ENV-510

Life cycle assessment in energy systems

Comparative LCA between a reusable reCIRCLE plate and a disposable cardboard plate

Final Report

Group 10 :

Dubettier Romain - Facchini Giulia - Lavine Salomé - Rouzier Roméo - Souquet Raphaelle - Wojciechowicz Wiktor

Professors : Prof. Manuele Margni & Prof. François Maréchal

Assistant : Dareen Dardor

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EPFL

1 Executive Summary

To address EPFL's question on whether the reusable ReCircle box is better than the Alphaform cardboard box, a comparative life cycle assessment (LCA) was conducted. Given the lack of meals for the EPFL community on campus, EPFL is considering installing vending machines with meals and needs to determine the best packaging solution. The goal of this LCA is to provide guidance to the EPFL catering service in making this decision. The functional unit (FU) used to compare both products is : "Serve a 250g meal in a box protected by a plastic film at EPFL Lausanne Campus in 2024."

Two process trees were created to illustrate the life cycle stages of both product systems. System boundaries were set using a cut-off method, excluding processes with negligible or identical processes in both cases. A recycled content approach was used for the ReCircle box's end-of-life, while a 50-50 method was applied to the Alphaform box to ensure accuracy. Key parameters were collected to calculate reference flows, and the product systems were modeled in OpenLCA using collected data and the Ecoinvent 3.6 database.

Data was collected throughout the study, mainly for establishing reference flows and modeling in OpenLCA, sourced primarily from the companies involved and research studies. Necessary assumptions were made to fill the lack of real data, including key assumptions from ReCircle regarding the features of their future product, fridge energy consumption of the fridges that will be used to store the meals, and the Alphaform box production process.

The IMPACT World+ Footprint v2.0.1 method was used to evaluate the environmental impact of each box across five impact categories: carbon footprint, fossil and nuclear energy use, human health damage, ecosystem quality damage, and water scarcity. Through an internal normalization, the results showed that the ReCircle box performs better in terms of ecosystem quality damage and human health damage, while the Alphaform box has a lower impact in terms of carbon footprint, fossil and nuclear energy use, and water scarcity. Meal preservation was identified as the largest contributor across all impact categories with the ReCircle box requiring more fridge energy consumption than the Alphaform box. A sensitivity analysis on fridge energy consumption revealed that using intelligent fridges could significantly reduce the ReCircle box's impact in fossil and nuclear energy use. Another sensitivity analysis showed that the ReCircle box has a higher initial impact due to production and end-of-life processes, but this is offset after about 50 uses. Beyond that point, the ReCircle box outperforms the Alphaform box, particularly in ecosystem quality damage and human health damage.

This study has limitations, particularly the lack of robustness due to assumptions made to compensate for missing data. Uncertainties include the number of uses per ReCircle box, influenced by consumer behavior, and EPFL's potential shift to a fully renewable energy mix, which could significantly lower energy-related impacts. Despite these limitations, the results offer a useful starting point for choosing the best box for future meal vending machines on the EPFL campus.

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3 Environmental Issues Associated with the Case Study

As production and consumption ramps up, so does the waste, creating a cycle of excess. This waste is currently partly responsible for the global climate change crisis meaning that every form of production must be analyzed, and reduce its impact. To do so, communities need to find a way to minimize CO_2 emissions, reduce waste and promote sustainable resources to mitigate climate change. Food supply, in particular, represents the consumption and production sector with the largest environmental impact, surpassing housing and transportation in Switzerland [1]. The production, packaging, and disposal of food contribute significantly to resource depletion, energy consumption and pollution [2]. By adopting practices such as reducing food waste and optimizing packaging, significant progress can be made in lowering the sector's environmental footprint [3]. Innovations in production and supply chains, alongside consumer awareness and policy interventions, are essential to achieving a more resilient and eco-friendly food system [4].

Takeaway food services, which account for 16% of the restaurant market in Switzerland [5], contribute to the production of various types of packaging. The most used are plastic containers, paper napkins, and single-use cups. These are often made from non-renewable materials, which pollute by generating greenhouse gases and toxic pollutants that exacerbate environmental degradation. These items are frequently discarded after use and are difficult to recycle once stained by food [6]. Reducing waste, which is currently recycled at a rate of 52% in Switzerland [1], is therefore a pressing issue. Promoting the use of reusable, biodegradable, or compostable alternatives can help reduce reliance on single-use materials and minimize pollution [7]. Additionally, improving recycling infrastructure and raising awareness among consumers about proper waste management are key steps toward mitigating the adverse effects of single-use packaging on the environment.

In order to reduce these wastes mainly caused by the single-use policy, a specific effort has been produced through the globalimplementation of reusable alternatives and improved resource management strategies [8]. To address the challenges provoked by climate change and the society, it is essential to rethink consumption and waste management while promoting sustainable solutions. One promising avenue is the adoption of reusable tableware in takeaway services, which has the potential to reduce the carbon footprint, and decrease dependency on single-use items [9]. Using reusable options in the food industry could substantially lower the environmental impact of packaging waste, support resource conservation, and contribute to a circular economy focused on long-term sustainability [10]. This shift requires collaboration among policymakers, businesses, and consumers to establish a supportive framework for reusable systems [11]. Additionally, investing in efficient infrastructure for the collection, cleaning, and redistribution of reusable items is essential to ensure the practicality and scalability of these solutions.

4 Review of Similar LCA Studies and Results

Several life cycle assessments have been conducted on reusuable against single use containers. For instance, a study by Aggarwal, 2024 [12] shows that single-use plastic tableware has a 59% higher climate change impact than reusable containers used 20 times. Despite the reusable option requiring 99% more water and 62% more non-renewable energy.
The European Paper Packaging Alliance (EPPA) asked the European Commission to conduct an LCA comparing a paper single-use dish system with equivalent multiple-use dishes in quick service restaurants. According to their findings, polypropylene reusable containers used 100 times have a 177% greater climate change impact than single-use paper packaging [13].

As pointed in a spatial LCA comparing reusable and recyclable food packaging containers networks, by Accorsi et al., 2022 [14], uncertainty remains regarding their true environmental impacts. This study examines the environmental impact of reusable plastic containers (RPCs) versus single-use options in Italy's food supply chain using Geographic Information Systems and digital twin technology. Analyzing nine packaging systems over 10 years, the study finds that, despite 23.8% higher transport emissions, RPCs achieve lower overall impacts than single-use options due to reduced production and disposal emissions.

Another study by Cottafava et al., 2021 [15] introduced a specific methodology for the interpretation of results from comparative LCA analyses in order to evaluate reusable versus single-use products. The methodology is based on three criteria: the product phase efficiency, the use phase efficiency, and the environmental break-even point. The break-even point represents the minimum number of times a reusable product has to be used in order to become environmentally better than an equivalent number of uses of a single-use product. The LCA, focused on four single-use and four reusable cup types, shows a break-even point of around 150 uses in the case of non-renewable energy but never reaches it for water scarcity. This highlights the importance of understanding processes and modeling for meaningful results.

Finally, a study by Yadav et al., 2024 [16] focuses on the cradle-to-grave life cycle assessment (LCA) of a reusable takeaway food container. In this LCA, the break-even point is reached at 6 uses of the reusable container.

Although many comparative LCAs have been conducted trying to assess whether single-use or reusable food containers have a lower environmental impact, the comparative life cycle assessment presented in this report is conducted in Lausanne EPFL campus at the end of 2024, for two specific food containers, the ReCircle reusable box, and the Alphaform single-use cardboard box. The time and location are important as they impact the energy mix of the life-cycle analysis and the characteristics of the food boxes are specific to two distinct packaging manufacturers. The results of this LCA aim to inform the EPFL community and help in decision-making when it comes to food containers on campus. The findings add to existing studies by the precise settings in which this study is conducted.

5 Project Objectives

The purpose of this comparative LCA is to assess the environmental impact (according to ISO-14044) of using reusable plastic food containers (ReCircle) versus single-use cardboard containers for EPFL's future vending machines.

Due to the need for more meals on the EPFL campus, BOKA Food plans to sell meals through vending machines (Husky fridges). The key question is : how will these meals be stored? Typically, BOKA Food uses cardboard boxes from Alphaform. However, EPFL mandates the elimination of single-use containers, opting instead for reusable food containers. Consequently, the goal of this project is to determine whether the reusable plastic containers, provided by ReCircle, have a lower environmental impact compared to single-use cardboard food containers. To achieve this, we are conducting a comparative LCA.

The primary audience for this study is BOKA Food and EPFL, which oversees sustainable practices on campus. By quantifying the environmental benefits of reusable versus single-use food containers, these stakeholders can implement vending machines on the EPFL campus with meals stored in ReCircle boxes.

The findings of this study may be shared with the public to validate the environmental advantages of reusable alternatives over single-use items. However, the study must first be reviewed by experts.

6 Product Systems Description

This study aims at comparing two different food boxes made from different materials.

The first product is a reusable food box from ReCircle, made from PBT and PET, with a plastic film cover. It weighs 160 grams without the film and 163.32 grams with it. The box is made of 97% recycled materials and 3% virgin materials, manufactured directly at the ReCricle factory. It is designed to be used about 200 times but this may vary due to damage or loss. The virgin materials are sourced from Sweden. The box is produced and recycled in Switzerland, and the plastic film is landfilled in Switzerland as well.

The second product is a disposable cardboard box from Alphaform, which includes a plastic film and weighs 33.39 grams in total. Unlike the ReCircle box, this box is meant for one-single use only, it is then disposed of. The cardboard, both recycled and virgin, is sourced from Europe. Production takes place in France, but the box is used in Switzerland, where both the box and plastic film are also recycled and disposed of respectively.

The manufacturing of a ReCircle box involves an aggregated (background cradle-to-gate) unit process of producing virgin plastic and electricity. It is followed by the filling of the box (foreground unit process), where a conserving gas is also used. The gas and the plastic film sealing the box are also considered background processes. The filled box is then transported to EPFL and stored in a fridge before being consumed by a consumer (all foreground unit processes). Once empty, the box is manually or professionally cleaned (foreground unit process) and reused up to 200 times before being recycled at the factory (shredded into PBT granulate and melted to produce a new box), supporting a closed-loop system, and highlighting its circularity.

For the disposable cardboard box, the manufacturing process involves aggregated unit processes of producing virgin cardboard and electricity. As for the ReCircle box, the empty cardboard box is transported to be filled with food and a conserving gas, and sealed with a plastic film (foreground unit process), before being transported to and stored in a fridge at EPFL (foreground unit process). Once the meal is consumed, the cardboard is recycled, while the accompanying plastic film is sent to a landfill (background unit process). About fifty percent of the recycled cardboard is then processed back into new cardboard.

7 Function and Functional Unit

7.1 Function

Both products serve the same purpose: containing food for a specific period opf time while extending its shelf life using a conserving gas. The disposable Alphaform cardboard box is designed to store food for a certain number of days, during which it can be preserved in a fridge and heated before consumption. After consuming the food, the cardboard box is discarded. Consumers use it solely for containing their meals, therefore the primary function is to contain food. The duration for which the box is conserve in a fridge at EPFL campus can vary, but it is always discarded after a single use, with no secondary function. In contrast, the reusable ReCircle box can contain food and be stored in a fridge, be heated, and be used as a plate multiple times. At EPFL, users who purchase a meal in a ReCircle box have the option to keep and wash it themselves for reuse or return it to EPFL for professional cleaning and subsequent reuse. This box is subject to a deposit of 10 CHF, aimed at reducing the number of lost boxes. Additionally, the ReCircle box can serve as a secondary function by being reused to contain other meals. The amount of food contained can vary.

7.2 Functional Unit

The functional unit (FU) allows to compare two different products. The functional unit for this study is: "Serve a 250g meal in a box protected by a plastic film at EPFL Lausanne Campus in 2024". An arbitrary mass of 250g has been chosen for the meal. It represents an average consumption for a light meal and is more representative and easier to measure than a volume. The location is important as it influences the energy mix and transportation flows. Additionally, specifying the date is also important because of technological advancements at different times may result in varying environmental impact from processes such as plastic production.

8 Process Trees and System Boundaries

8.1 ReCircle Box

The life cycle of the reusable ReCircle box (Fig: 3) begins with its manufacturing at the ReCircle factory in Einsiedeln, where virgin and recycled plastics along with electricity are utilized to produce each box (cradle-to-gate unit processes). After production, the box is transported to BOKA Food in Renens to be filled.

Within the aggregated unit processes, some processes have been left out of the system boundaries for various reasons, and are considered out of scope. The “food” is considered equivalent for both systems in terms of mass (250g) and volume, which justifies its exclusion from the calculations, plus the content can changed. The filled ReCircle box, containing food and the conserving gas (Aligal 13 [17]), is sealed with a plastic film and transported from BOKA Food in Renens to EPFL, where it is stored in a Husky Fridge for an average time of five days. Although we acknowledge that a ReCircle box occupies more space compared to an Alphaform box due to its circular shape, the production of the refrigerator is excluded from the system boundaries due to its long lifespan and negligible impact associated to preserving a single box. Nevertheless, the fridge electricity consumption is included because of the different boxes sizes alter the number of boxes per fridge and, consequently, energy usage per box. Regarding the microwaving process, a meal is not necessarily heated in order to be consumed. In addition, no studies found have shown a significant heating time difference between plastic and cardboard containers. Thus, heating time is assumed equal in both systems and microwaving is not considered within the system boundaries.

After consumption, the box must be cleaned before it can be reused. The cleaning process (gate-to-gate unit process) chosen a combination of 50/50 manual and professional cleaning, since the box can either be washed by hand or professionally at EPFL. The aggregated unit processes considered for these cleaning methods include the use of water, detergent, and electricity. The production of the dishwasher is not included in the system boundary of this LCA study. Given an average lifespan of 15 to 20 years [18] and daily use at EPFL for washing tablewares, the impact associated to washing a single ReCircle box is considered negligible.

Once the box is empty, the plastic film used to seal the food is discarded in a garbage bag and then transported to a landfill for incineration. The production of both the garbage bag and the bin are not included in this LCA study. This exclusion is due to the minimal volume of one film in a trash bag and the the bin’s long lifespan, making the impact associated to one plastic film insignificant.

The end-of-life process for the ReCircle box has been modeled using a recycled content approach within a closed-loop system (Fig: 2). This approach closely represents the objective life cycle of the product and emphasizes its circularity, highlighting how materials from used boxes are reused to manufacture new ones. The company shared insights on material losses during the product's life-cycle. Specifically, 3% additional raw material is required during the production process due to losses in the plastic injection phase. Then a 3% material loss occurs during the recycling process, mainly during the shredding of used plastic. These losses are accounted for in the LCA model to accurately reflect the efficiency of the closed-loop system and to identify opportunities for further improvement in material recovery and process optimization.

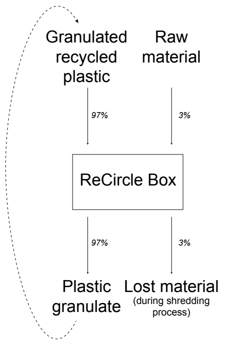


Figure 2: Recycled content approach

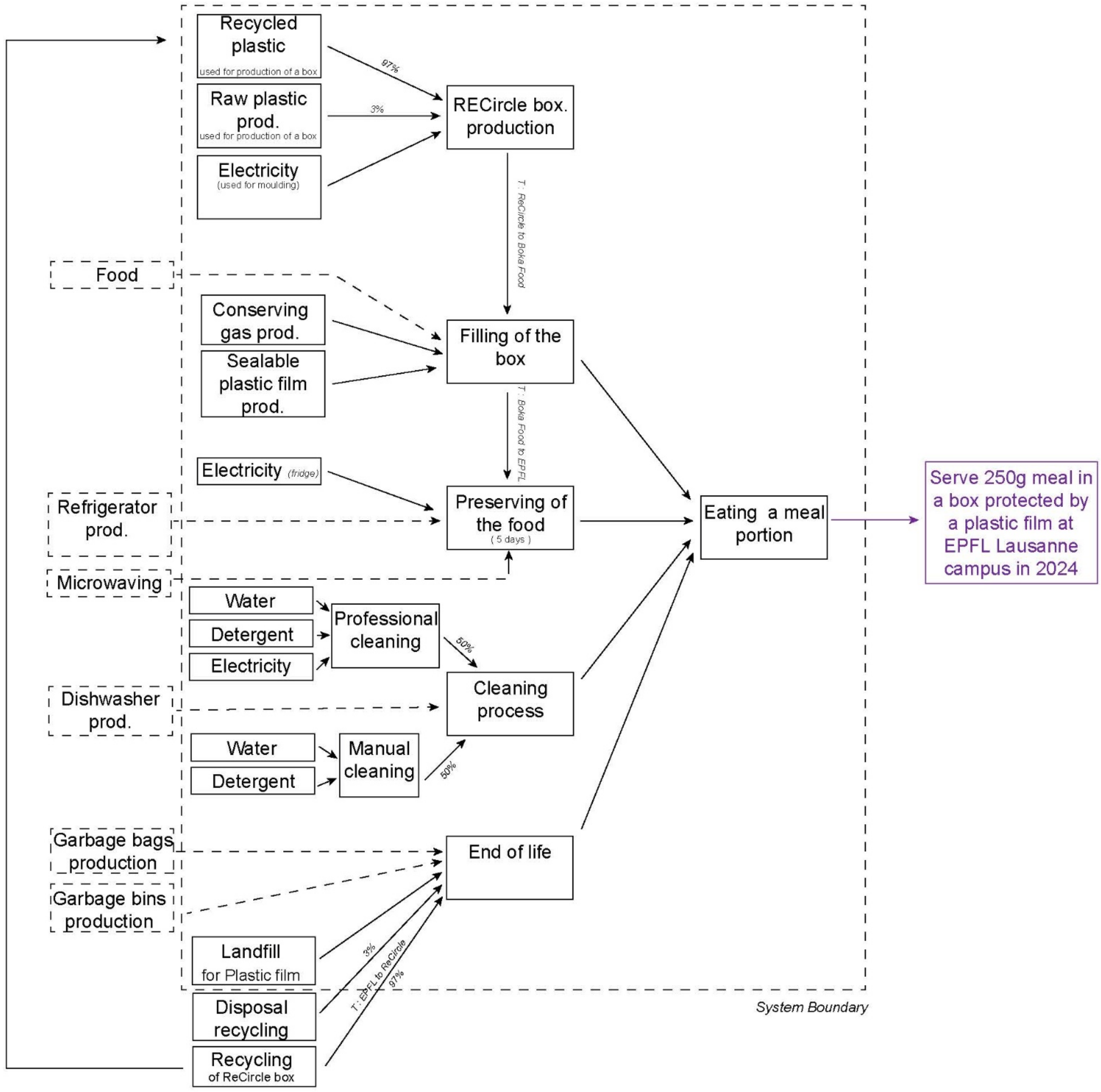


Figure 3: ReCircle Box Process Tree

8.2 Alphaform Box

The life cycle of a disposable Alphaform cardboard box (Fig: 4) starts with cradle-to-gate unit processes, including the production of the box in Beausemblant in France, using equal parts recycled and virgin cardboard, plus electricity. The produced box is then transported from Beausemblant to BOKA Food in Renens where it is filled with food and a conserving gas, and finally sealed with a plastic film. The box is then transported to EPFL campus and stored in a Husky Fridge for an average of five days. After the meal consumption, both the cardboard box and plastic film are disposed of. While one might think that there is the need to consider garbage bags since the cardboard box takes significant space, according to EPFL's guidelines [19], cardboard used for food content should be thrown away in specific containers without bags. Therefore, trash bags can be considered out of scope. Finally, the used cardboard is sent to a recycling facility in Switzerland, and the plastic film to landfill. It is assumed that the cardboard is recycled.

The fridge production, garbage bags and bin production, "food", and microwaving are considered out of scope for the same reasons as in the ReCircle process tree.

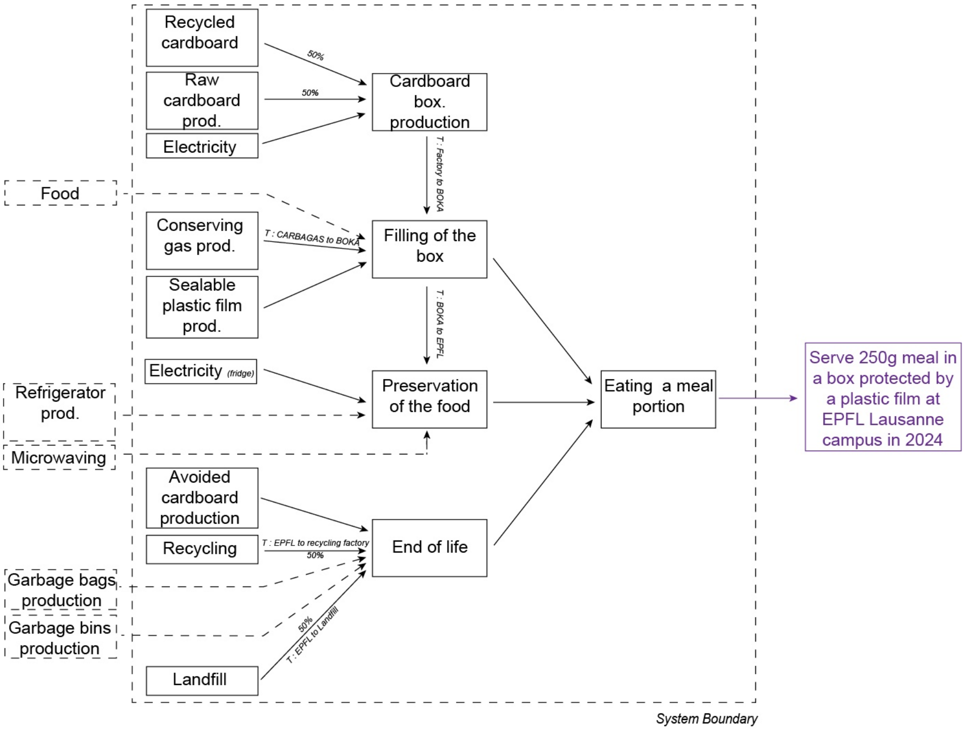


Figure 4: Process Tree of the Alphaform box

The 50/50 method ensures that half of the environmental impacts are assigned to the life cycle of the single-use box itself, and the other half are allocated to the future product systems that benefit from the recycled material (Fig 5). Therefore, this approach distributes the impact of resource consumption and waste management across multiple production and recycling stages of the product's life cycle. This method is particularly suitable for the cardboard box, since it has a high recycling rate and is often reintroduced into other product cycles [20].

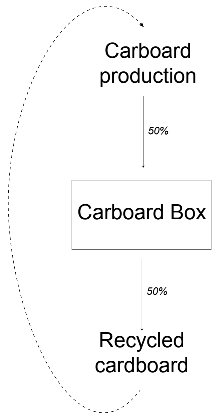


Figure 5: 50-50 recycling approach

9 Reference Flows and Key Parameters

9.1 Reference flows and Key parameters for the ReCricle box

By looking at the process tree of the ReCircle box (Fig: 3), one can see five references flows (Box production, Filling of the box, Preservation of the food, Cleaning process, and the End of life) necessary to achieve the final demand flow (Eating a meal portion). The corresponding equations for each reference flow are detailed below, some are directly calculated on OpenLCA using the Ecoinvent 3.6 database.

ReCircle Box Reference Flows		
Flow	**Formula**	**Unit / FU**
Production of the ReCircle Box		
Transportation of virgin material (Sweden) to the ReCircle manufactory	$\frac{(mass\_virgin\_material)\cdot(distance\_virgin\_material)}{number\_of\_uses}$	$8 \cdot 10^{-3}$ tkm
Transportation of the empty box ReCircle manufacorty to BOKA	$\frac{(mass\_empty\_box)\cdot(distance\_ReCircle\_BOKA)}{number\_of\_uses}$	$2,1 \cdot 10^{-4}$ tkm
Key Parameters: Distance virgin material to ReCircle: 1905 km Mass virgin material: 4.8 g of PBT Number of uses: 200 Distance ReCircle manufactory to BOKA: 263 km Empty box masse: 160g		

Box production	Plastic injection of 160 g (155.2 g of recycled plastic and 4.8 g virgin) divided by the number of uses	OpenLCA
Key Parameters: Number of uses : 200 Mass of recycled plastic: 155,2 g of the OpenLCA flow plastic granulate, unspecified, recycled (97% of the box) Tonned color: 1 g		
Preservation of the Box		
Fridge conservation at EPFL campus	$\frac{\text{daily\_consumption} \cdot \text{number\_of\_days}}{\text{number\_of\_boxes} \cdot \text{occupancy}}$	$0.416\,\text{KWh}$
Key Parameters: Number of days : 5 Number of boxes in the fridge (total capacity) : 30 Daily fridge consumption : 1,5 kWh [21] Occupancy : 60%		
Gas transportation	$\text{weight\_gas} \cdot \text{dist\_manufactory\_BOKA}$	$4.9 \cdot 10^{-4}\,\text{tkm}$
Key Parameters: Distance manufactory BOKA: 114 km Mass of the gas: 0,43 g		
Filling of the Box		
Sealing (machine) the box	$(\text{power\_sealing\_machine}) \cdot (\text{sealing\_time})$	$0.9\,\text{Wh}$
Key Parameters: Power of the sealing film machine: 1800 W [22] Time of the process: 2s		
Transportation of the filled box from BOKA to EPFL	$(\text{gas} + \text{plastic\_film} + \text{food} + \text{empty\_box}) \cdot \text{dist\_BOKA\_EPFL}$	$1,08 \cdot 10^{-3}\,\text{tkm}$
Key Parameters: Distance BOKA to EPFL: 2,6 km Mass of the gas: 0,43 g [17] Mass of the plastic film: 3,32 g Mass of the food: 250 g Mass of an empty box: 160 g OpenLCA flow for the film production: packaging film, low density polyethylene		

Cleaning Process		
Professional cleaning	$\frac{\text{electricity\_dishwasher}}{number\_of\_\text{boxes}}$	0.051 KWh
Key Parameters: Electricity of a profesional dishwasher for one cycle: 0,363 kWh [23] Number of boxes per cycle: 7 boxes		
Hand cleaning (hot tap water)	Hot tap water: OpenLCA flow heat, solora+gas, one-family house for hot water	2 L
Hand cleaning (soap)	Soap: OpenLCA flow soap	0.8 g
End of Life		
Transportation EPFL-ReCircle	$\frac{\text{empty\_box}\cdot\text{dist\_EPFL\_ReCircle}}{number\_of\_uses}$	0.42 tkm
Key Parameters: Distance EPFL to ReCircle: 262 km Number of uses : 200 Masse empty boxe : 160g		
Recycling plastic	160 g shredded plastic ; with 3% loss of material	OpenLCA
Key Parameters: OpenLCA flow : plastic granulate, unspecified, recycled		

The life cycle of this product involves several transportation flows which occur only once for a box that will be reused 200 times. Once the box is produced, it is transported from the ReCircle factory to the BOKA Food center, where it is filled with food, conserving gas, and sealed.The filled box is then delivered to EPFL. After the meal consumption and the cleaning process (at EPFL), the box is returned to BOKA Food for refilling. After 200 uses, the box is transported back to the ReCircle factory for recycling. This final transportation occurs only once in the box's lifetime.

9.2 Reference flows and Key parameters for the Alphaform box

Based on the process tree of the Cardboard box (Fig: 4), one can see four reference flows (Box production, Filling of the box, Preservation of the food, and the End of ife) required to achieve the final demand flow (Eating a meal portion). Since the cardboard box is disposable, there is no need for a cleaning process. For the end-of-life, a 50/50 method is used (see Figure 5). The corresponding equations for each reference flow are detailed below. Similar to the ReCircle box, the life cycle of the cardboard box involves multiple transportation flows.

Alphaform Cardboard Box Reference Flows		
Key Parameters	**Formula**	**Unit / FU**
Production of the Box		
Production of the Box	50% of energy needs of the production; following the 50/50 method	OpenLCA
Key Parameters: Mass of the empty box: 28,69 g OpenLCA flow : core board		
Transportation of the Alphaform box to BOKA	$\frac{1}{2} \cdot \text{weight\_Alphaform\_box} \cdot \text{dist\_manufactory\_BOKA}$	$7.88 \cdot 10^{-3}$ tkm
Key Parameters: Masse of the empty box: 28,69 g Distance cardboard manufactory to BOKA: 275 km		
Conservation of the Alphaform Box at EPFL Campus		
Fridge conservation at EPFL Campus	$\frac{\text{daily\_fridge\_consumption} \cdot \text{number\_of\_days}}{\text{number\_of\_boxes} \cdot \text{occupancy}}$	0.34 KWh
Key Parameters: Number of days : 5 Number of boxes in the fridge (total capacity) : 36 Daily fridge consumption : 1,5 kWh [21] Occupancy : 60%		
Gas transportation	$\text{weight\_gas} \cdot \text{dist\_manufactory\_BOKA}$	$4.9 \cdot 10^{-5}$ tkm
Key Parameters: Mass of the gas : 0,43g [17] Distance gas manufactory to BOKA: 114 km occupancy : 60%		
Filling of the Box		
Sealing (machine) the box	$\text{power\_sealing\_machine} \cdot \text{sealing\_time}$	0.9 Wh
Key Parameters: Power of the sealing film machine: 1800 W [22] Time of the process: 2s		
Transportation of the filled box from BOKA to EPFL	$(\text{gas} + \text{plastic\_film} + \text{food} + \text{empty\_box}) \cdot \text{dist\_BOKA\_EPFL}$	$7.3 \cdot 10^{-4}$ tkm

Key Parameters: Distance BOKA to EPFL: 2,6 km Mass of the gas: 0,43 g [24] Mass of the plastic film: 4,7 g Mass of the food: 250 g Mass of an empty box: 28,69 g OpenLCA flow for the film production: packaging film, low density polyethylene		
End of Life		
Cardboard recycling	50% ”recycled cardboard”	OpenLCA

10 Assumptions

10.1 Raw materials

The ReCircle boxes are composed of 97% recycled polypropylene granulate and 3% virgin polypropylene, based on prototype specifications provided by ReCircle. The Alphaform cardboard boxes are made from 100% recycled fibers, with production data sourced from the Ecoinvent 3.6 database assuming ”core board.”

10.2 ReCircle box

The box to be used is still in the prototype stage, and all data regarding its size, weight, and other parameters is assumed to match those of the 2M box (existing box) [25]. Another assumption is the number of uses (200), provided by the company, which is further discussed in the sensitivity analysis (see 13.1).

10.3 Transport

or ReCircle, we assume that the granulate is manufactured in central Sweden as we lack the precise location in Sweden. We assume that it is transported to Switzerland by freight lorry, where the injection molding process takes place. Similarly, we assume that the Alphaform boxes are transported from France (Beausemblant) to BOKA by freight lorry.

10.4 Amount of Food, Gas and Plastic film

We assume a standard meal portion of 250g of food for both Alphaform and ReCircle boxes, which can change, hence its impact is defined as out of scope.

For the conserving gas, both boxes use the same amount of gas (0.43g) based on typical modified atmosphere packaging (MAP) systems. This value aligns with the industry norms for food preservation [17].

The material for the plastic film is assumed to be the same for both ReCircle and Alphaform. As ReCircle is still in the prototype phase, the characteristics of the plastic film were assumed.

10.5 Cleaning Process

Since the ReCircle box can be cleaned either professionally or by hand, the LCA assumes an equal split, with 50% of the cleaning performed by hand and 50% professionally. As neither process has the highest impact across all categories, no sensitivity analysis was conducted to explore variations in these percentages.

10.6 Husky Fridges, Sealing machine and Dishwasher

Due to Husky Fridge not answering any inquiries, an energy consumption in kWh was assumed for both ReCircle and Alphaform based on the EPFL cantine manufacturer specifications [21] and typical operating conditions. As the ReCircle box has a larger volume, it is assumed that a full fridge consists of 30 ReCircle boxes and 36 Alphaform boxes.

Overall, the Swiss Energy mix was taken in OpenLCA with 15% of non-renewables. As the meal preservation significantly contributes to all impact categories, a sensitivity analysis about the fridge energy consumption was done (see 13.2).

As the final product is still in the prototype phase, the sealing is not yet determined. Therefore, an assumption is made that for both boxes the same sealing machine is used [22].

The ReCircle box is cleaned at different EPFL restaurants. After finding a Winterhalter dishwasher in a main EPFL kitchen, we assumed that all kitchen use this same dishwasher. The data (electricity, water and detergent consumption) comes from Winterhlater's techincal sheet [23].

The contribution for producing both the fridge and dishwasher has been omitted, due to their long lifetime of 15-20 years, which would minimally impact the final results. They are considered out of scope.

10.7 Garbage bins and bags

Garbage bins were considered out of scope due to their long lifespan. Garbage bags have also been excluded from the system boundaries, assuming the negligible impact associated to one plastic film, given the number of plastic films that can be held by one garbage bag. In the case of cardboard boxes, according to EPFL's guidelines [19], cardboard used for food content should be thrown away in specific containers without bags.

11 Data Sources

Most data was provided by stakeholders, some came from research papers, and gaps were filled with assumptions (see 10).

Data about the ReCircle box and its production is provided by the company and sourced from an LCA made for ReCircle [26], with values based on 200 uses. Data for the Alphaform box is based on Alphaform's documentation [27] and had to be partially assumed. Especially, the cardboard production was assumed and the "core board" was used in OpenLCA (Ecoinvent 3.6 database).

For the filling of the box, data about the conserving gas was found in [17]. Data about the sealable plastic film, and the sealing machine [22] was not provided by ReCircle or Alphaform and was therefore assumed the same for both products.

For the meal preservation, the boxes are stored in Husky Frigdes who never replied. Therefore, an average fridge consumption (of a non-intelligent fridge) was taken [21].

For the transportation of both products, the locations were provided by the relevant actors, and distances were calculated using Google Maps. Knowing the products' weights, EURO5 freight lorry data from Ecoinvent 3.6 database was used.

In the case of ReCircle, the dishwasher data is provided by EPFL cafeterias, where the professional cleaning takes place, and more specifically by the dishwasher brand technical sheet [18]. For the hand cleaning, some assumptions were made based on studies found [10].

For the end-of-life, ReCircle provided information indicating that the used plastic is shredded, recycled, and can be used to create new products. For Alphaform, a standard end-of-life scenario was assumed, with the cardboard being recycled.

Background processes, or cradle-to-grave flows, rely primarily on Ecoinvent 3.6 for material production, energy supply, transport, and waste management. Polypropylene and cardboard production data are sourced from Ecoinvent, with adjustments made for the recycled content in the ReCircle box. Electricity requirements for all processes are modeled using the Swiss electricity grid mix, except for Alphaform, where the electricity mix is based on regional Europe since the box is manufactured in France. Transportation emissions are calculated using distances derived from Google Maps and the known weight. Emission factors for transport are modeled using Ecoinvent's truck transport datasets EURO5. Gas production emissions are based on the Carbagas report [24], while waste management emissions for both boxes are modeled using standard recycling and landfill datasets from Ecoinvent.

This study incorporates data from various sources, including ReCircle, Alphaform, BOKA Food, Husky Fridges, Winterhalter (dishwashers), Carbagas (conserving gas), EPFL, and Ecoinvent 3.6 database. However, some gaps remain, such as the final design of the ReCircle box, details about the plastic film composition, and precise end-of-life recycling processes for the Alphaform box. Assumptions are made to fill these gaps (see section 10). These assumptions are explicitly documented and evaluated through sensitivity analyses to ensure transparency and strengthen the study's robustness.

12 Impact Assessment Results and Interpretation

The results presented were generated with the OpenLCA software using the Ecoinvent 3.6 database. The environmental impact assessment was conducted with the IMPACT World+ Footprint v2.0.1 method. Despite only incorporating five impact categories, these categories are sufficiently representative for the scope of this study and simplify drawing a conclusion compared to other methods with many more impact categories, such as IMPACT World+ V2.0 approach.

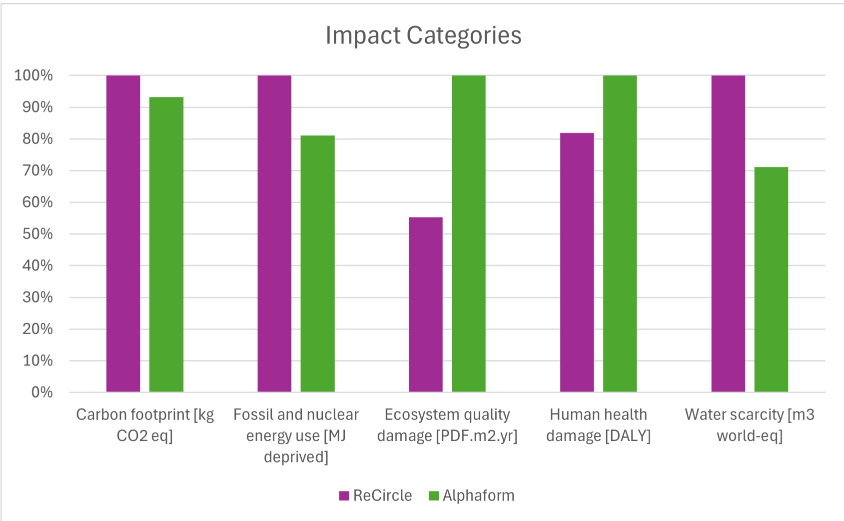


Figure 6: Impact Assessment by Impact Categories

Figure 6, shows normalized impact scores across five impact categories. A preliminary examination of the graph does not clearly indicate which solution, the reusable ReCircle box or the Alphaform cardboard box, performs better overall. The ReCircle box shows lower environmental impacts in two impact categories (Ecosystem quality damage, Human health damage), whereas the Alphaform box performs better in three impact categories (Carbon footprint, Fossil and nuclear energy use, Water scarcity).

In terms of carbon footprint, the two boxes perform almost the same, (less then 10% difference). However, the ReCircle box has a slightly higher impact in terms of fossil and nuclear energy use. This higher impact is attributed to the sourcing of virgin materials from Sweden, which incurs significant transportation impacts. Additionally, the energy-intensive injection plastic molding process used for the ReCircle box and the higher energy required for refrigeration due to its larger volume compared to the Alphaform box, contribute to this result. The ReCircle box also performs worse in terms of water scarcity. This is due to the water necessary for the cleaning process, both by hand or professional, which does not exist in the Alphaform box life cycle.

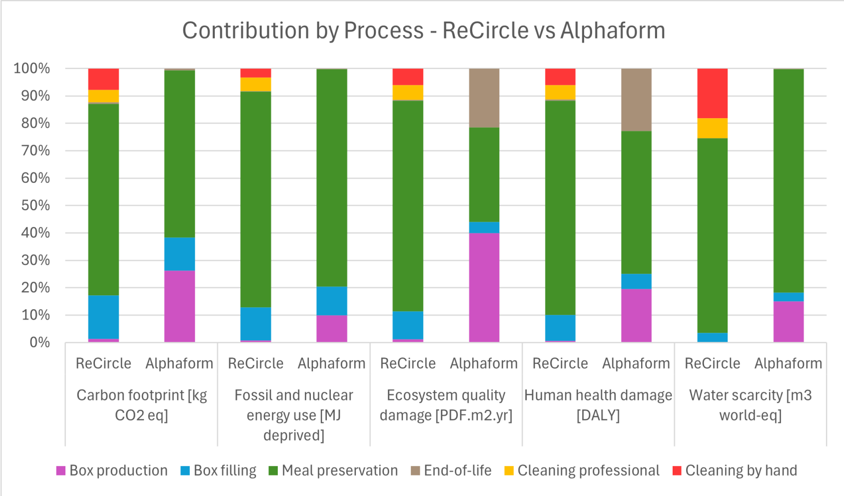


Figure 7: Impact Assessment - Contribution by Process for ReCircle and Alphaform

Conversely, the Alphaform box has a higher impact in terms of ecosystem quality damage. This is likely related to the cardboard box production and recycling. In fact, the production of cardboard, more specifically, core board production was selected in OpenLCA, includes deforestation, land use, and pulp processing. The latter is the industrial process of turning wood into pulp, the primary material to produce core board. This process often involves chemicals to break down wood chips [28]. Land use changes and toxic emissions are factors measured in this impact category [29].

The Alphaform box also performs worse in the human health damage impact category, for similar reasons as for the ecosystem quality damage impact category. This impact category measures the impact of toxic emissions, pollutants, and other environmental stressors on human health, which are involved in the cardboard production process, necessary for the box production.

Upon examining the impact categories, Figure 7 displays the contribution by process for every impact category. It was noticed that the most contributing process across every impact category and for both ReCircle and Alphaform, is the meal preservation, except for ecosystem quality damage for Alphaform where the box production contributes slightly more. An explanation for this is due to an assumption, where an average duration of five days is taken during which the meal is preserved in a fridge. Compared to other processes, such as the box production or the end-of-life for ReCircle that happens once for 200 uses, or the filling that happens once for each use of an Alphaform or ReCircle box, the meal preservation is an impactful process since the fridge requires continuous electricity use for five days.

By interpreting the results from Figure 6, it was assumed that the production of the ReCircle box significantly affected the fossil and nuclear energy use impact category. However, Figure 7 reveals a minimal contribution from box production for this impact category. This is because of the high number of uses. Therefore, despite producing one ReCircle box has a higher impact than producing one Alphaform box in this impact category, by dividing this impact by 200, the number of uses, the impact per use significantly decreases. Instead, the predominant contributor to the fossil and nuclear energy use impact category is the meal preservation. Preserving the meal in a fridge requires a lot of electricity. Despite the Swiss electricity mix incorporating only 15% of non-renewable energy sources, the continuous operation of the fridge over multiple days leads to a considerable impact.

In the case of Alphaform, the box production process consistently shows higher contributions across all impact categories compared to ReCircle. This is due to the single-use nature of the Alphaform box compared to the reusable nature of the ReCircle box, which significantly decreases the impact associated to a single use of the box.

For the water scarcity impact category, the meal preservation process is once again the largest contributor for both ReCircle and Alphaform boxes, possibly due to the water used for the cooling of the fridge. In the case of Alphaform, the box production also contributes significantly since producing cardboard is a very water-intensive process. Water is used both in the pulping process and for washing the fibers [28].

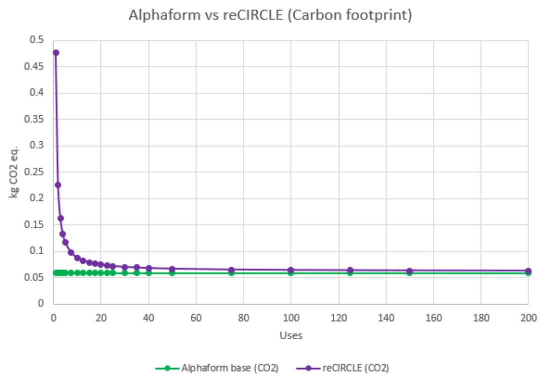
Cleaning processes, both by hand or professionally, only contribute for ReCircle since there is no cleaning process involved in the Alphaform box life cycle. Cleaning by hand requires more detergent and more water than cleaning professionally. The contribution in the carbon footprint and the fossil and nuclear energy use, is explained by the need to heat the water when cleaning by hand, and the electricity required by the dishwasher when cleaning professionally. Although there is a higher impact in terms of water for the cleaning by hand process, the professional cleaning has in general a lower impact in all categories. Therefore, customers should be encouraged and aware to avoid cleaning the ReCircle box at home.

Lastly, the contribution of the end-of-life process to impact categories is almost invisible for ReCircle. Once again, the end-of-life happens once in the life cycle of a ReCircle box used 200 times, and the circularity of the materials are highlighted. However, that is not the case for Alphaform, where the end-of-life process contributes to ecosystem quality damage and human health damage impact categories, due to the combustion of the landfilled waste.

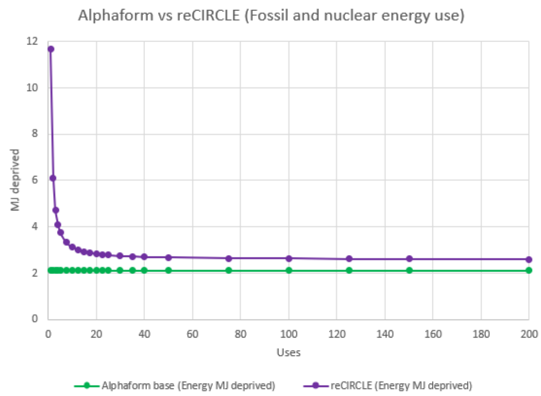
13 Sensitivity and Scenario Analyses

13.1 Number of uses of a ReCircle box

The first sensitivity analysis examines the break-even point for how many times a ReCircle box needs to be reused to match the environmental impact of a single-use Alphaform box. While the Alphaform box is single-use, the ReCircle box benefits in terms of environmental impact are only present if it is reused a sufficient number of times to offset the impacts of its production and end-of-life. Factors like premature breakage or loss by consumers could affect the results, making this parameter a key focus of the analysis.



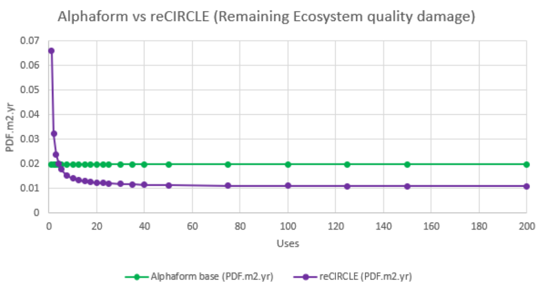
(a) Sensitivity of carbon footprint on number of uses



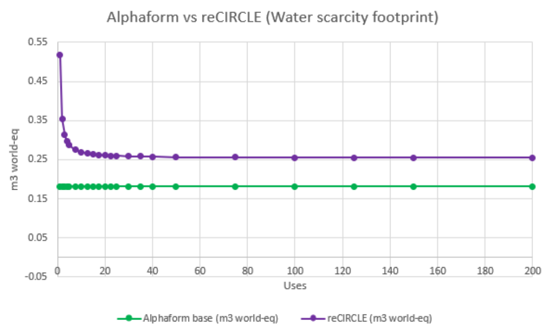
(b) Sensitivity of fossil and nuclear energy use on number of uses

Figure 8: Sensitivity of carbon footprint and fossil and nuclear energy use on number of uses

Figure 8a and Figure 8b show the carbon footprint and fossil and nuclear energy use of ReCircle and Alphaform over number of uses. For Alphaform, the impacts remain constant as it is single-use, while ReCircle can be used up to 200 times, depending on consumer behavior. For carbon footprint, the ReCircle box matches Alphaform's impact after about 50 uses. Beyond this point, the ReCircle impact curve flattens because the higher initial impacts from production and end-of-life are offset. The remaining impact comes mainly from cleaning, which stays constant and cannot be further reduced per use. Since the professionnal is lower, costumer should be aware not to clean at home the box. The impact For fossil and nuclear energy use, the ReCircle impact remains slightly higher even with up to 200 uses, likely due to higher fridge energy consumption required per box compared to Alphaform.



(a) Sensitivity of ecosystem damage on number of uses



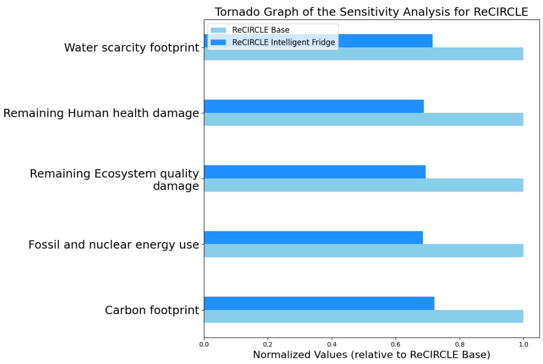
(b) Sensitivity of water scarcity on number of uses

Figure 9: Sensitivity of ecosystem quality damage and water scarcity on number of uses

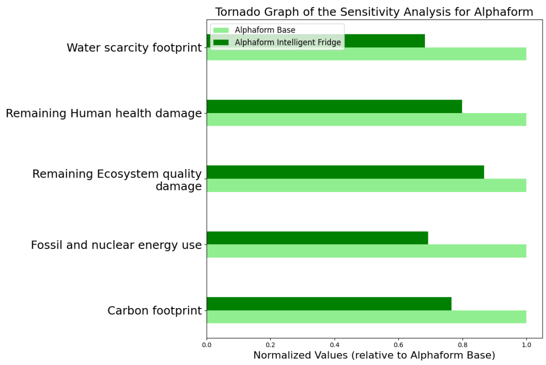
Similarly, Figure 9a and Figure 9b shows the Ecosystem quality damage and Water scarcity impacts of ReCircle and Alphaform over number of uses. For Ecosystem quality damage, the ReCircle box breaks even after just 6 uses, mainly due to the high impact of cardboard production, as explained in Section 12. However, for water scarcity, the ReCircle box has a significantly higher impact even after offsetting the initial higher impact from production and end-of-life, primarily due to the cleaning process.

13.2 Fridge energy consumption for box preservation

Through the impact assessment results, it is observed the meal preservation is the most contributing process through all impact categories. Indeed, it represents 70% of the carbon footprint of the ReCircle box and 61% of the cardboard box. Assumptions were made for this part. BOKA uses Husky intelligent fridges that adjust energy use based on the occupancy percentage. However, this data were never received from the company Husky Fridges about their energy consumption data. Therefore, an average value for regular fridges of 1.5kWh of electricity per day [21] was applied. Considering an average fridge occupancy of 60%, intelligent fridges are assumed to use 60% of the electricity of regular fridges. For these reasons, it makes sense to conduct a sensitivity analysis on the energy consumption of fridges used for meal preservation.



(a) Sensitivity of the meal preservation in a ReCircle box



(b) Sensitivity of the meal preservation in an Alphaform box

Figure 10: Sensitivity of fridge energy consumption for meal preservation

The results clearly shows that using intelligent fridges has a positive effect, reducing impacts to at least 70% of the original values. This impact is more significant for ReCircle boxes, as the preservation process contributes more to their overall impact compared to Alphaform boxes. As a result, changes in the meal preservation process are more noticeable. For ReCircle boxes, reducing fridge electricity consumption can lower impacts by 25–30% across all impact categories. A similar effect is seen for Alphaform boxes, but the reductions are less pronounced.

14 Uncertainties and Limits of the Study

14.1 Uncertainties

The main uncertainties rely on the assumptions made to conduct the LCA of each product (see section: 10). The fact that the assumptions exist impacts the reliability of the study as well as the interpretation of our results. An important uncertainty is also the final product created by ReCircle as for the moment only a prototype has been produced and the final form of the reusable container, and so its total impact is yet unknown, as its final size and shape. Furthermore, the impact assessment relies on various processes from the Ecoinvent database, which are general and may not fully match the specifics of our product systems, leading to potential inconsistencies.

14.2 Limitations

The main limitation is the break-even point of the reusable box. The single use container is assured to be used only once while the reusable container should be used 200 times based on information provided by ReCircle. In reality, the ReCircle box could be broken or lost much earlier, changing significantly its environmental impact. The simplification of the consumer behavior is one of our most important limitations as every box cannot be tracked. Other limitations can be found in the fact that not every process can be represented within Ecoinvent, or due to a lack of data. To simplify the LCA, a cut-off needs to be chosen to remove the non essential processes (as the production of garbage bags and bins, fridge, and dishwasher) from the LCA. While being mandatory to assure the feasibility of the project, these omissions could have a cumulative environmental impact. Because of these limitations, the sensitivity analysis is necessary as it takes into account the variability due to real-life conditions and increases the robustness of the study.

14.3 Data quality assessment

Based on Section 11, a data quality table has been created, see Figure 11. The reliability for both products is overall on the lower scale. Although the data collected from the companies is considered highly reliable, many assumptions had to be made. Not only for the production processes, but especially for the meal preservation, which is the largest contributor across all impact categories. The representativeness, is overall good, apart from production of Alphaform and end-of-life ReCircle. For Alphaform, the exact production steps are unknown. For ReCircle, the end-of-life may not be fully representative as there are some uncertainties even from ReCircle about the use of the shredded plastic. Currently, in Switzerland, reusing materials for food packaging is supervised by law, and the ReCircle compagnie is not validated at this time, [30]. Since the OpenLCA cannot be done on a product missing the end-of-life, this part incorporates assumptions.

Alphaform	Data quality		Contribution	Collection
Process	Reliability	Representativeness		
Production	3	4	26.20%	–
Filling	2	1	12.11%	+
Preservation	3	3	61.10%	-
End-of-life	2	2	0.58%	-

(a) Data quality assessment for Alphaform

reCIRCLE	Data quality		Contribution	Collection
Process	Reliability	Representativeness		
Production	3	3	1.35%	--
Filling	2	1	15.83%	+
Preservation	3	3	69.97%	-
Cleaning	1	2	12.25%	+
End-of-life	4	5	0.59%	-

(b) Data quality assessment for reCIRCLE

Figure 11: Data quality assessment for both products

15 Recommendations

The results of this Life Cycle Assessment (LCA) revealed that the ReCircle box is not currently the most environmentally friendly option across different impact categories. However, based on the assumptions made and sensitivity analyses conducted, several measures can be implemented to improve its ecological performance.

- **Smaller ReCircle boxes to reduce energy consumption**: Designing smaller ReCircle boxes would optimize fridge space utilization, thereby reducing electricity consumption per box for meal preservation. Since the box is not yet commercialized, this is a practical recommendation to propose to the producers during the development phase.

- **Improve the cleaning method of ReCircle boxes**: A main difference between the two boxes is the cleaning impact of the ReCircle box. Indeed, it represents at least 10% of the impact through all categories. For the water scarcity footprint (Figure 9b), the cleaning process for each use of the box is the reason why the ReCircle box underperforms compared to the cardboard box in this impact category even for a very large number of uses. To address this, the food cantine in charge of the cleaning process at EPFL, should explore ways to improve the water and energy consumption of the dishwashers, by making sure it doesn't increase their production pollution or decrease their lifespan. Also customer should be aware not to clean at home their ReCircle box.

- **Transition to a fully renewable electricity mix at EPFL**: EPFL's plan to shift to a fully renewable electricity mix [31] will significantly reduce the environmental impact of meal preservation, further enhancing the sustainability of the ReCircle box. Additionally, the European energy mix data used in the analysis is from 2014-2017 and includes 85%

renewable energy, which is not fully reflective of the current situation. Updating these assumptions with accurate data, would likely show further benefits of using renewable energy sources.

Currently, the reusable ReCircle box is not fully recommended as a better option than the Alphaform cardboard box. However, by following these recommendations, the ReCircle box could become the more environmentally friendly solution and be adopted by BOKA Food for serving meals on the EPFL campus while also meeting EPFL's requirement to eliminate single-use lunch boxes.

16 Conclusion

The main objective of this study was to assess which box, between a reusable ReCircle box and a single-use Alphaform cardboard box, has the lower environmental impact, to then inform EPFL about the findings so that they can proceed with the introduction of additional meals in vending machines (fridges). This comparative LCA has been conducted using the following FU : "Serve a 250g meal in a box protected by a plastic film at EPFL Lausanne campus in 2024". The two product systems were modeled in OpenLCA using the Ecoinvent 3.6 database, along with data from companies and studies. The impact of each box was assessed and compared across five impact categories from the IMPACT World+ Footprint v2.0.1 method : carbon footprint, fossil and nuclear energy use, human health damage, ecosystem quality damage and water scarcity.

The main findings show that the ReCircle box has a significant higher initial impact from production and end-of-life, which is offset after about 50 uses. After that, it outperforms the Alphaform box, particularly in terms of ecosystem quality damage and human health damage. However, it still has higher impacts per use in water scarcity due to the cleaning process and in fossil and nuclear energy use because of the higher fridge energy consumption needed to preserve a ReCircle box compared to an Alphaform box.

The ReCircle box shows great potential. Since it is still in the prototype phase, we recommend that ReCircle make a slightly smaller box to match the size of the Alphaform box and reduce the fridge energy consumption for its preservation. Additionally, as EPFL plans to transition to a fully renewable energy mix, this can contribute to lowering the impact of the meal preservation and of the electricity required by the dishwasher in the professional cleaning for ReCircle.

While some assumptions were made and the results are not entirely robust, they can serve as a basis for an initial decision on which box to use to serve meals in the upcoming vending machines on the EPFL campus.

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17 Appendix

17.1 Key parameters and Reference flows

Process tree	Key parameters	Alphaform	reCIRCLE
Transport	Mass (g)	14.345	160
Transport	Distance to reCIRCLE (t*km)	-	9.12E-04
Transport	Distance to BOKA (t*km)	7.88E-03	-
Transport	Distance to BOKA (t*km)	-	3.34E-03
Transport	Distance to EPFL (t*km)	1.09E-03	1.09E-03
Transport	Distance to landfill (t*km)	1.00E-03	-
Transport	Distance to recyling (t* km)	-	3.34E-03
Popypropylene	From openLCA (g)	-	4.2
Injection moulding	From openLCA (g)	-	160
Toner colour	From openLCA (g)	-	1
Core board	From openLCA (g)	28.69	-
Conserving gas	From openLCA (m3)	3.00E-04	3.00E-04
Packaging film	From openLCA (item)	1	1
Cleaning hand: Detergent	From openLCA (g)	-	0.8
Cleaning hand: Tap water	From openLCA (kg)	-	2
Cleaning hand: Heat	From openLCA (kWh)	-	0.07
Cleaning pro: Detergent	From openLCA (g)	-	0.2
Cleaning pro: Tap water	From openLCA (kg)	-	0.31
Cleaning pro: Power	From openLCA (kWh)	-	0.051
End-of-life	Uses	-	200
End-of-life	Recycling potential (%)	0	97%

Figure 12: Key parameters in openLCA

17.2 LCA results in absolute values

Impact Category	**Reference Unit**	**Result**
PDF.m^2.yr		
Climate change, ecosystem quality, long term	PDF.m^2.yr	0.003878138
Climate change, ecosystem quality, short term	PDF.m^2.yr	0.010648259
Freshwater acidification	PDF.m^2.yr	0.001199895
Freshwater ecotoxicity, long term	PDF.m^2.yr	0.009043098
Freshwater ecotoxicity, short term	PDF.m^2.yr	0.000386653
Freshwater eutrophication	PDF.m^2.yr	0.100897045
Marine acidification, long term	PDF.m^2.yr	0.000759202
Marine acidification, short term	PDF.m^2.yr	0.000068955
Marine eutrophication	PDF.m^2.yr	0.000825045
Land occupation, biodiversity	PDF.m^2.yr	0.000769502
Land transformation, biodiversity	PDF.m^2.yr	0.003252859
Water availability, freshwater ecosystem	PDF.m^2.yr	0.007021379
Water availability, terrestrial ecosystem	PDF.m^2.yr	0.180156106
DALY		
Climate change, human health, long term	DALY	1.53812E-07
Climate change, human health, short term	DALY	4.93932E-06
Human toxicity cancer, long term	DALY	1.59662E-10
Human toxicity cancer, short term	DALY	1.39336E-08
Human toxicity non-cancer, long term	DALY	1.52998E-09
Human toxicity non-cancer, short term	DALY	1.18986E-08
Ionizing radiation, human health	DALY	1.95559E-09
Ozone layer depletion	DALY	2.55273E-11
Photochemical oxidant formation	DALY	7.96972E-12
Other Units		
Fossil and nuclear energy use	MJ deprived	1.95030632
Ionizing radiation, ecosystem quality	Bq C-14 eq	3.93119E+12

Table 3: Impact categories by reference unit for Alphaform

Impact Category	Reference Unit	Result
PDF.m^2.yr		
Climate change, ecosystem quality, long term	PDF.m^2.yr	0.03627227
Climate change, ecosystem quality, short term	PDF.m^2.yr	0.01144687
Freshwater acidification	PDF.m^2.yr	0.00057694
Freshwater ecotoxicity	PDF.m^2.yr	19.5414485
Freshwater ecotoxicity, long term	PDF.m^2.yr	0.010423781
Freshwater ecotoxicity, short term	PDF.m^2.yr	0.000108049
Freshwater eutrophication	PDF.m^2.yr	4.971E-05
Marine acidification, long term	PDF.m^2.yr	0.000594839
Marine acidification, short term	PDF.m^2.yr	0.000059198
Marine eutrophication	PDF.m^2.yr	0.7157E-06
Land occupation, biodiversity	PDF.m^2.yr	0.00055917
Land transformation, biodiversity	PDF.m^2.yr	0.00319549
Water availability, freshwater ecosystem	PDF.m^2.yr	0.00371617
Water availability, terrestrial ecosystem	PDF.m^2.yr	0.10369482
DALY		
Climate change, human health, long term	DALY	1.58154E-07
Climate change, human health, short term	DALY	6.15831E-05
Human toxicity cancer, long term	DALY	6.679E-10
Human toxicity cancer, short term	DALY	1.7727E-08
Human toxicity non-cancer, long term	DALY	1.7748E-08
Human toxicity non-cancer, short term	DALY	1.1938E-08
Ionizing radiation, human health	DALY	2.4914E-09
Ozone layer depletion	DALY	3.066E-11
Photochemical oxidant formation	DALY	6.9945E-12
Other Units		
Fossil and nuclear energy use	MJ deprived	2.66170556
Freshwater eutrophication	kg PO_4 P-lim eq	1.3571E-05
Ionizing radiation, ecosystem quality	Bq C-14 eq	1.18639E+07
Land transformation, biodiversity	m^2 arable land eq	1.9695E-05
Particulate matter formation	kg PM2.5 eq	2.3447E-05
Mineral resources	kg deprived	0.00885165
Water scarcity	m^3 world-eq	0.18015161

Table 4: Impact categories by reference unit for reCIRCLE

17.3 Ecoinvent processes

Processes
injection moulding — injection moulding — Cutoff, S - RER
polypropylene production, granulate — polypropylene, granulate — Cutoff, U - RER
toner production, colour, powder — toner, colour, powder — Cutoff, S - GLO
market for transport, freight, lorry 3.5-7.5 metric ton, EURO5 — transport, freight, lorry 3.5-7.5 metric ton, EURO5 — Cutoff, S - RER
market for electricity, low voltage — electricity, low voltage — Cutoff, S - CH
packaging film production, low density polyethylene — packaging film, low density polyethylene — Cutoff, S - RER
heat production, at hot water tank, solar+gas, flat plate, one-family house — heat, solar+gas, one-family house, for hot water — Cutoff, S - CH
soap production — soap — Cutoff, S - RER
market for tap water — tap water — Cutoff, S - CH
Sealable plastic film production - CH

Table 5: Processes from Ecoinvent used for reCIRCLE box

Processes
core board production — core board — Cutoff, S - RER
market for transport, freight, lorry 16-32 metric ton, EURO5 — transport, freight, lorry 16-32 metric ton, EURO5 — Cutoff, S - RER
municipal waste collection service by 21 metric ton lorry — municipal waste collection service by 21 metric ton lorry — Cutoff, S - CH
market for electricity, low voltage — electricity, low voltage — Cutoff, S - CH
packaging film production, low density polyethylene — packaging film, low density polyethylene — Cutoff, S - RER
Sealable plastic film production - CH

Table 6: Processes from Ecoinvent used for Alphaform box