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Environmental and Techno-economic Assessment of Edible Packaging

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Rialtas na hÉireann
Government of Ireland

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2. Office of Environmental Enforcement
3. Office of Evidence and Assessment
4. Office of Radiation Protection and Environmental Monitoring
5. Office of Communications and Corporate Services

The EPA is assisted by advisory committees who meet regularly to discuss issues of concern and provide advice to the Board.

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Identifying pressures

Single-use disposable cups are a major feature of daily lives in Ireland. The time-saving and portability benefits, as well as an overall growing demand for coffee, have increased their usage significantly. It is estimated that 550,000 cups per day are used in the Irish market alone, and this could increase to an annual total of 300 million cups per year by 2025. Although there is a common perception among consumers that paper cups are recyclable, and thus a sustainable option, this is not necessarily true. These cups are lined with plastic, which is difficult to separate from the paper, and most paper cups are sent to residual waste streams for landfill or incineration. Disposable cups also make up a significant portion of litter. Reusable cups are an important part of the solution but may not be practical in all situations. Hence there is strong interest in the concept of edible packaging that could avoid littering and waste management burdens.

Informing policy

EAT-Packaging undertook a life cycle assessment across a range of relevant cup types and pertinent scenarios to identify where, when and how edible cups (or alternative options) could reduce environmental impact for the functional unit of a cup containing a single drink of coffee.

Edible cups are not a panacea and can have a higher environmental impact than conventional single-use cups. However, in the right situations, edible cups can be the lowest impact option. It may be appropriate to promote edible cups carefully in situations where they are likely to displace disposable cups, reduce littering and substitute other snacks. Promising scenarios identified by stakeholders include outdoor festivals, mobile markets, schools, cruise ships and beach cafes. Deployment in schools could play a dual educational role and encourage wider behaviour change. The comparatively high price of edible cups suggests that marketing them as a combined cup and snack could be an important strategy.

Developing solutions

Results from the techno-economic and life cycle assessments of various cup types support the following recommendations:

- Policymakers could increase efforts to encourage widespread and repeated use of reusable cups.
- Rinsing cups with cold water after each use, combined with a periodic full wash (in a dishwasher), minimises impact from an energy and environmental standpoint.
- Further clarity is needed to determine the status of edible cups from a regulatory perspective; specifically, whether they need to comply with both food and packaging regulations. Appropriate guidelines on transparent labelling will be needed.
- Clear guidelines are also needed to ensure sanitary handling measures at point of sale of edible cups, to avoid cross-contamination affecting consumers.
- Brown bins could be easily accessible at sales locations so that consumers can appropriately dispose of uneaten edible cups (the next best disposal options from an environmental perspective are animal feed, anaerobic digestion or composting).

EPA RESEARCH PROGRAMME 2021–2030

Environmental and Techno-economic Assessment of Edible Packaging

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by

University of Limerick

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The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

The increasing use of disposable takeaway coffee cups, and associated problems of littering and environmental impact, is driving interest in innovations such as edible packaging. Edible packaging is intended to generate no waste, as it can be consumed after serving its packaging purpose. The Environmental And Techno-economic assessment of edible Packaging (EAT-Packaging) project evaluated the techno-economic and environmental potential of edible coffee cups and benchmarked them against the main types of existing disposable and reusable cups.

Life cycle assessment quantifies the environmental impact of a product across its whole life cycle, from raw material extraction to disposal, and was conducted in this project using a functional unit of a single cup use for a small (*c.*100–200 ml) coffee. Across most impact categories, edible cups had the highest impact and reusable cups the lowest. Under default assumptions, per cup use, climate change burdens ranged from 0.003 to 0.078 kg CO_2 equivalent, eutrophication burdens ranged from 5.9×10^{-6} to 2.6×10^{-4} kg N, fossil resource depletion burdens ranged from 0.044 to 0.44 MJ and water depletion burdens ranged from 0.002 to 0.258 m^3. A separate littering metric was also applied to all cup types; edible cups scored well here, second only to stainless steel reusable cups, while polystyrene cups (now banned in Ireland) performed worst.

The large burdens for edible cups can be attributed to crop cultivation, land use change emissions from cocoa bean production and electricity usage during cup manufacturing. Sensitivity analyses indicate that results for edible cups were sensitive to assumptions about whether they are eaten after use or disposed of via other end-of-life streams. If edible cups are eaten after use *and* consequently substitute for a snack made from similar ingredients (e.g. a chocolate biscuit), then they may in fact have a negligible environmental impact and be the best environmental option. However, this is unlikely to be the average situation (in the default analysis, it was assumed that 50% of cups are eaten; more research is needed to understand consumer use of such cups).

Meanwhile, environmental hotspots arise during the use phase of reusable cups, specifically during washing. The number of times cups are reused and whether cups are washed in a dishwasher or by hand (using cold or hot water) significantly influence the environmental performance of reusable cups. This highlights the importance of consumer behaviour, although the environmental superiority of reusable cups over other cup types is robust to the aforementioned variations. For example, reusable cups made from polypropylene need to be used only 12 times for their climate change burden to be lower than that of the other cup types.

Edible cups are currently expensive, retailing at €0.42–€5.54 per cup versus €0.07–€0.33 per paper cup and a per use normalised price of €0.04–€0.07 for a polypropylene reusable cup. Prices could fall if edible cups become mainstream, and do include the cost of a possible snack in the cup itself. A stakeholder workshop was held to explore wider opportunities for, and barriers to, the use of edible and reusable cups. Participants included coffee cup suppliers in the UK and Ireland, environmental awareness officers, policymakers and representatives from waste management and non-profit organisations. The numerous barriers identified included the need to enhance the taste and increase the shelf life of edible cups. Crucially, the lack of lids on edible cups makes them impractical as a takeaway option in many situations. It was concluded that further research and development would be required to make edible coffee cups a commercially feasible and scalable sustainable option. Possible niche roles for edible cups may include situations where reusable cups are inconvenient and where littering (of disposable cups) is a particular problem, e.g. festivals, mobile markets, schools, travel hubs and beach cafes.

Overall, the results of this study reinforce the environmental superiority of reusable cups. Although such cups may not be practical in all situations, there could be a useful niche role for edible cups, in particular to reduce littering at outdoor events, beaches and travel hubs. In such situations, and more generally if edible cups can be deployed as a genuine cup-plus-snack option, they could play a modest role in a shift towards more sustainable coffee consumption.

1 Introduction

As the use of convenience and takeaway products grows, single-use disposable cups (SUDCs) are a major feature of daily life in Ireland. The perks of saving time and the ease of carrying coffee in workplaces, and also a growing demand for coffee, have increased their usage significantly. It is estimated that presently 200 million cups per year are used in the Irish market alone, and this could increase to a total of 300 million cups per year by 2025 (EnvEcon, 2022). Although there is a common perception among consumers that paper cups are recyclable, and thus a sustainable option, this is not necessarily true. Paper cups are lined with plastic to hold the coffee without tearing the cup (van der Harst and Potting, 2013; Foteinis, 2020). This layer of plastic is difficult to separate from the paper part, making the cup recycling process challenging (Foteinis, 2020). According to MyWaste (2018), although many disposable cups display the recyclable logo, such cups are typically not recyclable in Ireland and are often sent to the residual waste stream for landfill or incineration. The logo usually relates to the plastic lid and/or cardboard sleeve, which may be more easily recyclable. Disposable cups are also the source of significant littering in different environments, including on beaches, worldwide (Ocean Conservancy, 2011). The presence of such visible items of litter could even beget further littering (House of Commons, 2017).

Most disposable coffee cups are paper and plastic based (van der Harst and Potting, 2013). The problem of plastics is well known: the material can remain in the environment for a long time after its intended use (Andrady, 2011). Depending on how plastic waste is managed, it may pose a significant threat to the environment and contribute to climate change (Hamilton and Feit, 2019; Da Costa *et al*., 2020). To curb the problem of plastics, several measures and initiatives have been developed, such as bans on plastic bags, beach clean-ups and awareness campaigns, and more comprehensive strategies, such as the EU plastics strategy adopted in January 2018 (Haider *et al*., 2019). This strategy aims to "transform the way plastic products are designed, produced, used, and recycled in the EU" towards more sustainable production and consumption patterns (European Commission, 2018). One of the most notable components of this strategy is Directive (EU) 2019/904, or the Single Use Plastics Directive, which places significant restrictions on the sale and design of numerous plastic products, including packaging. Compostable plastics are a new generation of plastics generally derived from renewable raw materials such as starch, cellulose, soy protein and lactic acid. The American Society for Testing and Materials (ASTM) defines compostable plastic as plastics "capable of undergoing biological decomposition in a compost site as part of an available program, such that the plastic is not visually distinguishable and breaks down to carbon dioxide, water, inorganic compounds, and biomass, at a rate consistent with known compostable materials (e.g. cellulose) and leaves no toxic residue" (Akinola *et al*., 2014). Although bio-based plastics represent an attractive option, it has been shown that the overall environmental burden of bio-based materials can sometimes be greater than that of their conventional alternatives (Bishop *et al*., 2021). This is because of factors such as the need for significant non-renewable inputs in their production, including fertilisers and energy, and land use change associated with increased demand for arable crops.

According to the United Nations Environment Programme (UNEP, 2021) and research and consultancy group EnvEcon (2022), reusable cups are a more sustainable option than disposable cups depending on some conditions, such as washing practices and number of reuses. These studies also indicate that reusing a cup at least 10–20 times results in a lower environmental impact than using a disposable cup. To reduce the consumption of SUDCs and encourage the use of reusable cups throughout Ireland, a levy of €0.20 per SUDC has been proposed for hot beverages. The revenue generated from this levy will be directed to a circular economy fund for environmental initiatives. Similar to the plastic bag levy, the levy will be introduced, reported on and collected via the existing value-added tax (VAT) system, and should be charged at the point of sale of the coffee. This levy may provide an incentive for consumers to bring their own coffee cups to cafes, thus reducing waste and shifting consumer behaviour towards more sustainable (circular) practices. However, reusable cups may not be practical in all situations, and an increase in their use relies on consumer behaviour change. There is scope for more innovation in the packaging sector, especially in situations where it is not feasible to use reusable cups because facilities for cleaning and carrying the cups are unavailable.

There is increased interest in the development of innovative materials for packaging, such as edible packaging. Edible packaging typically consists of a biodegradable material that is used as a wrapping or coating around the food and can be consumed, and hence generates no waste (Petkoska *et al*., 2021). Edible packaging "protects food from outside influence and damage, contains the food, and increases convenience" (Marsh and Bugushu, 2007). It has been claimed that, alongside reducing waste, edible packaging could aid in maintaining food quality, extending shelf life and reducing costs (Petkoska *et al*., 2021). While there is currently strong interest in assessing the environmental impact of edible packaging, the focus of previous literature appears quite narrow, relating mainly to edible coatings and films that are typically less than 0.3 mm thick.

The objective of the Environmental And Techno-economic assessment of edible Packaging (EAT-Packaging) project was to gain an understanding of the potential environmental and techno-economic performance of edible packaging. An environmental impact evaluation through a life cycle assessment (LCA) and techno-economic analyses was undertaken to benchmark edible cups against mainstream coffee cup types in different situations. A workshop was also held with key stakeholders to gain more insight into consumer behaviour and deployment opportunities for and barriers to edible cup use in Ireland.

2 Methodology

2.1 Life Cycle Assessment Goal and Scope

LCA is a comprehensive tool used to calculate the environmental impact of a product over its entire life cycle. LCA helps to analyse the contribution of different life cycle stages to particular impacts, highlights possible burden shifting from one impact to another, and enables comparison across different products or services delivering the same functional value (Curran, 2015; Goedkoop *et al*., 2016). It is particularly useful in identifying and quantifying improvement opportunities for specific products. There are two main LCA approaches, namely attributional modelling and consequential modelling. The former approach is carried out when the overall environmental impacts of a product and environmental hotspots in its life cycle need to be known. The latter approach is employed when the consequences of a change compared with a baseline situation need to be investigated (Goedkoop *et al*., 2016).

In this study, a comparative attributional LCA of edible cups and other disposable and reusable coffee cups was conducted using OpenLCA version 1.10 software. The goal of the LCA was to identify the environmental hotspots of edible cups and to compare their environmental burden with that of mainstream cup types.

The functional unit for the LCA was the single use of a coffee cup for the consumption of one hot coffee beverage. The volume of coffee cups varies depending on the type of coffee and the type of cup. A long coffee can be made up to a range of cup volumes once the shot(s) of coffee has been added. For the LCA, we took typical sizes for each of the cups based on available data. Most of the coffee cups are 180 ml in capacity, but capacity ranges from 110 ml for edible cups to 200 ml for steel reusable cups.

2.2 System Boundary

The LCA was “cradle to grave”, i.e. the stages assessed ranged from raw material extraction to cup disposal/end-of-life (EOL) stream (Figure 2.1). Lids and the printing of information and labels on the cups were not considered in the system boundary. The cup types compared can be divided into two categories: those comprising materials obtained from abiotic resources (polypropylene, polystyrene (PS) and steel) and those comprising materials obtained from biotic resources (paper, polylactic acid (PLA) and wafer). Most of the raw materials were considered to have been obtained within Europe, except crops such as cocoa beans and palm oil, which are usually imported.

2.3 Inventory Analysis

Foreground data on material requirements, washing and EOL streams were obtained from peer-reviewed articles, reports and personal communication with a major supplier of edible coffee cups. Background data for material production and process burdens across different life cycle stages were extracted from the Ecoinvent v3.8 database (with cut-off classification), a reliable and commonly used source of data for LCA. Economic allocation was chosen to partition environmental burdens from multi-output processes into individual outputs (co-products) based on relative economic values (Wernet *et al*., 2016). A summary of important life cycle inventory (LCI) material and process inputs for the different cup types across various life cycle stages can be seen in Table 2.1, which includes information on the weight (volume) of the different cup types based on a review of previous studies. Full LCI inputs and outputs are detailed in a supplementary Excel file in an accompanying scientific article (submitted). An example is provided for edible cups in Table 2.2, followed by specific details of each cup type.

2.3.1 Edible cups

For this LCA, edible cups were considered to contain the main ingredients of a recipe by the company Better Me (Better Me, 2023). This company is a supplier of edible packaging, including coffee cups, in Ireland. The main ingredients used to produce 486 g of the product are 90 g butter, 77 g raw cane sugar, 220 g flour, 100 g dark chocolate and a few grams of coffee, vanilla and salt. Egg yolk (one) was replaced by an

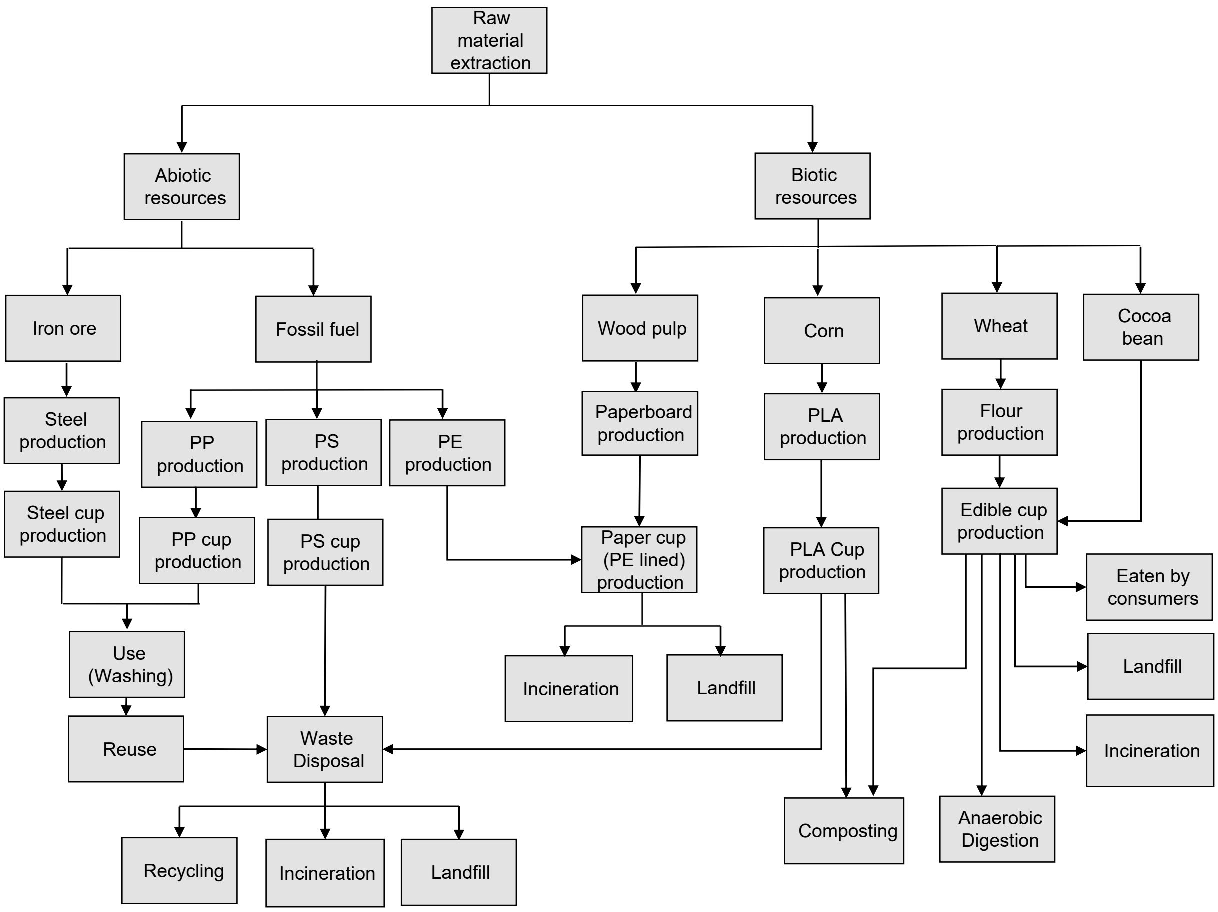


Figure 2.1. System boundary considered for the study, including supply chains for various types of plastic: polypropylene (PP), polyethylene (PE), polystyrene (PS) and polylactic acid (PLA).

Table 2.1. Summary of main input materials and processes involved in the manufacture and use of the various cup types

Cup type	Mass (g)	Raw material inputs	Material and process inputs for manufacture	Material and process inputs for reuse
Edible	14[a]	Wheat[f]	Medium voltage electricity	–
PLA	4.2[b]	Polylactide granulate	Thermoforming	–
Paper (lined with polyethylene)	5[c]	Solid bleached board	Liquid packaging container	–
PS	4.2[b]	PS	Thermoforming	–
Reusable – polypropylene	40[d]	Polypropylene granulate	Thermoforming	Water, electricity, detergent, dishwasher manufacture[g]
Reusable – steel	340[e]	Chromium steel	Metal working	Water, electricity, detergent, dishwasher manufacture[g]

[a]**Better Me (2023).**

[b]**van der Harst *et al.* (2014).**

[c]**Ligthart and Ansems (2007).**

[d]**Cottafava *et al.* (2021).**

[e]**Changwichan and Gheewala (2020).**

[f]**Ecoinvent v3.8.**

[g]**Martin *et al.* (2018).**

Table 2.2. Example of a life cycle inventory for an edible cup, expressed for a reference flow of 1 kg of cup batter

Stage	Process	Details	Quantity	Reference
1 Preparation	–	Inputs:		Better Me (2023)
		• cocoa bean	205.7 g	
		• coffee, green bean	8.5 g	
		• palm oil, refined	8.2 g	
		• sodium bicarbonate	8.2 g	
		• sugar, from sugar cane	316.8 g	
		• wheat flour	452.6 g	
		Outputs:		Better Me (2023)
		• edible cup batter	1 kg	
2 Production	Electricity, medium voltage (Ireland)	Electricity, medium voltage (Ireland)	4 kWh	Ecoinvent v3.8
3 Transport for waste disposal	Transport, freight, lorry (unspecified)	Transport, freight, lorry, unspecified	10 kg km	Ecoinvent v3.8
4 EOL	Eaten by people	Fraction eaten	50%	White (2012)
	Composting	Treatment of biowaste, industrial composting	14.8%	White (2012)
		Inputs:		White (2012)
		• diesel	0.0015 kg	
		• wood chips and particles	0.056 kg	
		• electricity, medium voltage	0.0448 kWh	
		Outputs:		White (2012)
		• compost (avoided fertiliser)	0.191 kg	
		• carbon dioxide (biogenic)	0.186 kg	
		• municipal solid waste	0.037 kg	
		• carbon dioxide (sequestered)	0.024 kg (calculated)	
	Anaerobic digestion	Treatment of biowaste by anaerobic digestion (modified)	9.5%	Ecoinvent v3.8
		Outputs:		Ecoinvent v3.8
		• digestate (avoided fertiliser)	0.62 kg	
		• electricity (avoided)	0.37 kWh (calculated)	
	Incineration	Treatment of municipal solid waste, incineration	14.2%	Ecoinvent v3.8
		Outputs:		Ecoinvent v3.8
		• electricity (avoided)	1.39 MJ	
		• heat (avoided)	2.85 MJ	
	Landfill	Municipal solid waste, sanitary landfill, (modified for Ireland)	11.5%	Ecoinvent v3.8

Other inventories are available in a supplementary Excel file.

equal mass of sodium bicarbonate, butter and palm oil. The minor quantities of vanilla and salt were not modelled because of the unavailability of data. Each cup was assumed to weigh 14 g as sold by the supplier and to be manufactured by baking in an electric oven for approximately 30 minutes (Better Me, 2023). For the modelling, background data for all the ingredients were taken from the Ecoinvent v3.8 database, as shown in Table 2.2.

2.3.2 Polylactic acid cups

PLA is a bio-based plastic used commercially for packaging. Initially, PLA cups were used for cold drinks, but recently thermostable PLA cups have also become available for hot beverages (van der Harst *et al*., 2014). Currently, the production of PLA is limited to a small number of locations around the globe. The manufacturing location was assumed to be France, where a global-scale PLA production facility is planned (European Bioplastics, 2020). Since data for thermostable PLA cups were not available, data for PLA cold drink cups were used as a proxy, as shown in Table 2.2.

2.3.3 Paper cups

Paper cups are always lined with a layer of plastic or bio-based plastic to avoid the leakage of liquid into the paper (Foteinis, 2020). In this study, a thin polyethylene (PE) coating was considered to represent 5% of the cup material by mass (BASF, 2022). The Ecoinvent process "liquid packaging board container" was used as a proxy for paper cup manufacture after changing the aluminium content to zero, as suggested by Foteinis (2020).

2.3.4 Polystyrene cups

Single-use cups may also be made from PS in some countries – although the sale of such cups has recently been banned across the EU. High-impact and expanded forms of PS are suited to hot beverages (UNEP, 2021). Although it is technically possible to recycle PS, recycling rates are low for both forms, and few countries include PS in their recycling streams (UNEP, 2021).

2.3.5 Reusable cups (polypropylene and steel cups)

As a baseline scenario, it was assumed that the reusable cups would be used 500 times (over 2 years) based on the average lifespan previously reported by Woods and Bakshi (2014). In the modelling for the reusable cups, an allocation problem occurred during the use phase, when the cups are cleaned in the dishwasher. Since other dishes, etc., are washed at the same time, water consumption, washing powder use and energy demand were allocated for one single cup based on the assumption that a single cup represents 2% (one-fiftieth) of the volume of dishes being washed. Thus, during a single wash cycle, one cup was allocated 0.4 l of water, 0.9 g of washing powder and 0.014 kWh of electricity. Energy and water consumption values for the dishwasher were taken from a certified energy-efficient machine (Martin *et al*., 2018). It was assumed that reusable cups would be washed after every three uses, on average. Reusable cups may also be made from stainless steel; data for regular steel cups from the Ecoinvent v.3.8 database were used as a proxy.

2.4 End-of-life Modelling

An "avoided burdens" (system expansion) approach was used to model EOL scenarios that included recycling, incineration, composting and anaerobic digestion (AD). This approach demonstrates the potential benefits of avoiding the future use of primary materials by considering the loads associated with the recycling and recovery processes beyond the system boundary (Heijungs and Guinée, 2007).

As a baseline scenario, it was assumed that 50% of the edible cups were eaten (by consumers) and 50% were sent for municipal waste management. Municipal waste management was modelled as per the average mix of municipal waste management in the EU – but recycling was replaced by composting and AD, as edible cups are biodegradable in nature. Similarly for PS cups, the waste management model was based on EU statistics for plastics. In the case of PLA cups, the recycling rate was taken from Moretti *et al*. (2021). Chemical recycling was considered, as the quality of the recycled PLA product is better than that produced via mechanical recycling (Cosate de Andrade *et al*., 2016). A process representative of a mixture of plastic in Ecoinvent v3.8 was used to model PLA landfilling, as previously suggested in the literature (Madival *et al*., 2009).

As paper cups are not recyclable because of the plastic coating present, it was assumed that these were sent for incineration and landfill. Reusable steel cups were assumed to be 100% recycled because of the high value and recyclability of scrap steel, while the EOL stream of reusable PP cups was considered the same as that of PS cups. A summary of the EOL scenarios considered is provided in Table 2.3.

2.5 Impact Assessment

A life cycle impact assessment (LCIA) of cup types was conducted using the Environmental Footprint 3.0

Table 2.3. End-of-life scenarios for the different types of cup

Type of cup	Assumed EOL scenario	References
Edible	Eaten by humans (50%), composting (14.8%), AD (9.5%), incineration (14.2%) and landfill (11.5%)	Eurostat (2023)
PLA	Composting (15%), incineration (39%), recycling (15%) and landfill (31%)	Moretti *et al.* (2021)
Conventional PS	Recycling (32.5%), incineration (42.6%) and landfill (24.9%)	Plastics Europe (2020)
Paper lined with PE	Incineration (77.1%) and landfill (22.9%)	Eurostat (2023)
Reusable – steel	Reused 500 times; 100% recycling	Woods and Bakshi (2014); Changwichan and Gheewala (2020)
Reusable – PP	500 times reuse; recycling (32.5%), incineration (42.6%) and landfill (24.9%)	Woods and Bakshi (2014); Plastics Europe (2020)

method. This method represents a harmonised approach to LCIA and has been referenced in EU policies and legislation, including the Taxonomy Regulation and the Green Consumption Pledge (European Commission, 2021).

2.6 Indicator of Littering Potential

One major limitation of LCA in a comparison such as this is that no impact category assesses littering (De Sadeleer, 2021). The importance of including the impact of littering was identified by the EAT-Packaging project researchers, and a project named MariLCA is being undertaken to address this shortfall in association with the Life Cycle Initiative and the Forum for Sustainability through Life Cycle Innovation. This project is in a developmental phase and aims to integrate the potential environmental impacts of marine litter, especially plastic, into LCA results (Boulay *et al.*, 2021).

In the absence of this methodology for the time being, and since coffee cups were identified as playing an important role in littering, with single-use plastic littering being a major concern, the littering potential (LP) of the cup types was analysed in this study according to an indicator developed for carrier bags by Civancik-Uslu *et al.* (2019):

$$LP = P_1^{fi}/P_2^{f2} \times P_3^{f3} \times P_4^{f4} \quad (2.1)$$

where LP = indicator for assessing the littering potential on the environment; P_1 = quantity of residual bags; P_2 = environmental release; P_3 = environmental dispersion; P_4 = environmental persistence; f1, f2, f3, f4 = weighting factors (all equal to 1, until further research inputs otherwise) and values are $0 < P_1, P_2, P_3, P_4 < 1$.

Based on Civancik-Uslu *et al.* (2019), littering is assumed to be proportional to (i) the number of cups required to fulfil the same function (i.e. 1 disposable cup or 1/number of reuses for reusable cups); (ii) the price of the cup (which defines the probability of being released to the environment); (iii) the probability of dispersion in the environment expressed as the weight of the cup; and (iv) the environmental persistence of the material, expressed as the biodegradability rate.

Equation 2.1 was applied to each of the cup types using appropriate data obtained from secondary sources.

2.7 Economic Analysis

An online search was conducted to determine the average price for each of the cup types evaluated. Although the search was conducted mainly using the websites of European retailers, in some cases it was necessary to search the websites of companies from other regions. For instance, one company selling edible cups was found in New Zealand. In some cases, it was necessary to convert the price to euros using the official currency exchange rate from the Central Bank of Ireland (CBI, 2023). In addition, the price per item was calculated when more than one item was included in the declared price. Finally, the price per use was calculated for reusable cups by dividing the price by the number of uses as per the baseline scenario, to express the price according to the functional unit.

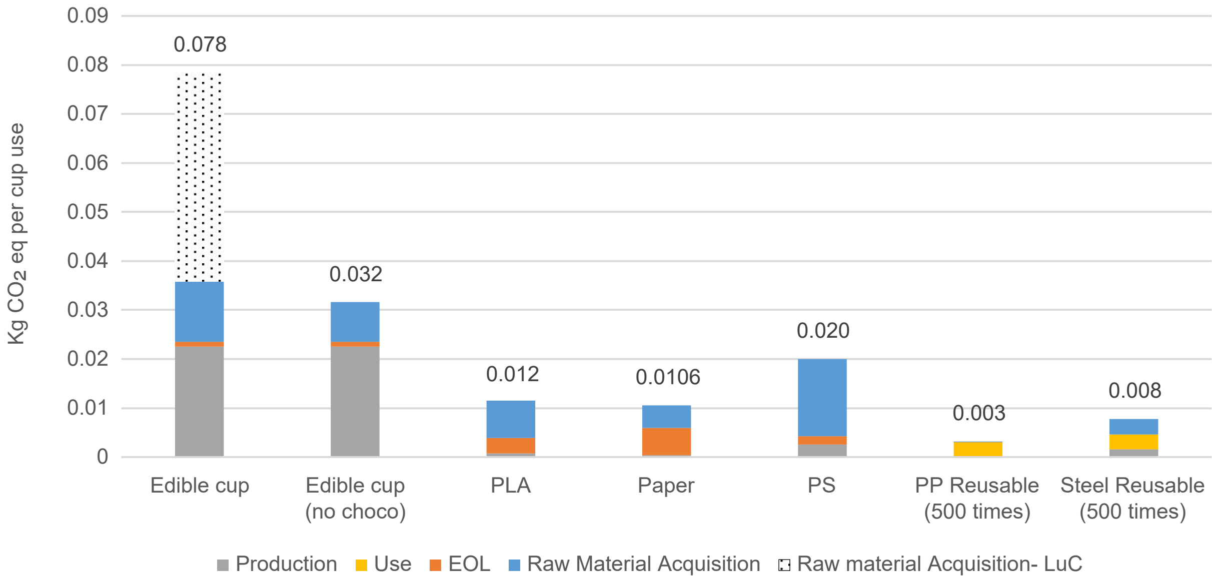
3 Results

3.1 Life Cycle Assessment Results

3.1.1 Comparative analysis of coffee cups

Figures 3.1 and 3.2 show the results from the comparative LCA of the coffee cup types across four important impact categories: “climate change”, “marine eutrophication”, “water use” and “resource use – fossils”.

As can be seen in Figure 3.1, regarding the climate change category, edible cups have the highest burden (0.078 kg CO_2 equivalent (CO_2e) per use), while reusable cups have the lowest (0.003 and 0.008 kg CO_2e per use for PP and steel cups, respectively). For the edible cups, interestingly, greenhouse gas emissions attributable to land use change, driven by cocoa bean production for



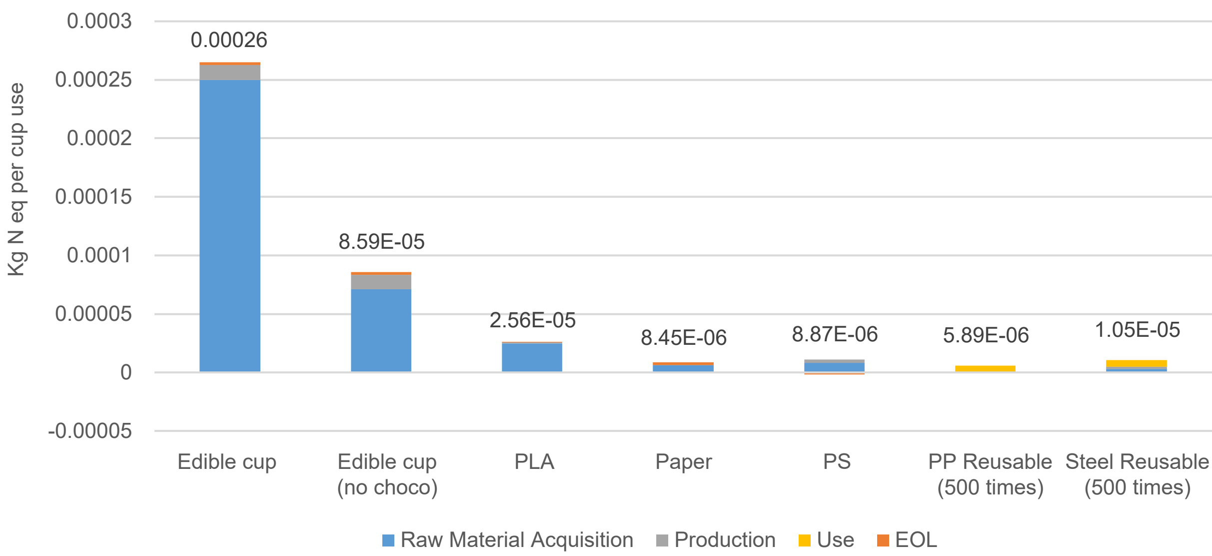


Figure 3.1. Comparison of the impacts of different cup types on the climate change (top) and marine eutrophication (bottom) categories. “Edible cup (no choco)” refers to edible cups without chocolate flavouring (cocoa) added. LuC, land use change.

the chocolate flavouring, and electricity usage, during production in the oven, were identified as environmental hotspots. As land use change emissions are somewhat uncertain, a separate calculation for edible cups with no cocoa added was also performed. Although this result indicates that edible cups with no cocoa added have a smaller carbon footprint, of 0.032 kg CO_2e per cup use, this was still a larger burden than that of the alternatives.

Figure 3.2 shows a similar pattern, where edible cups have the largest burdens and reusable cups (PP) the lowest burdens across the marine eutrophication (nitrogen pollution of coastal waters) and water use categories. In terms of marine eutrophication, edible cups contribute 0.00026 kg N per cup use; this can be attributed to the use of fertilisers in the production of the major edible ingredients of the cups, i.e. cocoa beans and wheat. However, each edible cup is

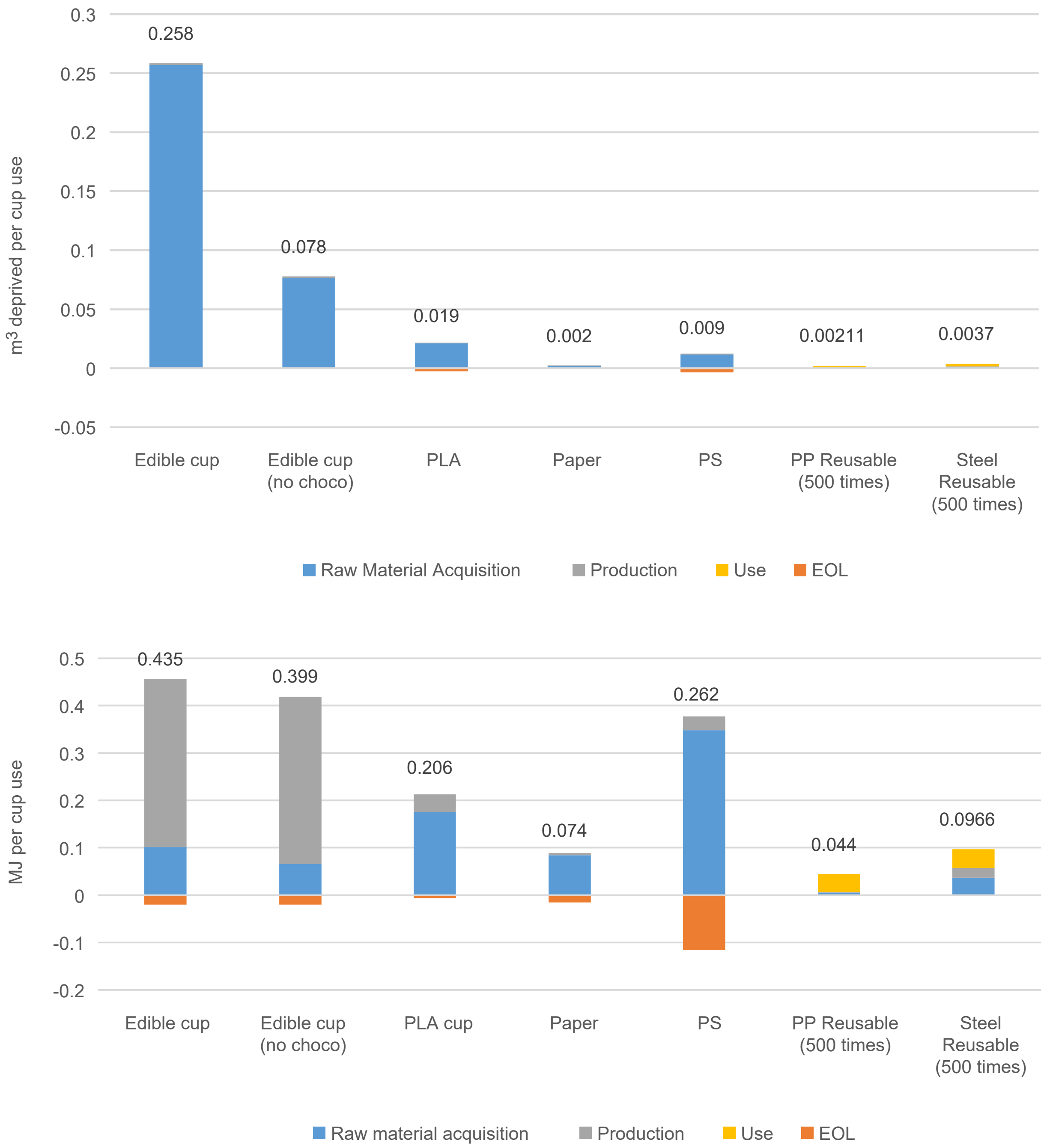


Figure 3.2. Comparison of the impacts of different cup types on the water use (top) and resource use – fossils (bottom) categories. "Edible cup (no choco)" refers to edible cups without chocolate flavouring (cocoa) added.

associated with the use of 0.258 m³ of water; yet again, the cultivation of cocoa beans and wheat accounts for the highest contributions because of the use of water for irrigation.

The results for the resource use – fossils impact category are similar to the results for the other categories: the environmental burden of edible cup production, use and disposal is the highest of all cup types (0.44 and 0.40 MJ for cups with and without chocolate, respectively). Fossil resource use can be attributed primarily to the electricity used for the oven baking of the cups. It should be noted that PS cups also have a significant resource use – fossil burden, of 0.26 MJ per cup, due to the production of PS.

Thus, edible cups have the highest environmental impact across the four major impact categories, while reusable PP cups have the lowest. Reusable steel cups generate the second lowest burden for climate change; however, they are slightly outperformed by paper cups in the other three impact categories. Nevertheless, it is important to highlight that it was assumed that reusable cups would be used 500 times (over about 2 years) and that the impact of reusable cups is highly dependent on the number of reuses (UNEP, 2021). For this reason, a sensitivity analysis of the effect of the number of reuses is presented in section 3.2.

3.1.2 End-of-life scenarios for edible cups

An EOL scenario analysis was conducted for edible cups to determine how the environmental performance of these cups is influenced by different waste management strategies. As edible cups can be eaten, analyses were conducted considering their consumption by humans, substituting for another snack, or their potential consumption by animals, substituting for animal feed (depending on the waste stream that the cups end up in; the use of edible cups for animal feed is unlikely under current regulations, but a possible future option). In addition, it was assumed that 100% of the cups would be sent for composting, 100% for AD or 100% for incineration, or that 100% would not be disposed of (i.e. 100% would be eaten without product substitution). Figure 3.3 shows the radar plot of normalised results for each scenario for different impact categories. These results indicate the normalised scores for the different cup types across the different EOL scenarios. The

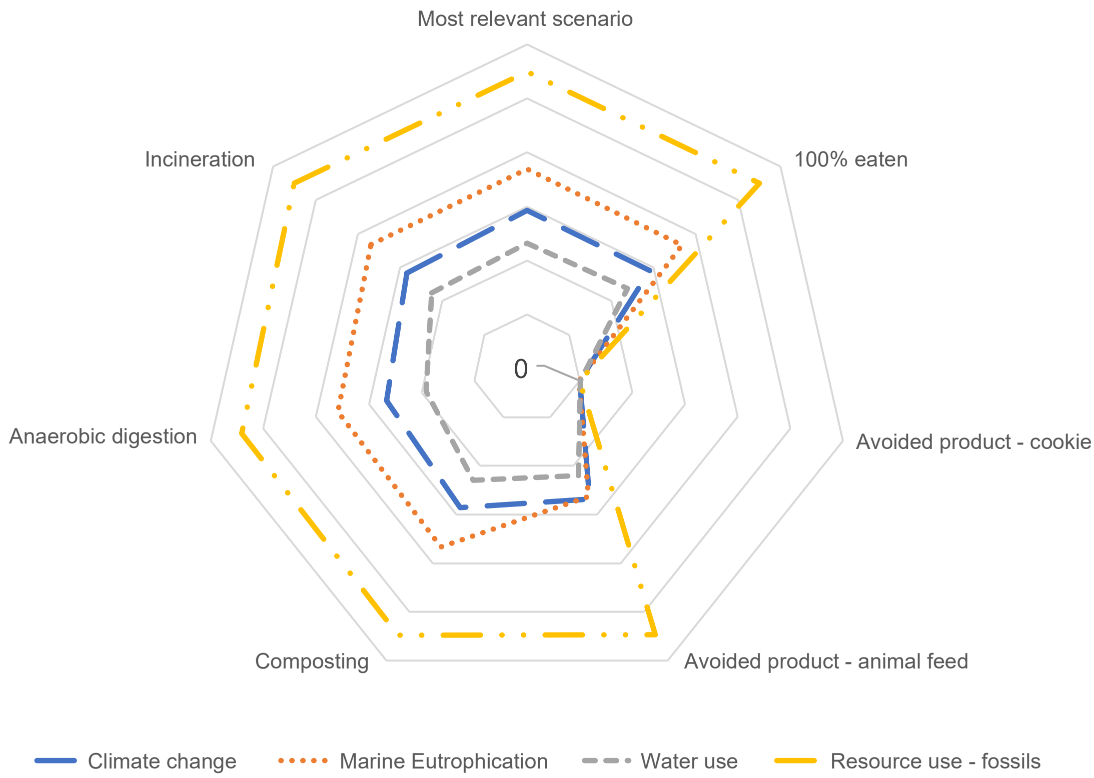


Figure 3.3. Comparison of normalised scores for end-of-life scenarios for edible cups across impact categories.

normalised scores are calculated in relation to the total environmental impact caused per capita in Europe. The scenarios considered were the default situation (baseline scenario), "100% eaten", "avoided product – cookie", "avoided product – animal feed", "composting", "anaerobic digestion" and "incineration".

The radar plot in Figure 3.3 indicates that, for all four impact categories, the burden of edible cups is negligible if their use leads to product substitution, that is, avoids the consumption of another similar product, e.g. a cookie. This is therefore the best-performing scenario for edible cups, and indeed across all cup types. In the climate change category, AD and animal feed substitution mitigate total burdens somewhat compared with the baseline scenario. It is also important to note that, when 100% of cups are eaten without product substitution, life cycle burdens are greater than they are for the other waste management scenarios, where some type of product substitution arises. This is because of the selected modelling approach, in which AD, composting and incineration lead to a burden being avoided thanks to the generation of products such as biogas, fertilisers and energy that somewhat mitigate life cycle environmental burdens. If the consumption of edible cups does not lead to the substitution of a similar product, then it could be considered an excessive consumption of calories, which might affect not only the environment but also the health of the consumer; however, this impact was not considered in the evaluation.

Normalised scores for the impact categories marine eutrophication, resource use – fossils and water use followed a similar pattern to those for the climate change category. The avoided product – animal feed scenario had quite a strong mitigating effect on the marine eutrophication category, reflecting the effects of avoiding crop cultivation for animal feed.

3.2 Sensitivity Analysis

A set of sensitivity analyses was conducted to determine the effects of the most influential parameters on results. Table 3.1 shows the parameters that were considered for the sensitivity analyses and the percentage change in calculated burdens across different categories. Since it was observed that the weight of an edible cup is much higher (about three times) than that of the other disposable cup types, which resulted in higher burdens, the weight of the edible cup was reduced to 10 g as a hypothetical

Table 3.1. Sensitivity analysis: percentage changes in environmental burdens of relevant cup types with changes in most influential parameters

	Change in burden by impact category			
Parameters considered for relevant cup types	**Climate change**	**Marine eutrophication**	**Resource use – fossils**	**Water use**
Edible cup: decrease in mass from 14 g to 10 g	–29%	–27%	–29%	–29%
Edible cup: use of alternative recipe	–3%	–5.6%	3.1%	–18%
Edible cup: use of paper sleeve	2.3%	0%	38%	0.4%
No. of reuses				
Reusable cup – PP: 12 reuses	237%	79%	644%	160%
Reusable cup – steel: 300 reuses	109%	69%	104%	68%
Handwashing				
Reusable cup – PP	–70%	–24%	–79%	–12%
Reusable cup – steel	–41%	–17%	–48%	–9%
Use of renewable energy				
Edible cup	–27%	–4%	–76%	25%
PLA cup	–18%	–1.2%	–49%	47%
Paper cup	–22%	–17%	–49%	349%
PS cup	–18%	–22%	–9.8%	23%
Reusable cup – PP	–55%	–17%	–66%	272%
Reusable cup – steel	–34%	–24%	–28%	422%

future strategy for impact reduction. As can be seen in Table 3.1, this hypothetical weight reduction resulted in a consistent and significant decrease in burden, of about 28.5%, across all impact categories.

Moreover, because of the limited literature regarding the composition of edible cups, another recipe for edible cups was considered. During the review of recipes for edible cups, it was found that recipes are generally very similar. For this sensitivity analysis, a recipe was considered that contained a minor variation in the type and quantity of the ingredients (presented in Appendix 1). This resulted in an insignificant change in the results compared with those for the baseline recipe, except for a 17.5% decrease in the water use category due to the use of less wheat flour and chocolate.

For hygiene purposes, edible cups are usually sold commercially with a wrapping sleeve made of paper or plastic around each cup. The sensitivity analysis of the effect of using a paper sleeve indicated a negligible change in impact category results, except for the resource use – fossils category, where electricity usage for the production of paper sleeves substantially increased the burden.

Although reusable cups have the lowest burdens in general, results are highly dependent on the number of times the cups are reused. Therefore, a break-even analysis was conducted for the reusable cups to indicate the minimum number of times they would need to be reused to have lower burdens than SUDCs. The analysis indicated that, for the climate change category, the PP cup and steel cup types need to be reused at least 12 and 300 times, respectively, to have lower burdens than SUDCs. A similar result was found by UNEP (2021). As shown in Table 3.1, burdens significantly increased with smaller numbers of reuses. Another user-dependent aspect of reusable cups was evaluated: handwashing of cups (with cold water) versus using the dishwasher. This was considered important for the analysis, as the results show that the use of dishwashers for cleaning cups is the main environmental hotspot for reusable cups, and such cups may be used in, for example, an office environment where they may not be regularly washed in a dishwasher. Handwashing using cold water shows a substantial decrease in burdens for reusable cups, with a reduction of up to 70% in the climate change impact category (Table 3.1).

Finally, an analysis was conducted on the use of renewable energy for electricity generation, reflecting a trajectory towards a less fossil-based society in future. For modelling simplification, this analysis considered electricity generated in Norway, where the grid mix is dominated by renewables, in particular hydroelectric sources. The results indicate a significant reduction in most impact categories for all cup types, but especially in the climate change and resource use – fossil categories for edible and reusable cups. However, water use burdens increased by around three to four times for some cup types because of the inferred water use for hydroelectricity generation. The use of renewable energy also altered the ranking of the cup types: the comparative burden of paper cups increased in the marine eutrophication category and that of reusable steel cups increased in the water use category. Similarly, in the resource use – fossils category, the use of renewable electricity resulted in a huge decrease in the impact of edible cups, making PS and PLA cups the worst-performing options.

Figure 3.4 shows the results of the break-even analysis of the reusable cup types in comparison with the other cup types for the climate change category. Along with the baseline scenario of using the cups 500 times, using cups fewer times was analysed. It can be inferred that the climate change burden of reusable PP cups is comparable to that of the other disposable cup types when they are used 12 times. The burden of the PP cup decreases significantly when it is used 100–500 times. The reusable steel cup has a similar climate change burden to that of the other cup types when used around 300 times. The burden greatly increases and surpasses that of the other cup types when used around 200 times or fewer.

3.3 Littering Potential

The results of the adapted LP indicator are provided in Table 3.2 and Figure 3.5. It is possible to see that LP varies as follows: PS > paper > PLA > PP > edible > steel cup.

Thus, edible cups are second only to steel cups in terms of having the lowest LP, while PS cups scored the worst – owing to their low price, low density and poor biodegradability. There is a huge difference in performance between the best and worst cup types using this indicator.

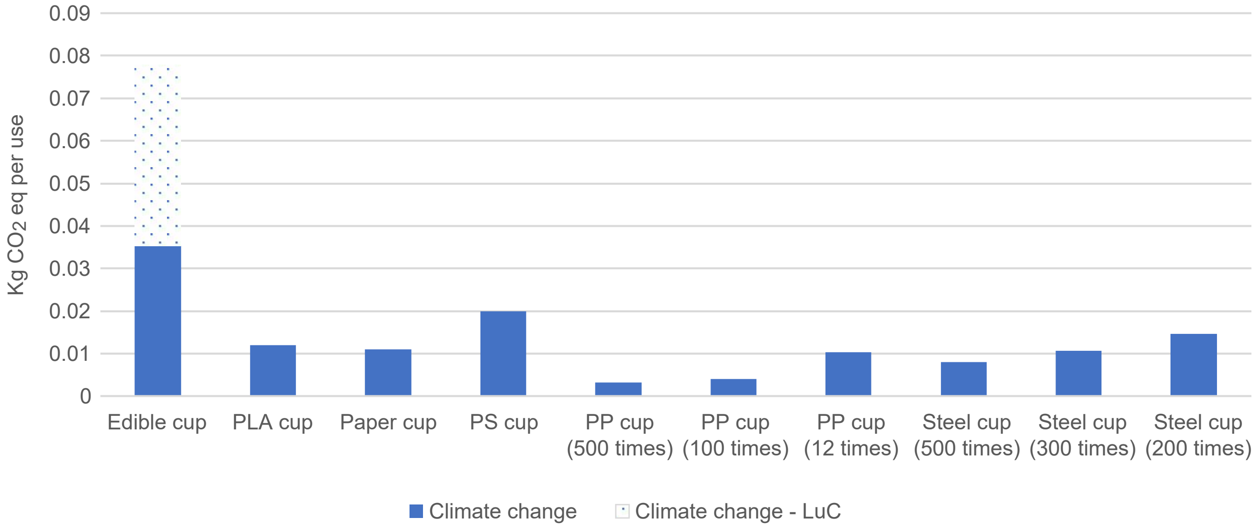


Figure 3.4. Break-even analysis of reusable cups (for the climate change impact category). LuC, land use change.

Table 3.2. Comparison of littering potential of cup types

Cup type	Littering potential (LP score)
Edible	24
PLA	1219
Paper	1134
PS	347,124
Reusable – PP	73
Reusable – steel	6.8

A high LP score denotes a high potential littering impact.

3.4 Economic Analysis

Figure 3.6 compares minimum, maximum and mean prices of the different cup types, expressed per use, based on values in the literature. It is clear that edible cups have the highest price per use, with a mean value of €2.56 and a maximum value of €5.54, which is considerably more than the average price of a cup of coffee.

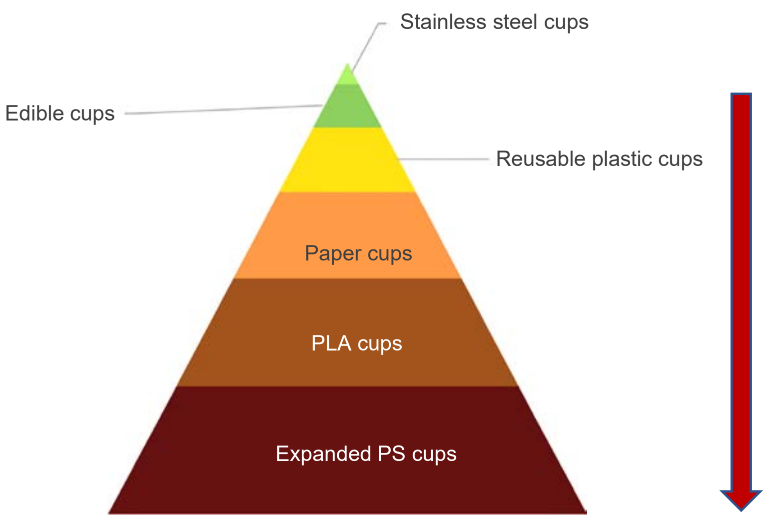
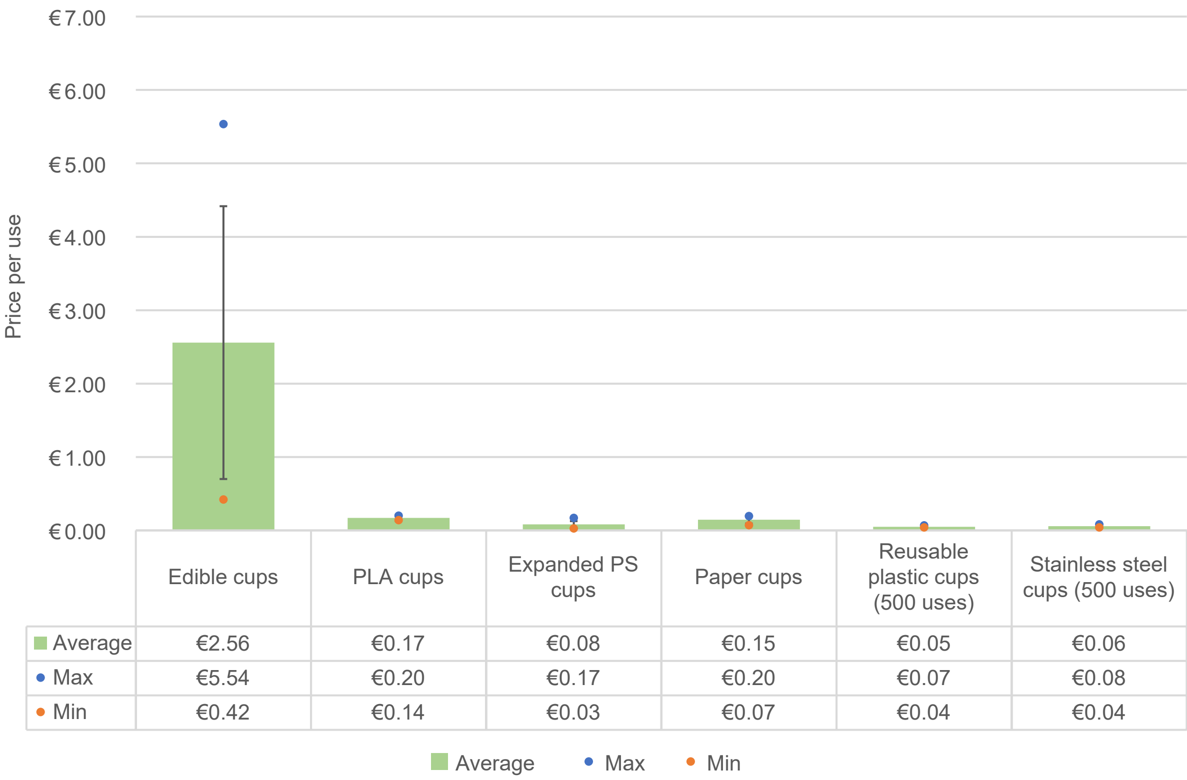


Figure 3.5. Littering potential scores for different cup types (the lowest scores at the top indicate cup types with the lowest potential to contribute to littering).



	Edible cups	PLA cups	Expanded PS cups	Paper cups	Reusable plastic cups (500 uses)	Stainless steel cups (500 uses)
Average	€2.56	€0.17	€0.08	€0.15	€0.05	€0.06
Max	€5.54	€0.20	€0.17	€0.20	€0.07	€0.08
Min	€0.42	€0.14	€0.03	€0.07	€0.04	€0.04

Figure 3.6. Comparison of prices reported for different cup types, expressed per use. Data sources: ediblecup.coffee, shop.cupffee.me, amazon.com, promotionalgifts.eu, alibaba.com, nisbets.ie, etsy.com, janitorialdirect.co.uk, bizay.ie, vikingdirect.ie, igopromo.ie, https://twiice.co.nz/ and igreengadgets.com.

4 Discussion

This research aimed to assess the environmental sustainability of various coffee cup types available on the market today through LCA. Edible cups are an innovative alternative being proposed as having less impact on the environment because of their biodegradable nature and lower potential for littering, especially if consumed after drinking the coffee. The results show that edible cups actually have comparatively large environmental burdens across different impact categories; however, burdens might be negligible in the best-case situation, that is, if the cups are eaten and substitute for similar edible items. Although the order of impacts of the different cup types varies across the different impact categories, the reusable PP cup is the alternative that consistently shows the lowest environmental burden, under default assumptions. Woods and Bakshi (2014) and Martin *et al*. (2018) drew a similar conclusion about reusable cups.

To put the environmental footprints of coffee cup use into context, they were compared with the total environmental footprint of serving a cup of brewed coffee. The impact of coffee depends mainly on the type of brewing method used, and ranges from 0.03 to 0.18 kg CO_2e per cup (125 ml), with an average of 0.11 kg CO_2e per cup (Humbert *et al*., 2009; Brommer *et al*., 2011). This shows that for the cup types with the highest burdens, such as edible cups and PS cups, the life cycle of the cups themselves could make an important contribution to the total carbon footprint of a coffee serving – and may in some cases exceed the footprint of the brewed coffee they contain.

The sensitivity analysis further indicated the importance of using renewable energy and how this can alter the impact of the cup types, particularly on the resource use – fossils category, where the impact of edible cups is lower than that of PLA and PS cups. The impact of a reusable cup also varies significantly with the number of times it is reused. The PP cups and steel cups need to be used at least 12 and 300 times, respectively, to have a lower impact than the other cup types. In the case of the steel cups, there is a significant risk that they may be discarded or lost before reaching this "carbon payback" point.

An economic analysis was also conducted for the different cup types, highlighting the current high price of edible cups. Although the price of edible cups could decrease with market growth, reusable cups are likely to remain the best-value option by some margin (depending on the number of uses), followed by paper and plastic cups. The new levy on disposable hot drinks containers (EnvEcon, 2022) will further improve the economic advantage of reusable cups (edible cups will be liable for this levy, as a single-use item). However, if edible cups are also marketed as a snack, this would (i) give rise to a question mark over the appropriateness of paying a levy on them and (ii) change the factors considered in a price comparison, as the price of an equivalent snack would need to be included.

Overall, the results reinforce previous findings that reusable cups are the best option to reduce environmental impacts, so long as they are used at least a minimum number of times. However, a novel finding in this study is that, despite their production having a large environmental burden, if edible cups replace the consumption of another similar edible item, the environmental impact is negligible. As reusable cups may be impractical in certain situations where they may not be cleaned or carried easily, edible cups might be a better option in these situations. This is particularly true where such situations coincide with a high risk of and impact from littering. During a workshop held in the course of this research (Appendix 2), a number of such situations were proposed by stakeholders. The top-ranked situation was outdoor festivals, followed by mobile markets and airports. Other situations might include schools, cruise ships and beach cafes, where people are more likely to consume the cup (and avoid littering and its associated impacts). One participant also suggested that edible cups could offer a useful option for providing nutrition after catastrophic events.

It is worth noting that the use of edible cups at conferences and meetings and in coffee shops was identified as less suitable, mainly because of the price and the perceived poor taste of the cups (although more research is needed in this area). Several additional barriers to the sustainable deployment of edible cups in the Irish market were identified by the stakeholders. These barriers can be grouped into four main categories:

1. consumer behaviour;
2. techno-economic aspects;
3. convenience constraints;
4. waste management challenges.

Regarding consumer behaviour, edible cup use faces barriers such as a lack of motivation from the consumer to try new things, subjective taste preference and people not wanting to eat the cup owing to, for example, calorie counting. Although some strategies may be applied to incentivise the public to try new products (e.g. offering free samples or marketing campaigns), there is a risk that demand will not be sustained because of a loss of novelty in the long term.

Regarding the techno-economic aspects, the high price of edible cups was identified as the main barrier to their extended use. Moreover, from a technical perspective, minimising the effects of hot liquid on cup structure, a reduction in cup thickness to match end-user expectations and an increase in the lifespan of cups must be addressed. Reducing cup thickness is challenging, since it should be done in a way that increases the capacity of the cups without affecting their main function of safely containing a hot liquid. Research is also necessary to ensure that cups are tasty without modifying the organoleptic properties (i.e. the colour, taste, smell and texture) of the coffee itself.

Regarding convenience, edible cups give rise to hygiene concerns at the point of sale and need special packaging to avoid losses during distribution because of the fragile nature of the product, and the coffee needs to be drunk before the final part of the cup is eaten. In addition, the lack of a lid limits the use of edible cups as a takeaway option.

Similarly, regarding waste management, two main concerns were identified: the lack of infrastructure for proper management (lack of brown bins) and the potential to attract vermin and leave a mess if cups are disposed of in public spaces. The relative performance of the different cup types is somewhat sensitive to the prevailing waste management infrastructure in the locality of use (another advantage of reusable cups is that they are far less sensitive to this variable).

Two additional barriers were identified by the stakeholders. From the cafe perspective, introducing edible cups wholesale might risk losing market share, as some consumers are likely to keep looking for conventional alternatives. There is also a barrier related to a lack of clarity about the applicable legislation: since the cups are edible items, it is not clear if they should comply with various food labelling regulations. There is a need for more clarity on the status of and regulatory requirements for edible cups in Irish and EU law.

The multitude of issues raised above indicate that more research is needed to decide if and how an extended deployment of edible cups in the Irish market could be achieved in a sustainable manner. Such research must focus on consumer behaviour to determine the extent to which edible cups might in fact be regarded as a genuine snack (alternative), capable of substituting for a similar snack product. This will require extensive product development to ensure that cups are tasty, long-lasting and robust. Other research priorities include lid development; strategies to guarantee hygiene and proper labelling at the point of service; clarification of the legal frameworks applicable to edible cups; and secondary packaging development to ensure safe distribution without increasing costs or environmental impacts.

The above challenges and requirements are not to dismiss the potential contribution of edible cups, which could play an important role in reducing environmental burdens in specific situations. Consumer behaviour will play a crucial role in any prospective uptake of edible cups, which would need to be supported by strong product development, governmental regulation and appropriate marketing strategies. A positive aspect mentioned during the workshop was that we are in an era of change in which people are open to trying new things, and legislation is increasingly promoting alternatives to single-use paper and plastic cups. So, there are some glimmers of opportunity, even if it is clear that edible cups are far from the panacea to the 300 million coffee cups projected to be discarded annually in Ireland by 2025.

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Abbreviations

AD	Anaerobic digestion
CO_2e	Carbon dioxide equivalent
EOL	End-of-life
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LP	Littering potential
PE	Polyethylene
PLA	Polylactic acid
PP	Polypropylene
PS	Polystyrene
SUDC	Single-use disposable cup

Appendix 1 Ingredients of Alternative Edible Cup

Table A1.1. Ingredients of an alternative edible cup recipe, expressed per reference flow of a single cup

Ingredient	Mass (g)
Soft butter	2.03
Sugar	3.93
Salt	0.036
Baking soda	0.036
Vanilla	0.072
Egg	0.30
Sour cream	1.22
Flour	4.58
Dark chocolate	1.79

The butter was replaced by palm oil for the modelling. Ingredients including salt, egg, vanilla and sour cream were not considered because of data unavailability.

Source: The Flava Chef (2020).

Appendix 2 Online Workshop Report

A workshop was held on 10 February 2023 with the aim of gathering insights from important stakeholders in the food (packaging) and waste management sectors to co-create a road map for sustainable coffee cup policy. The results of the LCA were also shared during the workshop. A total of 92 potential participants were identified through a web search and recommendations from the project steering committee. A total of 13 stakeholders attended the workshop from several sectors, as displayed in Figure A2.1. A high proportion of participants were from governmental/administrative bodies; however, representatives from industry and national and international associations were also part of the event.

The workshop was structured as shown in Box A2.1.

Box A2.1. Stakeholder workshop

Welcome and introduction

Presentation of results of LCA of coffee cups and Q&A session

Interactive poll session

- Barriers to reusable cup use
- Opportunities for the deployment of edible cups
- Barriers to the deployment of edible cups

Breakout discussion sessions

- Where and when can and should edible cups be used?
- Will people eat them as a (substitute) snack?

Future priorities

- What best describes your view on the possible role of edible cups in a more sustainable economy?
- Future and further research on edible packaging alternatives

Final wrap-up and closure

Interactive polls were created to capture the views from the stakeholders regarding barriers to and opportunities for the deployment of edible cups and the barriers to the use of reusable cups as the most appropriate solution for drinking coffee. The results from the polls are shown in Figures A2.1–A2.4.

Breakout room sessions were then held with the aim of understanding the most suitable scenarios for the use of edible cups and how likely it would be for the cups to be eaten as a substitute for another type of snack. Finally, an open discussion session was held with the participants to gain an understanding of the role of edible cups and future research needs for edible packaging alternatives.

The following sections provide a summary of the findings and conclusions of the workshop.

A2.1 Barriers to the Deployment of Edible Cups

The following barriers were identified for the deployment of edible cups:

- high price;
- people not wanting to eat the cup;
- negative interaction with the taste of the coffee;
- taste preference (cups not considered that tasty): this is a highly subjective issue that depends on each individual's preference (so in reality a range of cup flavours would need to be offered);
- hygiene concerns: how could coffee be served in edible cups at the point of sale with minimum contamination risk;
- cups being fragile (therefore significant amounts of secondary and tertiary packaging may be needed to keep them intact during distribution);
- the lack of infrastructure for proper waste management for cases in which the consumer decides not to eat the cup (i.e. lack of publicly accessible brown bins on many premises);
- lack of consumer motivation to try new things;
- the short life of the cup, i.e. of around 30 minutes to a few hours, which discourages the consumption of the cup;

- the type of coffee influencing the longevity of the cup (partly due to heat);
- the need to drink the coffee **before** eating the final part of the cup;
- possible novelty value wearing off (lack of sustained demand);
- the cup/snack being perceived as too thick/big for some people;
- the limited capacity of the cups, making them suitable for short coffees only;
- a lack of clarity about the legislation applicable to edible cups: as food (nutritional and allergen information should be display), as packaging, as a cup;
- the lack of a lid, which limits cup use as a takeaway option;
- the potential to attract vermin and leave a mess if disposed of in public spaces;
- the perceived risk of market loss due to consumers looking for conventional cups (in case of a wholesale switch);
- the risk of cups being left on desks, etc., and disintegrating to spill coffee.

A2.2 Possible Situations for the Deployment of Edible Cups

The scenario identified as having the highest potential for the deployment of edible cups was festivals, where people might be more likely to eat the cup. Mobile markets were identified as the situation with the second highest potential for edible cup deployment and airports were identified as the third most suitable scenario. Other scenarios might include deployment in schools (children likely to eat cups after their milk), as a nutritional solution after catastrophic events, or on cruise ships and at beach cafes, where people are also more likely to consume the cups.

Use at conferences and meetings and in coffee shops was identified as less suitable because of several of the barriers mentioned in the previous section, mainly regarding the price and the taste of the cups.

A positive aspect mentioned during the workshop was that we are in an era of change in which people are open to trying new things, and legislation is increasingly promoting alternatives to single-use paper and plastic cups; however, realising this vision needs both top-down and bottom-up efforts to appropriately address all aspects required for the sustainable use of edible cups.

A2.3 Barriers to the Use of Reusable Cups

The main barrier to the use of reusable cups identified was the lack of convenience. This is related to aspects such as forgetting to bring the cup when needed, the weight of the cup while carrying it, hygiene concerns due to the logistical difficulties of adequately washing cups outside home settings or taste modification caused by the use of a plastic cup.

The cost of reusable cups was also identified as one of the main barriers to their use. Even if these cups are used several times, the initial cost might represent a barrier for consumers.

Recycling of reusable cups was also identified as a concern, along with difficulties related to the shift in the current culture of using single-use cups.

A cultural shift is important to educate people on the importance of incorporating reusable items into their daily lives. This could help in putting the environment before convenience.

A2.4 Research Needs Identified

The following research needs were identified:

- empirical consumer behaviour studies to determine the extent to what edible cups would be eaten as substitutes for similar products;
- research on the environmental and economic impacts of packaging for edible cup distribution;
- work on the development of lids;
- product development (taste) studies to ensure that consumers will keep the habit of consuming coffee in edible cups;
- research into how to increase shelf life;
- research into how to guarantee hygiene at the point of service;
- research into legal aspects and the classification of edible cups as food;
- research on how to provide the required information to the consumer without increasing the costs or environmental impacts (it is important that ingredients and allergens are listed on either the sleeve of the cup or the menu, to ensure transparency, which is important for edible items).

A2.5 Conclusions

More research is needed for the extended and sustainable deployment of edible cups in the market.

Consumer behaviour plays a crucial role in the use of edible cups, which would need to be supported by strong product development, governmental regulation and suitable marketing.

A2.6 Figures Derived from Workshop Survey Responses

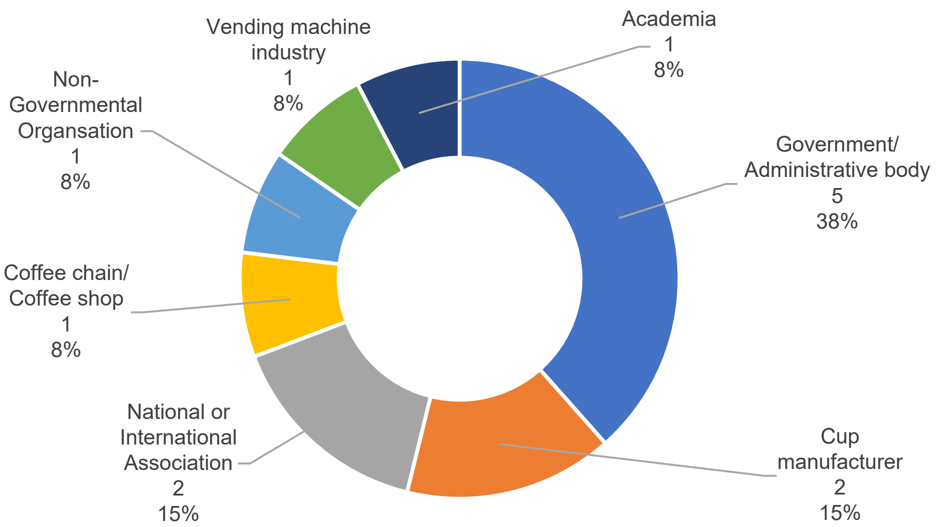

Figure A2.1. Sectors taking part in the workshop.

Figure A2.2. Barriers to the use of reusable cups.

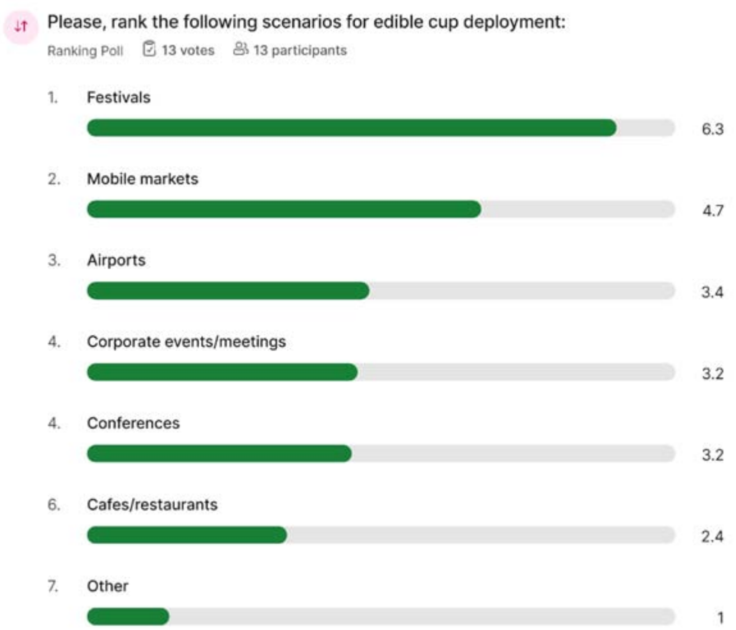

Figure A2.3. Scenarios for edible cup deployment.

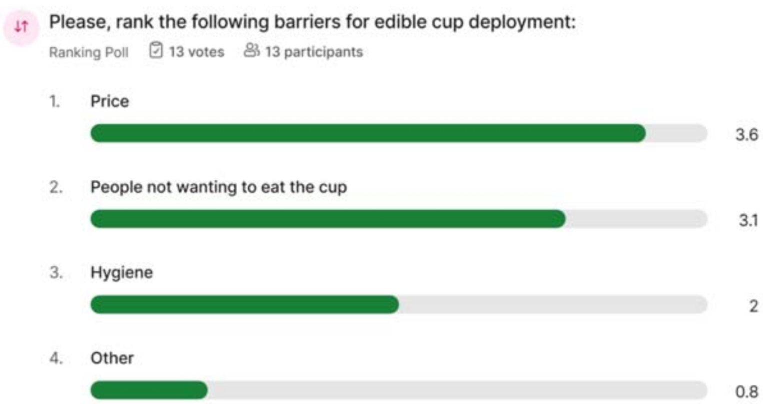

Figure A2.4. Barriers to edible cup deployment.

An Ghníomhaireacht Um Chaomhnú Comhshaoil

Tá an GCC freagrach as an gcomhshaol a chosaint agus a fheabhsú, mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ar thionchar díobhálach na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialáil: Rialáil agus córais chomhlíonta comhshaoil éifeachtacha a chur i bhfeidhm, chun dea-thorthaí comhshaoil a bhaint amach agus díriú orthu siúd nach mbíonn ag cloí leo.

Eolas: Sonraí, eolas agus measúnú ardchaighdeáin, spriocdhírithe agus tráthúil a chur ar fáil i leith an chomhshaoil chun bonn eolais a chur faoin gcinnteoireacht.

Abhcóideacht: Ag obair le daoine eile ar son timpeallachta glaine, táirgiúla agus dea-chosanta agus ar son cleachtas inbhuanaithe i dtaobh an chomhshaoil.

I measc ár gcuid freagrachtaí tá:

Ceadúnú

- Gníomhaíochtaí tionscail, dramhaíola agus stórála peitril ar scála mór;
- Sceitheadh fuíolluisce uirbigh;
- Úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe;
- Foinsí radaíochta ianúcháin;
- Astaíochtaí gás ceaptha teasa ó thionscal agus ón eitlíocht trí Scéim an AE um Thrádáil Astaíochtaí.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Iniúchadh agus cigireacht ar shaoráidí a bhfuil ceadúnas acu ón GCC;
- Cur i bhfeidhm an dea-chleachtais a stiúradh i ngníomhaíochtaí agus i saoráidí rialáilte;
- Maoirseacht a dhéanamh ar fhreagrachtaí an údaráis áitiúil as cosaint an chomhshaoil;
- Caighdeán an uisce óil phoiblí a rialáil agus údaruithe um sceitheadh fuíolluisce uirbigh a fhorfheidhmiú
- Caighdeán an uisce óil phoiblí agus phríobháidigh a mheasúnú agus tuairisciú air;
- Comhordú a dhéanamh ar líonra d'eagraíochtaí seirbhíse poiblí chun tacú le gníomhú i gcoinne coireachta comhshaoil;
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Dramhaíola agus Ceimiceáin sa Chomhshaol

- Rialacháin dramhaíola a chur i bhfeidhm agus a fhorfheidhmiú lena n-áirítear saincheisteanna forfheidhmithe náisiúnta;
- Staitisticí dramhaíola náisiúnta a ullmhú agus a fhoilsiú chomh maith leis an bPlean Náisiúnta um Bainistíocht Dramhaíola Guaisí;
- An Clár Náisiúnta um Chosc Dramhaíola a fhorbairt agus a chur i bhfeidhm;
- Reachtaíocht ar rialú ceimiceán sa timpeallacht a chur i bhfeidhm agus tuairisciú ar an reachtaíocht sin.

Bainistíocht Uisce

- Plé le struchtúir náisiúnta agus réigiúnacha rialachais agus oibriúcháin chun an Chreat-treoir Uisce a chur i bhfeidhm;
- Monatóireacht, measúnú agus tuairisciú a dhéanamh ar chaighdeán aibhneacha, lochanna, uiscí idirchreasa agus cósta, uiscí snámha agus screamhuisce chomh maith le tomhas ar leibhéil uisce agus sreabhadh abhann.

Eolaíocht Aeráide & Athrú Aeráide

- Fardail agus réamh-mheastacháin a fhoilsiú um astaíochtaí gás ceaptha teasa na hÉireann;
- Rúnaíocht a chur ar fáil don Chomhairle Chomhairleach ar Athrú Aeráide agus tacaíocht a thabhairt don Idirphlé Náisiúnta ar Ghníomhú ar son na hAeráide;
- Tacú le gníomhaíochtaí forbartha Náisiúnta, AE agus NA um Eolaíocht agus Beartas Aeráide.

Monatóireacht & Measúnú ar an gComhshaol

- Córais náisiúnta um monatóireacht an chomhshaoil a cheapadh agus a chur i bhfeidhm: teicneolaíocht, bainistíocht sonraí, anailís agus réamhaisnéisiú;
- Tuairiscí ar Staid Thimpeallacht na hÉireann agus ar Tháscairí a chur ar fáil;
- Monatóireacht a dhéanamh ar chaighdeán an aeir agus Treoir an AE i leith Aeir Ghlain don Eoraip a chur i bhfeidhm chomh maith leis an gCoinbhinsiún ar Aerthruailliú Fadraoin Trasteorann, agus an Treoir i leith na Teorann Náisiúnta Astaíochtaí;
- Maoirseacht a dhéanamh ar chur i bhfeidhm na Treorach i leith Torainn Timpeallachta;
- Measúnú a dhéanamh ar thionchar pleananna agus clár beartaithe ar chomhshaol na hÉireann.

Taighde agus Forbairt Comhshaoil

- Comhordú a dhéanamh ar ghníomhaíochtaí taighde comhshaoil agus iad a mhaoiniú chun brú a aithint, bonn eolais a chur faoin mbeartas agus réitigh a chur ar fáil;
- Comhoibriú le gníomhaíocht náisiúnta agus AE um thaighde comhshaoil.

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta agus nochtadh an phobail do radaíocht ianúcháin agus do réimsí leictreamaighnéadacha a mheas;
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha;
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta;
- Sainseirbhísí um chosaint ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Ardú Feasachta agus Faisnéis Inrochtana

- Tuairisciú, comhairle agus treoir neamhspleách, fianaise-bhunaithe a chur ar fáil don Rialtas, don tionscal agus don phobal ar ábhair maidir le cosaint comhshaoil agus raideolaíoch;
- An nasc idir sláinte agus folláine, an geilleagar agus timpeallacht ghlan a chur chun cinn;
- Feasacht comhshaoil a chur chun cinn lena n-áirítear tacú le hiompraíocht um éifeachtúlacht acmhainní agus aistriú aeráide;
- Tástáil radóin a chur chun cinn i dtithe agus in ionaid oibre agus feabhsúchán a mholadh áit is gá.

Comhpháirtíocht agus Líonrú

- Oibriú le gníomhaireachtaí idirnáisiúnta agus náisiúnta, údaráis réigiúnacha agus áitiúla, eagraíochtaí neamhrialtais, comhlachtaí ionadaíocha agus ranna rialtais chun cosaint chomhshaoil agus raideolaíoch a chur ar fáil, chomh maith le taighde, comhordú agus cinnteoireacht bunaithe ar an eolaíocht.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an GCC á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóir. Déantar an obair ar fud cúig cinn d'Oifigí:

1. An Oifig um Inbhunaitheacht i leith Cúrsaí Comhshaoil
2. An Oifig Forfheidhmithe i leith Cúrsaí Comhshaoil
3. An Oifig um Fhianaise agus Measúnú
4. An Oifig um Chosaint ar Radaíocht agus Monatóireacht Comhshaoil
5. An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tugann coistí comhairleacha cabhair don Ghníomhaireacht agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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