag 2019;**89**:284-93 doi: 10.1016/j.wasman.2019.04.021.
16. Brouwer MT, Thoden van Velzen EU, Ragaert K, ten Klooster R. Technical Limits in Circularity for Plastic Packages. Sustainability 2020;**12**(23) doi: 10.3390/su122310021.
17. Thoden van Velzen EU, Molenveld, K., Brouwer, M.T., van der Zee, M., Smeding, I. Issue paper: Recycling of different waste streams. Wageningen: WFBR, 2021:2209. DOI 10.18174/555442
18. Brouwer MT, Thoden van Velzen, E.U. Multi-dimensional sustainability assessment of product-packaging combinations. Wageningen: WFBR, 2023:2442. DOI: 10.18174/633072
19. Hygiene-code Horeca. https://www.khn.nl/onderwerpen/ondernemen-in-de-horeca/hygienecode , accessed on June 30th 2023.
20. Hobart presentation with technical data, named "Hobart reusables", https://www.canva.com/design/DAFfZliFcSU/R8u-mVs4PlNIYMKzmDDKGg , Accessed July 7th 2023.
21. HTP, Elaboration of an aluminium sorting model, Presentation, March 2019, Aachen.

# Annex 1 Source and adjustments of background data

| Food product | Source | Comment/Adjustments |
|---|---|---|
| plant-based and margarine, NL | [8] | |

| Materials | Source | Comment/Adjustments |
|---|---|---|
| Aluminium, PP and PE granulate, paper | Ecoinvent / IPCC 2013 GWP 100a V1.03 | |
| Recycled Aluminium | [9] | |
| Aluminium foil | https://apps.carboncloud.com/climatehub/product-reports/id/140563845212 | |
| Cellophane | https://apps.carboncloud.com/climatehub/product-reports/id/1267952392638 | Cellulose film as proxy |
| PBAT | European Commission, 2019 | PLA/PBAT film as a proxy |
| moulded paper | Ecoinvent / IPCC 2013 GWP 100a V1.03 | Kraft paper, unbleached as proxy |
| Glass plate | http://www.gabi-software.com/fileadmin/gabi/EULA_European_Commission_-_use_of_thinkstep_LCI_data.pdf | Glass container as proxy |

| Production processes | Source | Comment/Adjustments |
|---|---|---|
| All other production processes in database / used in cases | Ecoinvent / IPCC 2013 GWP 100a V1.03 | |

| Reuse process | Source | Comment/Adjustments |
|---|---|---|
| Energy use (kWh), Water use (L), soap use (kg) of domestic dishwasher.<br><br>Scenario REUSE | Data from Google on dishwater energy water and detergent use | Demand for a commercial dishwasher fitting 40 plates<br><br>1 kWh / run with 40 reusable plates<br><br>15 ltr / run with 40 reusable plates<br><br>15 grams / run with 40 reusable plates |
| Energy use (kWh), Water use (L), soap use (kg) of a semi-professional combination of a dishwasher and a dryer<br><br>Scenario REUSE-PII | Data from Hobart presentation [20] | Demand for a commercial dishwasher fitting 40 plates<br><br>3.2 kWh / run with 40 reusable plates<br><br>8 ltr / run with 40 reusable plates<br><br>2 grams / run with 40 reusable plates |
| Energy use (kWh), Water use (L), soap use (kg) of a professional dishwasher<br><br>Scenario REUSE-P | Data from Hobart presentation [20] | Demand for a commercial dishwasher fitting 25 plates<br><br>0.9 kWh / run with 25 reusable plates<br><br>2 ltr / run with 25 reusable plates<br><br>2 grams / run with 25 reusable plates |

| End-of life (EOL) processes | Source | Comment/Adjustments |
|---|---|---|
| All other EOL processes in database / used in cases | Ecoinvent / IPCC 2013 GWP 100a V1.03 | |
| Incineration of paper, fossil-fuel and biobased plastics | Own estimate | |
| Recycling of PE, PP, aluminium | [9] | |
| Incineration of margarine | [10] | Food waste as a proxy |
| Industrial composting of margarine | [11] | Food waste as a proxy |

| Recycling processes / efficiencies | Source | Comment /Adjustments |
|---|---|---|
| All data | Background knowledge of researchers of WFBR based on previous projects, such as: [12], [13], [14-18] | |

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