PR3 | Columbia University
MS in Sustainability Management

STADIUMS' IMPACT:

HOW SPORTS AND BEER CAN CHANGE THE WORLD

INTEGRATIVE CAPSTONE WORKSHOP | FALL 2024

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BACKGROUND

Over 350 million fans attend sporting or entertainment events every year in the United States, requiring approximately 3 billion single-use items, and many of these items will be beverage cups (Green Sports Alliance, 2024). The average sports stadium in the US throws away 5.4 million cups every year (Prindiville, 2023). Using single-use items such as beverage cups is undeniably convenient. However, this convenience is associated with negative environmental and social impacts at each stage of a cup's life cycle. Single-use plastic poses additional concerns for human and environmental health from its production, use, and disposal (Geneva Environment Network, n.d.). By addressing the externalities of single-use plastic cups and examining attributes of successful reuse systems, this report underscores the environmental and economic benefits of transitioning to reusable food and beverage containers.

KEY FINDINGS

The key findings from this research span four main areas considering the environmental, social, and economic impacts of stadiums switching from single-use to reusable cups.

Literature Review of Life Cycle Assessments (LCAs): A lack of transparency in existing LCAs makes comparison difficult, necessitating a transparent, stadium-specific LCA to fully understand the environmental impacts.

Designing a Successful Reuse System: Successful reuse service providers share common implementation strategies, where they can offer a package deal to stadiums.

The Business Case for Stadiums: The cost of a reuse service provider contract is a major driver of net benefits in the cost-benefit analysis (CBA) for stadiums, and as a result can limit the financial viability of stadium-level reuse.

Understanding Hidden Costs: While negative environmental and social costs of plastic exist, they need to be more precisely quantified, especially regarding beverage cups.Based on our findings, switching to reusable cups can mitigate over $300,000 in emissions from World Cup games in the US.

FOREWORD

About This Report

This report represents the collaborative work of Columbia University students as part of the Master of Science in Sustainability Management program. Building upon the Green Sports Alliance's (GSA) Reuse Playbook, the main objective of this report is to deepen insights, provide actionable recommendations, and support the strategic growth and integration of reusable cups within sports stadium operations (Green Sports Alliance, 2024). By addressing the externalities of single-use plastic cups, this report underscores the environmental and economic benefits of transitioning to reuse systems in sports stadiums.

PR3

This report was prepared for PR3, the Global Alliance to Advance Reuse (referred to hereafter as "the client"). PR3 is a non-profit organization bringing together corporate, government, and non-governmental organization (NGO) stakeholders to establish guidelines for reusable packaging systems. Reuse systems are currently fragmented. The PR3 Standards will enable interoperability and expansion of reuse systems by providing a common framework that enhances economic viability, consumer convenience, and operational efficiency, ultimately optimizing environmental outcomes (PR3, n.d.).

Acknowledgements

Our team would like to thank PR3 for their collaboration and support in developing this report and for trusting us with this project. We would also like to thank the many interviewees who offered their time and shared industry expertise that significantly contributed to the outcomes presented in the following pages. Lastly, we would like to extend our gratitude to our Faculty Advisor, Chandler Precht, for her endless support and guidance throughout the semester.

GLOSSARY

Break-even point	Number of uses required for reusable cups to have a lower environmental impact than single-use cups
CBA	Cost-benefit analysis
Circular economy	Economic model that aims to keep products, materials and resources in use for as long as possible to mitigate their environmental impacts
Closed-loop system	In a closed system, the reusable serviceware is intended to be returned before leaving the premises. Examples include stadiums, arenas, and music venues where fans cannot take their reusable items outside (Green Sports Alliance, 2024).
FIFA	Fédération Internationale de Football Association
GSA	Green Sports Alliance
KDP	Keurig Dr. Pepper
kg CO_2e	Kilogram carbon dioxide equivalent
kg SO_2e	Kilogram sulfur dioxide (SOx) equivalent
kg PO_4e	Kilogram phosphate equivalent
LCA	Life cycle assessment
NGO	Non-governmental organization
NPV	Net present value
Open-loop system	In an open system, customers can leave a venue or space with reusable serviceware. Examples include restaurant takeout programs or to-go coffee at cafes, as items can be consumed off-premise and returned to the vendor later (Green Sports Alliance, 2024).
PET	Polyethylene terephthalate
PLA	Polylactic acid
PP	Polypropylene (a.k.a. plastic #5)
Return rate	Percentage of reusable containers used and collected over a specific period of time
SS	Stainless steel

INTRODUCTION

Problem: Single-Use Plastic

The current linear economy follows a ‘take-make-waste’ approach where raw materials are extracted from the earth to create products that are likely to be used only once before being discarded. A circular economy is one that aims to keep products, materials, and resources in use for as long as possible, resulting in reduced negative environmental impacts. See Figures 1 and 2 for example system maps of linear and circular systems. While circular systems present opportunities for all materials, designing away from single-use plastic presents additional opportunities due to the harmful effects of plastic on environmental and human health (Geneva Environment Network, n.d.). Using plastic products like single-use cups is undeniably convenient; however, the volumes of waste and pollution generated from manufacturing, transporting, and disposing of containers for this convenience represent a cost far beyond the nominal “sticker price” of a single cup. The client’s goal of advancing reuse is motivated by an overarching mission of eliminating historical patterns of single-use consumption and waste. This report highlights often overlooked hidden costs associated with single-use systems, including environmental degradation, public health, waste management burdens, and long-term financial impacts. Furthermore, this report compares these hidden costs to the nominal costs of implementing reuse systems and reviews existing literature and best practices for reusable cups and their implementation.

Solution: Reusable Cups at Stadiums

Over 350 million fans attend sporting or entertainment events every year in the United States, generating around 3 billion single-use items of waste (Green Sports Alliance, 2024). Many of these single-use items will be beverage containers, whether cups, cans, or bottles. The environmental impact of the consumption of single-use containers on such a massive scale provides an opportunity for change. Thus, this report focuses on replacing single-use beverage containers with reusable inventory, a minor adjustment to existing operational processes that is a highly effective step toward sustainable waste management.

Why Stadiums?

As indicated by the rapid growth in their sustainability-related initiatives, sports teams and sporting event venues are increasingly concerned with their impact on the environment and communities. Stadiums, in particular, are a centralized source of impact as they bring thousands of fans together in one place at one time, and many consume food and drinks purchased within the stadium. Stadiums offer a perfect environment for a successful reuse system because they act as closed-loop systems where drinks are bought and consumed in the stadium and returned at the end of the game. This is in contrast to open-loop systems, which rely on the consumers bringing their own containers and risk loss or improper disposal of these cups. Sports fans bring enthusiasm, camaraderie, and loyalty to their team, their sport, and their stadium, making consumer engagement a critical component of a successful reuse system.

Reuse systems require dishwashing facilities, often offsite and operated by a third-party reuse service provider. The reuse service provider industry is still immature, although a few notable players are in the market. For the growth of this market to continue, these service providers need to expand into new cities, but in order to do so, they need a reliable client base in each city. With thousands of visitors and consistent game schedules, stadiums are a perfect "anchor" client to ignite a new market area for reuse service providers. In turn, reuse being established in new markets provides economic growth and job opportunities in these communities, especially for historically marginalized groups.

Figure 1. Linear system map illustrating stages of single-use cup consumption

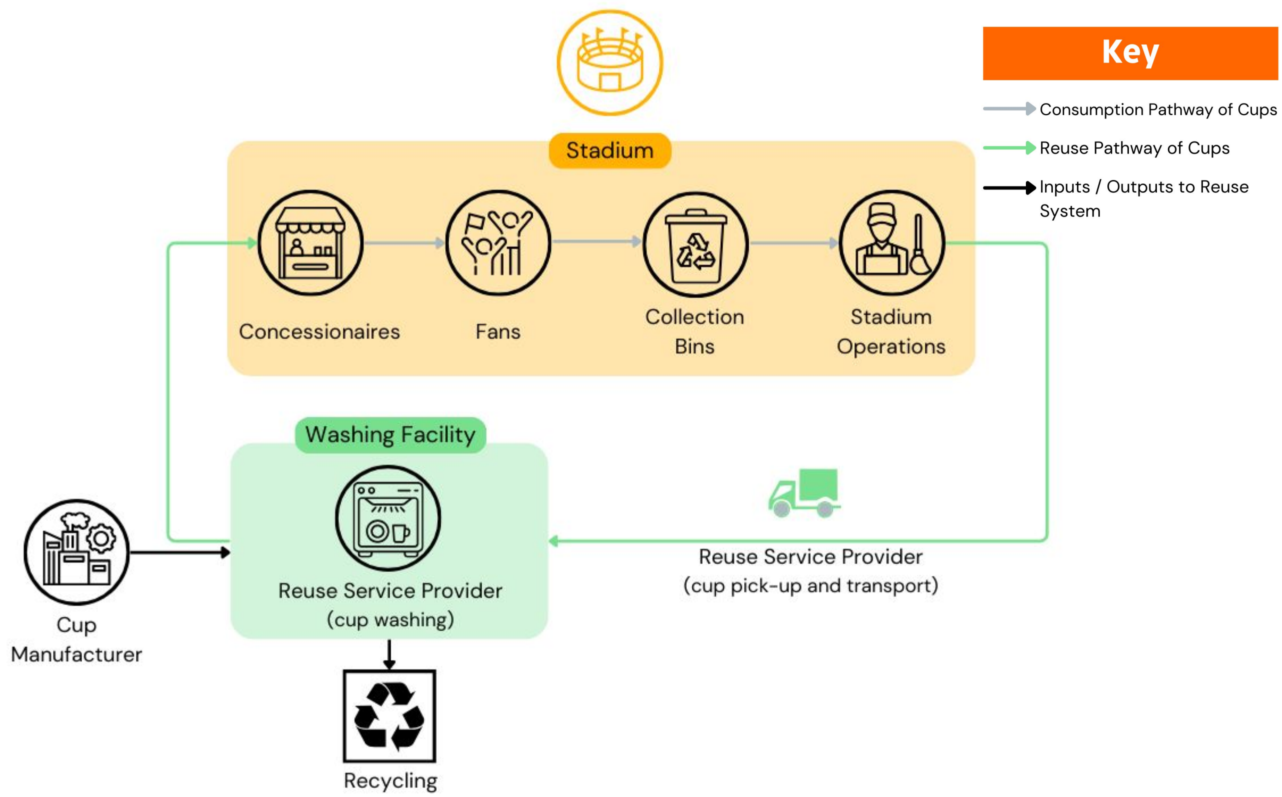


Figure 2. Circular system map illustrating stages of reusable cup consumption

Opportunity: 2026 FIFA World Cup

While there are some examples of successful reuse markets in the United States, they are limited. Major sporting events can be catalysts for change, and the 2026 FIFA World Cup presents a unique opportunity to be just that. The 2026 FIFA World Cup will be hosted by Canada, Mexico, and the US in 16 stadiums (Figure 3). Out of the 16 stadiums in North America, 11 are located in the US, and cumulatively will host 78 the of World Cup matches, bringing hundreds of thousands of fans together in person and millions more on television. The 2022 FIFA World Cup in Qatar hosted a cumulative 3.4 million spectators in person, with an average overall attendance capacity of 96.3% ("FIFA World Cup Qatar 2022™ in Numbers," n.d.). Additionally, FIFA suggests that around 5 billion people were engaged with tournament content across media platforms ("The FIFA World Cup 26™ stadiums," 2024).

As of time of writing this report, none of these large stadiums currently have reuse systems in place (though pilot programs may be on the horizon), but the World Cup could be a turning point for them to transition away from single-use beverage containers.

Figure 3. Map of 2026 FIFA World Cup Stadiums (Source: Flytrippers)

Insights for Stakeholder Engagement

This report was tailored for several audiences involved in sports stadium operations and reuse systems. A cost-benefit analysis conducted by the research team, accompanied by design and implementation strategies, provides valuable financial insights for stadium owners and investors. Later, an analysis of plastic production and its broader economic impacts demonstrates the scale of the single-use plastic problem and highlights stadium beverage cups as a unique opportunity for green investors and local governments to get involved with the reuse transition. Reviews and gap analyses of relevant literature point to opportunities for stakeholders in academia to strengthen the technological foundations upon which reuse advocacy is based. The research team recognizes the need for collaboration at the core of all sustainability initiatives, and the structure of this report ensures that all stakeholders, including those displayed in Table 1, are adequately represented.

Table 1. Reuse stakeholder groups, their components, and their relevance

Stakeholder Groups	Stakeholders	Relevance to Reuse
Drivers / Influencers of Reuse	• Corporate Sponsors • Stadium Owners • Sports Teams • Government Agencies • NGOs • Hospitality Partners	These stakeholders play a crucial role in promoting and implementing reuse systems by providing funding, setting policies, and raising awareness about sustainable practices.
Reuse / Single-Use System Users	• Cup Manufacturers • Concessionaires • Fans • Stadium Operations • Waste Collectors and Sorters • Reuse Service Providers	These stakeholders are directly engaged with the system at some point along the value chain from raw material extraction to consumption through end-of-life.
Impacted Communities	• Communities Living Near Manufacturing Sites • Communities Living Near Landfills or Incenerators	Although not necessarily directly engaged with the system, these stakeholders are directly affected by the impacts of the system.

ASSESSING THE IMPACTS OF SINGLE-USE VERSUS REUSABLE CUPS

Objective, Scope and Context

Life Cycle Assessment (LCA) is a powerful tool for calculating a product's environmental footprint over its lifetime. As defined by the International Organization for Standardization (2006), an LCA "addresses the environmental aspects and potential environmental impacts throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal (i.e., cradle-to-grave)." LCAs typically measure environmental impact categories such as energy use, climate change, and air pollution, among others. They can inform decision-making, identify product impact reduction opportunities, provide environmental performance indicators, and support marketing-related environmental claims (ISO, 2006). A comparative LCA measures the impacts of two or more products simultaneously, allowing professionals to determine which has a lesser environmental impact (Figure 4).

Starting with the assumption that reusable cups are a more environmentally friendly alternative to single-use cups, the research team conducted a literature review of existing comparative LCAs.

This review addressed the following research questions:

1. Are reusable cups more **environmentally sustainable** than single-use cups?
2. Are there reusable or single-use cup materials that consistently have the **largest or smallest environmental impacts?**
3. Are there **significant gaps in existing LCAs** comparing single-use to reusable cup materials in a context relevant to stadium use?

The research team reviewed relevant, publicly available LCAs evaluating the environmental footprints of different cup materials. Numerous LCAs that compare single-use and reusable hot beverage cups were identified, typically in home, office, or restaurant settings. These studies often compared single-use cups made of paper or Styrofoam® to reusable ceramic cups. Such studies were generally not applicable to this report, as their focus on hot beverage cups does not align with the primary use of cups at stadiums for cold beverages like water, fountain drinks, and alcoholic beverages. Moreover, stadiums uniquely operate in a closed-loop system in which beverages are consumed onsite and the reusable cups returned before patrons leave the venue, as opposed to the open-loop system of a space in which items are taken and consumed offsite (Green Sports Alliance, 2024).

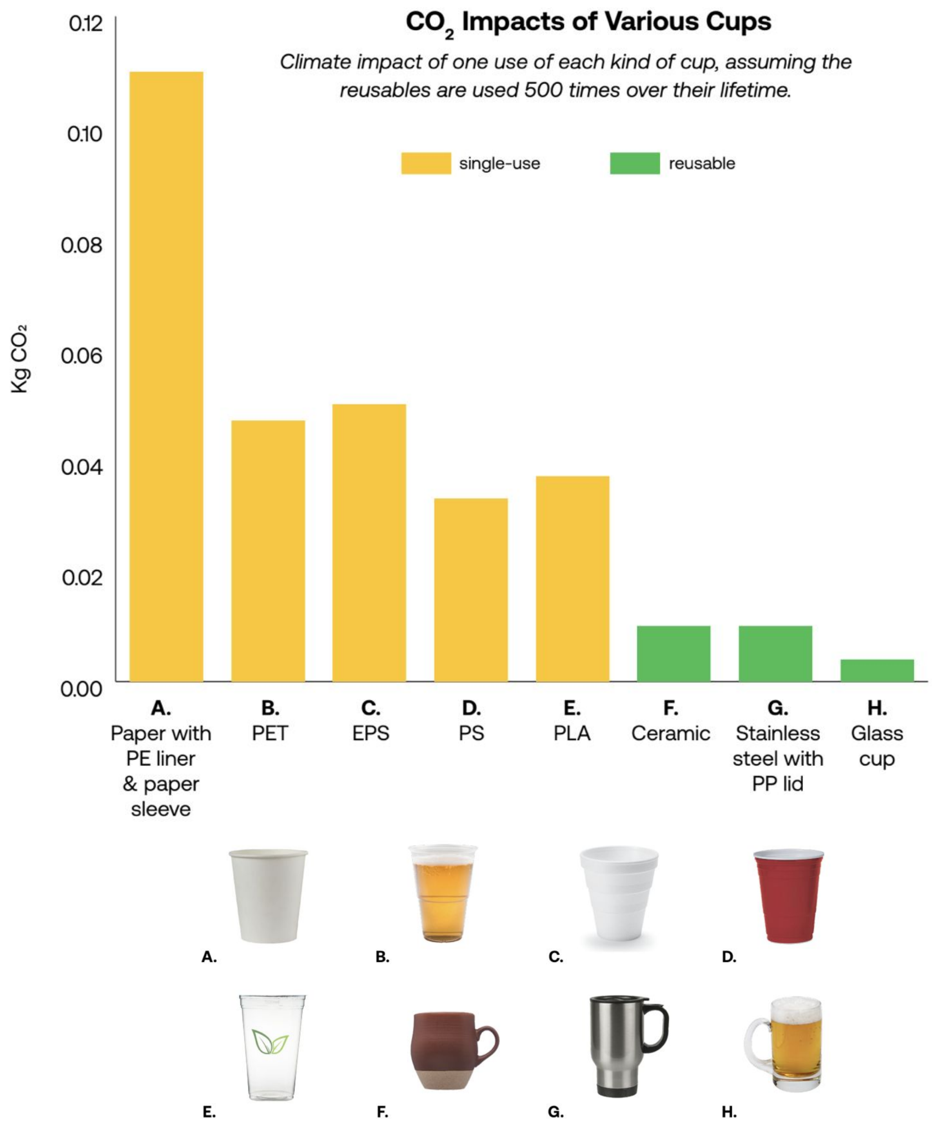


Figure 4. Comparative LCA: climate impacts of various cup materials when used 500 times. (Source: Wentz, 2021)

Summary of Relevant LCAs

To answer research questions 1 and 2 noted above, the research team analyzed two comprehensive meta-analyses comparing the results of different LCAs focusing on both hot and cold beverage cups, nine individual LCAs comparing single-use and reusable cold beverage cups, and two LCAs comparing single-use and reusable hot beverage cups (Table 2). Two hot beverage cup studies were reviewed to ensure that this part of the literature is represented; these studies still have applicable findings, particularly in the use phase (Martin, Bunsen, & Ciroth, 2018; Woods & Bakshi, 2014). Of the 11 individual LCAs, four were specific to large-scale events such as sporting events at stadiums (de Sadeleer & Lyng, 2022; Pladerer et al., 2008; Vercalsteren, Sprinckx, & Geerken, 2010; Wentz, 2021).

Table 2. Summary of LCAs Reviewed for this report

Study Type	Title	Focus	Source
Meta-analysis	Single-use beverage cups and their alternatives	Hot and cold cups	Lewis et al., 2021
Meta-analysis	A critical comparison of ten disposable cup LCAs	Hot and cold cups	Van der Herst & Potting, 2013
Large Event Context			
Comparative LCA	The Life Cycle Assessment on Single-use and Reuse Beer Cups at Festivals	Cold cups	de Sadeleer & Lyng, 2022
Comparative LCA	Comparative Life Cycle Assessment of various Cup Systems for the Selling of Drinks at Events: Focussing on major events such as the European Football Championships UEFA EURO 2008 in Austria and Switzerland as well as the German "Bundesliga"	Cold cups	Pladerer et al., 2008
Comparative LCA	Life cycle assessment and eco-efficiency analysis of drinking cups used at public events	Cold cups	Vercalsteren, Sprinckx, & Geerken, 2010
Comparative LCA	Reuse wins at events	Cold cups	Wentz, 2021
Other Context			
Comparative LCA	Assessment of the environmental break-even point for deposit return systems through an LCA analysis of single-use and reusable cups	Cold cups	Cottafava et al., 2020
Comparative LCA	Environmental Evaluation of Single-Use and Reusable Cups	Cold cups	Garrido & Alvarez del Castillo, 2007
Comparative LCA	The re:dish Reusables Program: LCA Findings Report	Cold cups	Re:dish, 2023
Comparative LCA	Reusable is Futurable: A comparative life-cycle assessment on the environmental performance of reuse and disposable Cup Systems in East Asia.	Cold cups	Sauerwein & Chopra, 2023

Table 2. Summary of LCAs Reviewed for this report (cont.)

Other Context			
Comparative LCA	Reusable and Disposable Cups: An Energy Based Evaluation	Hot and cold cups	Hocking, 1994
Comparative LCA	Case Study: Ceramic cup vs. paper cup	Hot cups	Martin, Bunsen, & Ciroth, 2018
Comparative LCA	Reusable vs. disposable cups revisited: guidance in life cycle comparisons addressing scenario, model, and parameter uncertainties for the US consumer	Hot cups	Woods & Bakshi, 2014

Findings: Meta-Analyses

The research team examined two studies that comprehensively compared multiple LCAs and 11 individual LCAs.

The first of the two comprehensive studies, “Single-use beverage cups and their alternatives,” provides insight into how LCAs can inform policy decisions related to single-use plastic cups (Lewis et al., 2021). The study analyzed ten LCAs comparing single-use cups against reusable alternatives for hot and cold beverages. Lewis et al. (2021) concluded that across studies no single-use material consistently outperformed other single-use materials, and no reusable material consistently outperformed other reusable materials. However, when comparing reusable cups to single-use cups, they concluded that reusable cups are the better alternative, especially where there is high grid renewable energy penetration, single-use cup recycling rates are low, and users are cognizant of best practices for cup washing. The authors found that cup material, manufacturing, and end-of-life emerged as the most impactful phases, with recycling shown to significantly reduce environmental impacts. It was also determined that the break-even point—the number of uses required for reusable cups to have a lower environmental impact than single-use cups—ranged from between 10 uses (for reusable polypropylene cups vs. single-use polylactic acid lined paper cups) to over 1,000 uses (for reusable plastic cups vs. single-use 80% recycled polyethylene lined paper cups). Regardless of material, the climate change break-even point for the majority of studies was between 10 and 140 uses. This range arose from the variability of materials selected, as well as the sensitivity of LCA results to geographical context, variable functional units (e.g., a single beverage versus a given mass of plastic), reuse assumptions (number of reuses and washing behavior), choice of environmental impact categories, modeling choices, and end-of-life parameters (Lewis et al., 2021). This variability makes it challenging to establish a definitive threshold for the number of uses required for a reusable cup to have a lesser environmental impact than a single-use cup.

The second of the comparative analyses, “A critical comparison of ten disposable cup LCAs,” compiled the results of ten LCAs evaluating the environmental impacts of single-use hot and cold beverage cups (van der Herst & Potting, 2013). The study was published in the peer-reviewed Journal of Environmental Impact Assessment Review and aimed to directly compare cups’ climate impacts by standardizing cup sizes and recalculating study results. Just as Lewis et al. (2021) concluded, the authors found that no cup material was consistently the best or worst compared to other materials. They observed variable functional units and heavy emphasis on the climate impact category over other categories such as water depletion or ecotoxicity. The study identified raw material extraction, cup manufacturing, and end-of-life as the most impactful phases. Notably, the study concluded that differences in methodological modeling choices were often based on differing product systems, which are unavoidable. Differences in modeling include variable cup materials and cup sizes, functional units (e.g., 750 milliliter (mL) of beverage served 300 times, or one 16 fluid ounce (oz) cup), and datasets used. Other factors that make product systems inevitably unique include the use of different technologies in cup manufacturing, the sourcing of energy from varying grid mixes depending on the geographical location of manufacturing and washing, and the differing waste treatment pathways to recycling or incineration based on final end-of-life location (van der Herst & Potting, 2013).

Based on the takeaways of these two comparative analyses, it is difficult to compare studies due to variability in the methodologies, assumptions, and conclusions, but this does not diminish their inherent value. An LCA's applicability depends on how well it aligns with the researchers’ required context.

Findings: Comparative LCAs in a Large Event Context

One of the most context-relevant of the 11 individual LCAs the research team reviewed is “Reuse wins at events” by the reuse change agency Upstream (Wentz, 2021). This LCA provides a stadium-specific analysis of reusable cups in a closed-loop system and recommends reusable cup adoption based on a comparison of multiple materials’ impacts and break-even points. Incorporating a system boundary of a sports stadium provides crucial insights into sports and entertainment venues' sustainability, operations, maintenance, and challenges. Wentz (2021) evaluated 16 oz single-use cups made from polyethylene terephthalate (PET), polylactic acid (PLA), and aluminum, and 16 oz reusable cups made from polypropylene (PP) and stainless steel (SS) by examining their environmental impacts across energy consumption (megajoules (MJ)), carbon emissions (kg CO_2e), air acidification (kg SO_2e), water eutrophication (kg PO_4e), and waste generation (tons of waste landfilled). Findings were reported using the footprint of each cup after a certain number of uses. For example, Figure 5 illustrates that the total energy consumption of one 16 oz reusable PP cup after 5 uses is comparable to that of one 16 oz single-use PET cup but progressively decreases after additional uses.

This provides a helpful visual that communicates the correlative relationship between an increased frequency of cup reuses and reduced environmental impacts. However, while all chosen impact categories are reported, the report's conclusions focus solely on the climate change and energy consumption impact categories, neglecting to examine air acidification, water eutrophication, and waste generation (Wentz, 2021).

Three other studies were also conducted with a large event context, but are slightly less applicable than Wentz (2021) because they focused on European countries (de Sadeleer & Lyng, 2022; Pladerer et al., 2008; Vercalsteren, Spirinckx, & Geerken, 2010). This is significant due to the differences in grid mix and end-of-life pathways in European countries compared to the US. Still, each of these three studies offers unique insights.

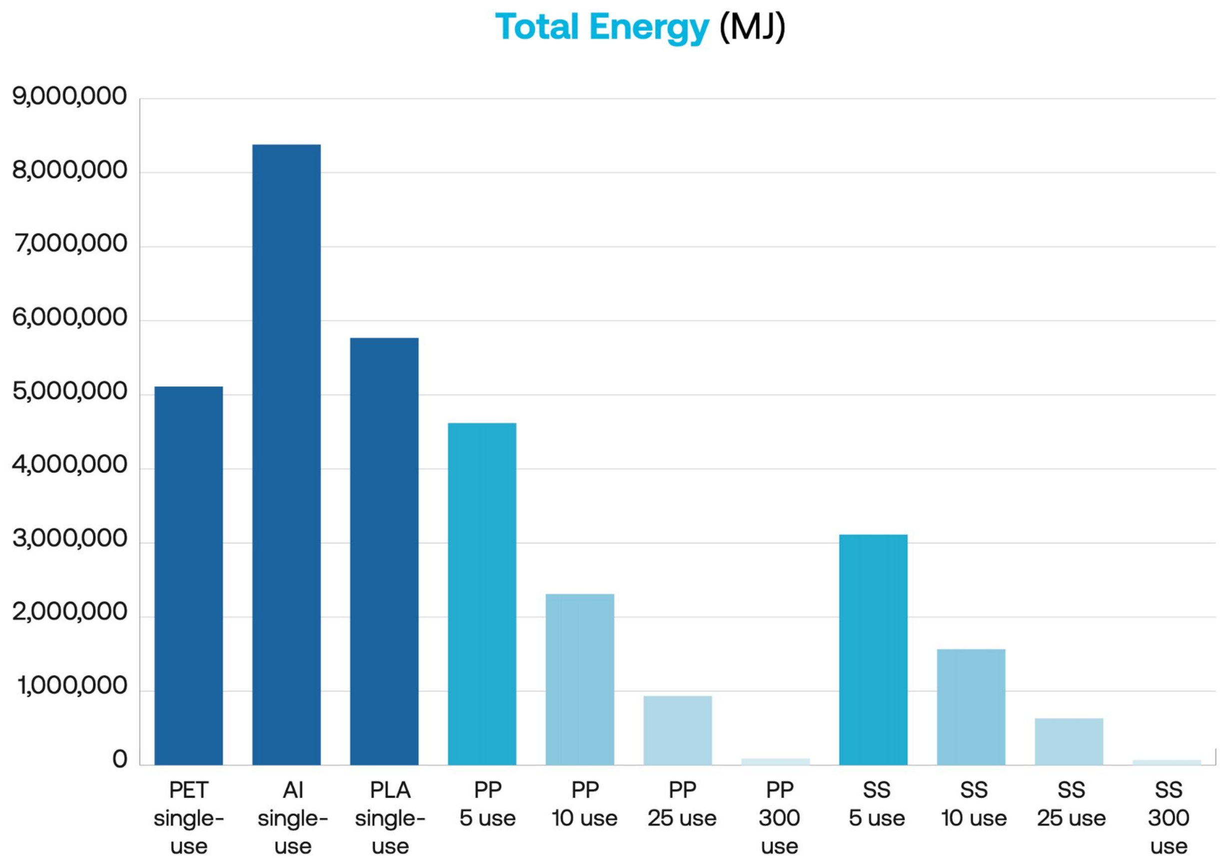


Figure 5. Total energy consumption (MJ) of cups from an 18,000-seat venue with 300 sold-out events (Source: Wentz, 2021)

Vercalsteren, Spirinckx, & Geerken (2010) compared the environmental impacts of single-use and reusable systems at both small (2,000-5,000 attendees) and large (>30,000 attendees) events in Belgium. They measured the impacts of reusable polycarbonate cups against those of single-use PP, single-use polyethylene coated cardboard, and single-use polylactic acid cups based on a functional unit of a serving of 100 liters of beer or soft drinks

They concluded that no cup system has the highest or lowest footprint for all impact categories. Notably, they found that reusable cup systems had a heavier environmental burden for large events than small events and attributed this to cup washing. The authors argued that the need for machine washing at large events led to greater use of energy, water, and transportation fuel (Vercalstern, Spirinckx, & Geerken, 2010). However, these results are in direct conflict with the findings of a number of other studies which found that machine washing is more efficient than hand-washing (Cottafava et al., 2020; Garrido & Alvarez del Castillo, 2007; Hocking, 1994; Martin, Bunsen, & Ciroth, 2018; Woods & Bakshi, 2014). The drivers behind this disagreement remain unclear, highlighting the challenges related to the inter-comparability of LCAs.

Both de Sadeleer & Lyng (2022) and Pladerer et al. (2008) analyzed the footprint of reusable PP cups against several single-use cup materials. De Sadeleer & Lyng (2022) reported on an exhaustive list of 18 environment impact categories and concluded that if cup return rates (the percentage of reusable containers used and collected over a specific period of time) are high, the reusable cup system outperforms single-use cups (PP and PET) in all but four of these categories. While the authors did not define what may constitute a “high” return rate, some reuse clients have been found to achieve rates of 90% or higher (Interviewee 11, personal communication, November 21st, 2024). Meanwhile, Pladerer et al. (2008) reported on eight impact categories and found that reusable cups significantly outperformed every single-use material (polystyrene, coated cardboard, biodegradable polylactic acid, and BELLAND recycled material) across all impact categories. Of the four categories found by de Sadeleer & Lyng (2022) to be worse for reusable cups, Pladerer et al. (2008) looked at only eutrophication; however, while the former distinguished between freshwater and marine eutrophication, the latter did not. The study conclusions highlight the influence that different selections of environmental impact categories can have on findings.

Despite this, both studies came to the same conclusions regarding the substantial contribution of the materials, manufacturing, and end-of-life phases to systems’ environmental impacts as well as the critical influence of return rates, wherein higher return rates significantly decrease the environmental impacts of reusable cups. Strategies to maximize cup return rates in reuse systems are discussed in Section III. of this report, “Review of Successful Reuse Systems at Stadiums.”

Findings: All Studies

Though all studies possessed unique structures and contexts, some clear trends emerged. Firstly, the materials, manufacturing, and/or end-of-life phases were consistently determined to contribute most to cups' environmental impacts (Cottafava et al., 2020; de Sadeleer & Lyng, 2022; Garrido & Alvarez del Castillo, 2007; Hocking, 1994; Lewis et al., 2021; Pladerer et al., 2008; re:dish, 2023; Sauerweign & Chopra, 2023; van der Herst & Potting, 2013; Wentz, 2021).

Secondly, cup washing was found to have significant effects on the environmental performance of reusable cup systems. This is largely due to the additional energy, water, and transportation requirements which do not exist in single-use cup systems. Of the studies identifying the use (washing) phase as particularly important, the majority concluded that dishwashing was more efficient than hand-washing (Cottafava et al., 2020; Garrido & Alvarez del Castillo, 2007; Hocking, 1994; Martin, Bunsen, & Ciroth, 2018; Woods & Bakshi, 2014). Of these, some specifically highlight the importance of dishwasher efficiency (Hocking, 1994; Martin, Bunsen, & Ciroth, 2018; Woods & Bakshi, 2014). Notably, Cottafava et al. (2020) found that hand-washing reusable cups is the worst option across all environmental impact categories, while offsite industrial dishwashing is the best option where round-trip transport distance is less than 50 km. This distance threshold is a unique observation of their study and warrants some consideration when conducting future research or designing reuse systems. Despite this consensus, three studies reach contradictory conclusions. While Vercalsteren, Spirinckx, & Geerken (2010) found the use phase to be significant, they concluded that hand-washing was more efficient. Meanwhile, Pladerer et al. (2008) and Wentz (2021) found the use phase's influence to be negligible. The cause of these discrepancies remains unclear.

Finally, the most commonly analyzed reusable cup material was polypropylene (PP), which was considered in seven of the 11 comparative LCAs studied (Cottafava et al., 2020; de Sadeleer & Lyng, 2022; Garrido & Alvarez del Castillo, 2007; Pladerer et al., 2008; Sauerwein & Chopra, 2023; re:dish, 2023; Wentz, 2021). While climate change was not the only impact category for which a break-even point was calculated, it was the most commonly reported across studies, making it the focus here. Across these studies, the climate break-even point of PP ranged from between two uses (against single-use PLA cups (Wentz, 2021)) to ten uses (against single-use coated cardboard (Cottafava et al., 2020; Pladerer et al., 2008)). The range of climate break-even points across all reusable and single-use materials was between two uses (reusable PP against single-use PLA (Wentz, 2021)) and 89 uses (hand-washed ceramic against single-use PE coated paper (Sauerwein & Chopra, 2023)). Cottafava et al. (2020) reported most thoroughly on different environmental impact categories' break-even points, finding that reusable cups performed best in climate change, ozone depletion, and non-renewable energy use.

With respect to research question 1 ("Are reusable cups more environmentally sustainable than single-use cups?"), the findings of the literature review support the conclusion that reusable cups are more environmentally friendly than single-use cups, as long as they are washed with industrial dishwashers and system return rates are sufficient. As for research question 2 ("Are there reusable or single-use cup materials that consistently have the largest or smallest environmental impacts?"), the research team concluded that no individual material outperformed others in their same use-case, though PP emerged as a popular option

A tabular review of the 11 LCAs the research team analyzed is available upon request.

Gap Analysis of Existing and Relevant LCAs

The research team conducted a gap analysis to answer research question 3 ("Are there significant gaps in existing LCAs comparing single-use to reusable cup materials in a context relevant to stadium use?"). This analysis identified weaknesses in the existing literature and made recommendations for future research to enhance stadiums' and stakeholders' understanding of the potential environmental impacts of implementing a reusable cup system versus a single-use cup system in the status quo (Figure 6).

Figure 6. Overview of LCA Gap Analysis

Transparency

One overarching finding of the gap analysis was the need for increased disclosure of methodologies and assumptions within LCAs. Several studies only partially disclosed the assumptions being made in each LCA phase, making it challenging to understand the drivers behind some studies' conclusions. This lack of transparency can also misconstrue the influence of different factors on final results.

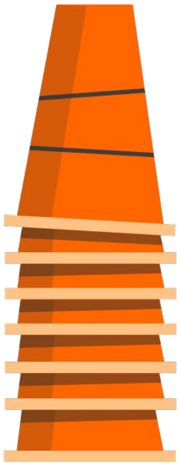
For example, several LCAs did not disclose their cup manufacturing assumptions, such as processes, location, and packaging (de Sadeleer & Lyng, 2022; Garrido & Alvarez del Castillo, 2007; Pladerer et al., 2008; Re:dish, 2023; Sauerwein & Chopra, 2023; Vercalsteren, Spriinckx, & Geerken, 2010; Woods & Bakshi, 2014). Many also did not disclose their transportation-phase assumptions, including vehicle type and distance between manufacturing center and final destination (Hocking, 1994; Pladerer et al., 2008; Re:dish, 2023; Sauerwein & Chopra, 2023; Vercalsteren, Spriinckx, & Geerken, 2010). This information is crucial for linking product emissions to the carbon intensity and energy demands of manufacturing processes.

In general, the materials, use, and end-of-life phases have the most information available amongst the studies examined. However, assumptions vary widely even within these phases. For example, some LCA studies state their specific inputs for dishwasher water and energy use (Cottafava et al., 2021; Garrido & Alvarez del Castillo, 2007; Hocking, 1994; Martin, Bunsen & Ciroth, 2018; Wentz, 2021; Woods & Bakshi, 2014), while others only mention an assumption of industrial dishwasher use (Pladerer et al., 2008; Sauerwein & Chopra, 2023; Re:dish, 2023; Vercalsteren, Spriinckx, & Geerken, 2010). Additionally, further inconsistencies arise in transportation data, where only some studies disclose the specific mileage and vehicle assumptions for round-trip transportation to the washing facility (de Sadeleer & Lyng, 2022; Garrido & Alvarez del Castillo, 2007; Martin et al., 2018; Pladerer et al., 2008; Wentz, 2024; Woods & Bakshi, 2014).

Comparability

Beyond the need for more transparency regarding study assumptions and inputs, a broader challenge emerges when comparing LCAs. Given their reliance on highly detailed, specific data, LCAs are inherently context-sensitive. Geographical location affects factors like grid energy mix and waste management pathways such as recycling or incineration. For example, these factors would have very different inputs in Norway than in the US, or in California than in Texas within the US. (Lewis et al., 2021; van der Herst & Potting, 2013; Woods & Bakshi, 2014).

Similarly, variations in use-cases, such as using a cup in a closed-loop stadium versus using a cup in an open-loop system, will fundamentally alter an LCA's structure (e.g. functional unit, objectives, and/or modeling choices). For example, the meta-analysis by Lewis et al. (2021) found that all 10 studies used different functional units, ranging from "one year of coffee drinking" to "750 x 300 mL of coffee served in a cup – washed by hand." This creates extreme but unavoidable variability between studies, making their results incomparable.



Context

One observation of the selected LCAs is that many focus on hot beverage cups, comparing single-use paper options to reusable ceramic alternatives. Relatively few LCAs specifically focus on cold beverage cups, and even fewer examine their use in a stadium or large event setting. For example, many of the studies in the Lewis et al. (2021) meta-analysis looked at reuse systems in coffee shops or in undefined contexts, making it difficult to understand the applicability of their conclusions.

Similarly, Re:dish (2023) assessed the environmental footprint of reusable products in offices and restaurants, and while this included reusable cups, the study primarily focused on reusable clamshell food containers. This lack of context-relevant studies limited the number of LCAs that were useful to the research team. Of the 11 LCAs reviewed by the research team, only four pertain to large event contexts, and just nine focus on cold beverage cups relevant to stadium systems.

Impact Categories

Overall, Wentz (2021) comes the closest to fitting this report's research needs due to its assessment of relevant stadium reuse systems, above-average transparency of assumptions, and relevant reusable and single-use cup materials. It reports on the environmental impact categories of energy consumption, carbon emissions, air acidification, eutrophication, and waste generation; however, it addresses the results of just two of these impact categories: energy use and carbon emissions. In addition to the visual results shown in the graphs (see Figures 5 & 7), Wentz (2021) reports break-even points of two to five uses for both PP and SS reusable cups, compared to the polyethylene, polylactic acid, and aluminum single-use cups.

The conclusions emphasize that PP and SS cups achieve break-even with all single-use cup materials under all stadium-size and recycling scenarios after five to six uses. However, these break-even points are only reported for the climate change and energy consumption impact categories. Other impact categories such as eutrophication show higher break-even points. For instance, SS cups may require somewhere between 25 to 300 uses to break-even with all types of single-use cups (Figure 7) (Wentz, 2021). The reporting bias towards the climate change and energy use impact categories in the report by Wentz (2021) aligns with the findings of the two comparative analyses that climate change impacts are often overemphasized (Lewis et al., 2013; van der Herst & Potting, 2013). This does not imply that reusable cups are worse (in terms of environmental impacts) than single-use cups, but highlights a general emphasis of results that better align with researchers' expectations. To avoid this, stadiums and reuse stakeholders should carefully consider their prioritization of environmental impact categories. Future studies should be cautious of overemphasizing specific results while neglecting others, ensuring

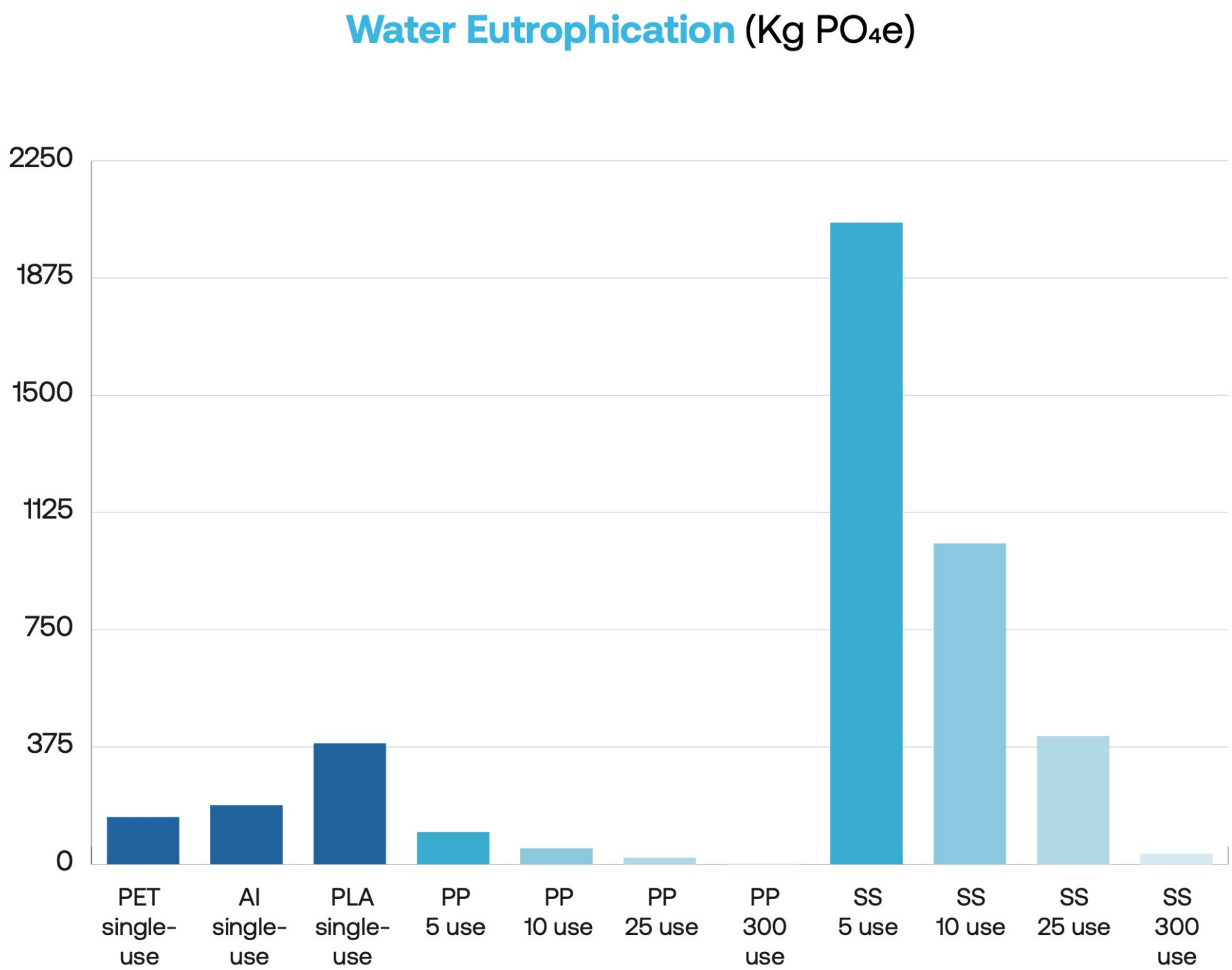


Figure 7. Total water eutrophication (kg PO4e) of cups from an 18,000-seat venue with 300 sold-out events (Source: Wentz, 2021)

that trade-offs—where benefits in certain impact areas may come with drawbacks in others—are acknowledged. Based on international LCA standards, if certain impact categories are favored, this should be explicitly communicated and objectively justified (ISO, 2006).

Recommendation

A reuse system would have unique characteristics depending on the stadium in which it is implemented, including manufacturer selection, grid electricity mix, washing provider, and end-of-life pathways. However, the overall system design across stadiums may still be similar in terms of design and context (e.g., closed-loop system, large events, cold beverage cups). Therefore, the research team recommends that one "Model LCA" with a stadium context, using average US grid emissions and average US recycling rates, is conducted. This Model LCA could compare the environmental impacts of stadiums' most common single-use cup materials to various reusable cup options. While other reusable cup materials may be included in the study, **polypropylene (PP) cups should be assessed** as they have emerged as a prominent reusable option due to their lightweight and durable properties. The results of this Model LCA could be transferable to any large stadium in the US, and could serve as a valuable resource for stadiums seeking to build an environmental business case for reuse systems.

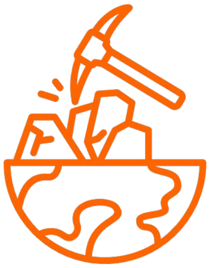
Building Comparable and Context-Relevant LCAs

The Model LCA and any future studies conducted for a stadium context should transparently report all assumptions and data inputs for each life cycle phase. After analyzing 11 LCAs with varying structures, the research team identified some standardizable parameters that the Model LCA should follow which will enhance its comparability to existing and future research.

Functional Unit

The recommended functional unit is a 16 oz cold beverage cup – this is a standard cup size in stadiums and is commonly used in existing literature.

Materials Phase



The following information should be disclosed:

a. Cup material, size, and weight
b. Source of raw material (extraction or production location)

Manufacturing Phase

The following information should be disclosed:

a. Cup manufacturing location, and relevant energy grid emissions factors
b. Cup production processes (e.g., injection molding, thermoforming, etc.)

Transportation Phase

The following information should be disclosed:

a. Vehicle and fuel type
b. Distance between manufacturing location and final destination

Use Phase

The following information should be disclosed (not applicable to single-use cups):

a. Dishwasher energy use, and relevant energy grid emissions factors
b. Dishwasher water use
c. Assumptions for the number of cups washed per dishwasher cycle
d. Transportation vehicle and fuel type, if washing is offsite
e. Round-trip transportation distance from stadium to washing facility, if facility is offsite

End-of-Life Phase

The following information should be disclosed:

a. Regional end-of-life recycling and incineration and applicable emission factors

Ensuring that the Model LCA and any future LCAs conducted to evaluate the environmental impacts of a reusable cup system in stadiums contain the information outlined above will enable stakeholders to better determine the life cycle phases and impact categories of greatest and least importance. This will help stakeholders optimize their reuse systems by better understanding where improvements might be made to minimize environmental impacts and increase efficiency in future iterations of reuse systems.

SUCCESSFUL REUSE SYSTEMS AT STADIUMS

Kaitlin Reese

The research team conducted 17 in-depth interviews with diverse stakeholders, from stadium operations personnel to concessionaires to environmental consultants to reuse service providers, to evaluate key components of reusable cup designs and best practices for successful reuse systems in stadiums. These conversations provided valuable insights into the user experience, financial feasibility, and sustainability impacts of reuse systems within sports stadiums and large venues. In a reuse system, the primary measure of success is the return rate, or the percentage of reusable containers that were used and collected over a specific period of time (Green Sports Alliance, 2024). This section describes strategies to increase return rates, which is a key focus for stadiums and reuse service providers in operating successful reuse systems. Figure 8 visualizes the potential impact of reuse, with 4,340 single-use cups being saved from landfills every Kansas City Current game due to the implementation of reuse replacing single-use cups.

Figure 8. Display at the Bold Reuse washing facility in Kansas City with 4,340 cups stacked in a silo representing the avoided single-use cup waste from one Kansas City Current game (Source: Mason Hines)

Reusable Cup Design

Graphic Design

Graphic design is an effective way for stadiums to spread awareness of the reuse program at a venue while also ensuring the cups are kept within the reuse rotation and not taken home by customers. Some stadiums which have implemented a reuse system design their cups around the stadium's branding rather than the team that plays there. An example of this is shown in Figure 9, a cup designed by Bold Reuse for CPKC Stadium in Kansas City, Missouri, that uses the stadium's signature blue and red colors. Using the stadium's branding instead of the team's can help prevent fans from mistaking the reusable cup for a souvenir and taking it home, which would negatively affect return rate.

Reusable cups can also be an important point of engagement with fans to garner buy-in with the reuse program and to facilitate proper disposal of cups. Having facts about the benefits of reuse on the cup with information such as how many tons of plastic waste is avoided each game or definitions of what reuse is can help boost fan awareness and encourage them to return the cup to the proper collection bin (Figure 9). Additionally, some existing cup designs include illustrations with bright colors that indicate where a reuse cup should be disposed. Reuse service provider r.World utilizes bright colors and reuse marketing in their design (Figure 10). Their cups also display the same bright yellow colors and drawings of the reuse bins to help strengthen the fan association (Figure 11).

Figure 9. Cup with a sustainability fact designed by Bold Reuse for CPKC Stadium (Source: Chandler Precht)

Figure 10. Reusable cup collection bin with "no trash" messaging, designed by r.World (Source: r.World)

Figure 11. Reusable cup with messaging to return to a collection bin, designed by r.World (Source: r.World)

Cup Material

Currently, most stadiums and reuse service providers in the US prefer to use polypropylene (PP, plastic #5) cups. For venues such as stadiums where large crowds gather, fan and athlete safety is a top priority, so stadiums prefer not to use cup materials, such as aluminum or stainless steel, which could turn cups into potential projectiles (Green Sports Alliance, 2024). In addition, polypropylene is lightweight, making it suitable for stadiums. While it is important to limit the use of virgin plastic in these cups, recycled plastic content should be carefully considered because they can contain a higher number of volatile organic chemicals than virgin plastic (Wilcox, 2024). The higher amount of chemicals in recycled plastics is from relaxed voluntary approval policies for recycled plastics by the U.S Food and Drug Administration (Wilcox, 2024). These toxic chemicals could leach out during high-heat washing and long-term use, posing a health risk to consumers (Green Sports Alliance, 2024). Other chemical standards, such as BPA-free, should be followed as well (Green Sports Alliance, 2024).

Cup Size and Shape

Other logistical considerations are also critical to cup design, such as the need for cups to be compatible with seat cup holders in the respective stadium and other relevant stadium-specific requirements. Thorough coordination between the stadium and reuse service provider is key to covering these logistics (Green Sports Alliance, 2024).

Cup Lids

According to one reuse service provider, return rates significantly decrease when a reusable cup has a lid (Interviewee 10, personal communication, October 28th, 2024). When these reusable cups have lids, fans are more likely to take them out of the stadium due to convenience, resulting in a higher loss rate (Interviewee 10, personal communication, October 28th, 2024). The environmental impact of washing the lids and lost lids becoming waste are further negative impacts, so a cup design without lids may be the best practice when applicable.

Stakeholder Engagement

Fan Education

Besides reuse-specific marketing being directly on the cups, stadiums can post this information around the stadium. The Moda Center, located in Portland, Oregon and home of the Portland Trail Blazers, markets its reuse efforts via signage throughout the stadium, encouraging fans to drop the cups off in their collection bin (Figure 12). This signage is located near waste bins, as well as concession stands where fans are likely to interact with the cups when purchasing food and returning the cups. One stadium operator stated they take time to promote their sustainability efforts on the jumbotron during high-traffic times such as kickoff, halftime, and at the end of the game (Interviewee 13, personal communication, November 6th, 2024). Posting reuse messaging on the jumbotron and throughout the stadium will help fans take notice of the stadium's efforts and can lead to them positively engaging with the reuse system.

Figure 12. Signage located near a concession stand directing fans to appropriate disposal of reuse cups (Source: Eco-Products)

Stadiums have also turned to social media as a way to promote their efforts. CPKC Stadium's Facebook page has posted videos showcasing their reuse system and guiding fans on where to place their reusable cups (CPKC Stadium, n.d). This can increase fan awareness and target fans who are passionate about the team if they interact with their social media.

Some stadiums could share metrics boasting the positive environmental impacts of their reuse system, such as on its website. An example of this can be seen on r.World's website, which highlights current return rates (Figure 13).

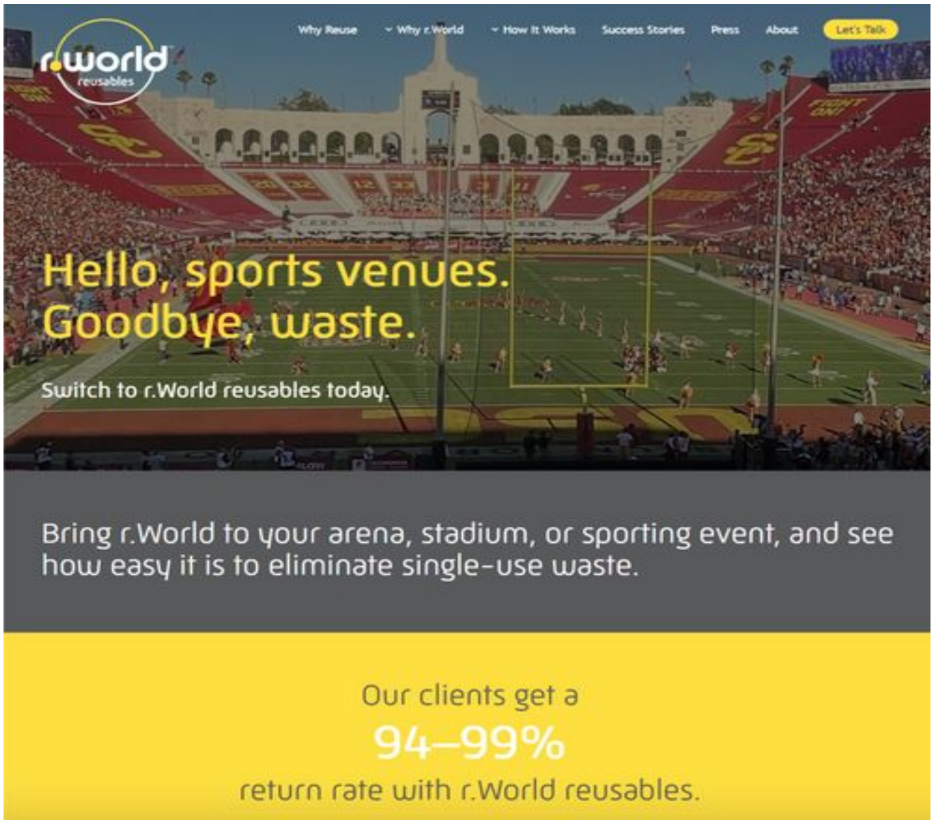


Figure 13. r.World website with high return rates communicated (Source: r.World)

Employee Engagement and Education

A reuse system is only as successful as the people who help it operate, which is where employee training and management become key to success. Since reuse is not widespread, it is likely that every employee would need training to understand what the system does or how it works. A lack of awareness or understanding can lead to employees improperly sorting the cups, causing a high number of cups to be accidentally thrown away and not returned to the reuse system.

A reuse service provider shared an example of why employee education is critical (Interviewee 1, personal communication, October 8th, 2024). A staff member at an elementary school (with a reuse system) had accidentally misidentified the reuse cups as trash and threw the cups out, leading to substantial decrease in cup inventory. This issue was quickly detected and resolved by the reuse service provider due to their diligent cup tracking. Although instances like these do not happen often, these types of mistakes can be avoided with proper staff training and education.

Employees interacting with the system also provide an opportunity to educate fans about the program. In an interview with a stadium operator, it was mentioned that stadium employees seen picking up trash in the parking lot and sorting the waste were approached by curious fans. The fans had questioned why they were putting waste into different bags represented for trash, compost, and recycling. (Interviewee 13, personal communication, November 6th, 2024). This led to a positive exchange between the employees and fans, in which they discussed the waste management system, how it functions, and provided the context on the environmental benefits of this waste organization method. These types of interactions between the fans and stadium personnel help the overall awareness of a stadium's sustainability efforts (like a reuse program) and are likely to encourage more fans to engage effectively (e.g., properly returning reusable cups to the system).

Reuse Infrastructure

Collection Bins

In an interview, a reuse service provider noted that collection bins should be placed alongside other waste receptacles throughout the stadium (Interviewee 11, personal communication, November 21st, 2024). This ensures that the bins are as visible and accessible to fans as regular trash cans. The bins should include instructions on how the reuse system works to help education efforts. That way, fans understand that the collection bin is meant for only reusable cups. One stadium approaches by having the cups, collection bins, and signage reflect the same branding – colors, logos, and text styles– to help fans associate the cups with the bins (Interviewee 15, personal communication, September 9th, 2024). This strengthens the fan's association between the cups and the collection bins, hopefully leading to the correct behavior of placing the reuse cups into the collection bins.

Dishwashing Facilities

A new logistical consideration for stadiums implementing reuse systems is washing and drying a large volume of cups that would have been discarded with single-use systems—often "out of sight, and out of mind." This requires using a large-scale washing facility, which many stadiums may not be equipped with. Two potential approaches for implementing a washing facility are building one on-site or outsourcing the washing process to an external facility.

An on-site washing facility would offer the stadium complete control over its reuse system, including how many cups go through the system and on-demand washing for additional cups as needed during an event. This would also require more staffing to sort, wash, assess cup quality, and return the cups to the reuse system—calling for a significant upfront investment since stadiums would have to either build out existing washing facilities or construct entirely new ones that can handle the increased demand from the reusable cups (Interviewee 1, personal communication, October 8th, 2024).

With the large upfront investment in mind, most stadiums with reuse systems have chosen to partner with reuse service providers that handle off-site washing, usually within 15 miles of the stadium. In the case of CPKC Stadium, their reuse service provider, Bold Reuse, has a washing facility 11 miles from the stadium (Bold Reuse, 2024). Outsourcing the dishwashing to the reuse service providers' facilities allows stadiums to take advantage of reuse without the risk of building their own washing facilities before proving that the system is successful and works for them. Partnering with these providers also transfers the burden of collection, quality control, and re-ordering cups – since they have trained staff and automated systems that make the overall process more efficient. The main drawback of outsourcing the washing and management of cups is the cost of partnering with a reuse service provider, which is explored in greater detail later in this report.

Concessions

Reuse systems in stadiums require concessionaires to have the appropriate beverage service equipment, which may not already be present. To implement a reuse system, stadiums must invest in draft beer dispensers and soda fountains to serve the drinks in reusable cups. If the refill infrastructure is already available, that will help with the efficient implementation of the reuse system since staff would most likely be trained to dispense the liquid concessions in cups rather than handing out pre-packaged beverages.

Figure 14. Example of a water refill station (Source: Vapur, n.d.)

Stadiums may also want to invest in self-serve water stations so customers can easily refill their cups or water bottles brought from home (Figure 14). Owners of the stadium, who typically control net margins and operations, may collaborate with food service providers to adjust their contracts to reflect any added costs. This process requires alignment between the food and beverage providers, owners, and other stakeholders to reach an agreement. One concessionaire interviewed noted that the trend towards "frictionless" ("just walk out" markets) grows to improve the speed of service, and venues are shifting greater portions of their beverage portfolio to bottles or cans. This presents another challenge for integrating reuse systems (Interviewee 11, personal communication, November 21st, 2024.)

Other Considerations for Reuse Programs

Gamification

Gamification is the application of game mechanics such as rewards, points, competition, and interactive challenges to increase motivation and engagement with preferred behaviors (Shahzad et al., 2023). It is uniquely suited to address issues relating to sustainable behavior (Taylor, 2021). In the case of reuse in stadiums, gamification often consists of providing prizes or rewards as an incentive to fans who properly return their reusable cups to the collection bins. According to Yu-kai Chou, Founder of a global gamification and digital engagement consulting firm, there are six types of rewards in gamification: Fixed Action Rewards (Earned Lunch), Random Rewards (Mystery Box), Sudden Rewards (Easter Eggs), Rolling Rewards (Lottery), Social Treasure (Gifting), and Prize Pacing (Collection Set) (Chou, 2024). The Fixed Action Rewards model is one of the most commonly implemented gamification types in a reuse program context, where the user knows what must be done to get the reward. Such rewards for returning cups could include exclusive merchandise, drink discounts, or other prizes designed to make fans feel involved and celebrated for participating in the reuse system (Green Sports Alliance, 2024). The Rolling Rewards is another suitable model for the context of reuse, where rewards are given to a select number of winners by chance after they take a specific action, like purchasing a lottery ticket or entering a contest (Chou, 2024). One of the reuse service providers interviewed noted this concept of a “raffle ticket” as a highlight of gamification (Interviewee 11, personal communication, November 21st, 2024).

Many of these gamification models leverage technology and innovation. In the context of reuse, this includes using apps, cups with QR codes, and smart collection bins with simple RFID or QR code-based technology, allowing reuse service providers or stadiums to track and reward attendees for returning products (Green Sports Alliance, 2024). Gamification paired with technology can provide stadiums valuable data-driven insights into fan behavior and preferences for informed product offerings (Green Sports Alliance, 2024). Furthermore, with a gamified approach, fans can be more than just spectators– they can be active participants in creating sustainable events (Green Sports Alliance, 2024).

Based on interviews with three prominent reuse service providers, two embrace this gamified approach (Interviewee 1, personal communication, October 8th, 2024; Interviewee 10, personal communication, October 28th, 2024; Interviewee 11, personal communication, November 21st, 2024). One of the key benefits of gamification is increased engagement and education, especially among a younger audience. On the other hand, one prominent reuse service provider shared that they are moving away from gamification. This particular provider has tested out gamification in various venues and came to the conclusion that fans do not like it as much as expected (Interviewee 10, personal communication, October 28th, 2024). They observed that gamification creates long lines for returning reusable cups, leading many fans to throw them away because they do not want to wait. While all three reuse service providers interviewed suggest installing as many collection bins as there are other waste receptacles (e.g., placing collection bins next to all trash, recycling, and composting bins) in a respective venue, gamifying the action of returning a cup seems to inevitably lead to long lines at the venue. While weighing the pros and cons of gamification will vary depending on the venue and audience, it is nonetheless a tool worth looking into when developing reuse programs.

Regulations

Since stadiums serve alcohol, liquor control board regulations must be considered when implementing reusable cups. In the US, each state has its own liquor control board and/or local authority to regulate the production, sale, and distribution of alcohol within its borders, so the approach to addressing these regulations will be dependent on the location of the venue (Alcohol and Tobacco Tax and Trade Bureau, 2024). In some states, liquor control boards may mandate stadiums to use different colored or labeled cups for various types of alcoholic beverages (e.g., a specific color for beer and another for wine or cocktails) to reduce the risk of underage consumption (California Department of Alcoholic Beverage Control, n.d.). Therefore, when implementing reusable cups at stadiums, implementers must consider questions such as, “Does the cup need to be clear?” and “Do I need to ensure the cup design between an alcohol and soda cup is different?” This is an area that would benefit from further research since there is limited publicly available information on how these liquor control board regulations affect stadiums with reuse programs.

Performance Factors

Many factors contribute to the economic and environmental performance of a reuse system. Most stadiums will partner with an outside entity, a reuse service provider, who provides the full service of cup logistics, washing, and return to the stadium. These contracts are generally based on a charge per cup, and increasing the number of uses for each cup reduces the cost of each use. Thus, the return rate is the primary indicator for economic performance for a reuse system. Investing in reuse infrastructure will affect a stadium’s economic performance. Initially, a stadium will need to ensure there are clearly marked collection bins for reusable cups. Investment in signage all around the stadium is also necessary to inform and encourage fans to dispose of their cups in the appropriate bins. In addition to educating fans, stadium staff may also require training to support the reuse system. Next, investment in cups requires large amounts of upfront capital, compared to the

> “The primary measure of success for a reuse program is the **return rate** - the percentage is calculated by tracking how many items were used and collected over a specific period of time.”
> (Green Sports Alliance, 2024)

status quo of using single-use cups. Stadiums will need an upfront investment and back stock, which depends on their return rate and the rate at which cups need to be retired due to damage or aesthetic deterioration.

The primary motivation for implementing a reuse system is to minimize single-use waste. Similar to economic performance, the return rate will be a significant driver of environmental performance. Reusable cups are more expensive to purchase than single-use cups as they are designed and manufactured to withstand repeated use and cleaning (Interviewee 2, personal communication, October 10th, 2024). Therefore, a reusable cup that is not reused many times will have greater environmental impacts than a single-use cup because of the raw materials and manufacturing processes.

Aside from the manufacturing of the cup itself, the other processes affecting the environmental performance of the reuse program include washing the cups and transportation to and from the stadium to the washing facility, if offsite. The energy- and water- efficiency of the washing process will dictate the environmental impact of each use. The water temperature, cleaning agent, facility energy source, and washing machine efficiency will all impact the washing stage. Furthermore, the transportation distance and the vehicle will affect the amount of fuel (or electricity for an electric vehicle) required to transport cups to and from a washing facility.

The greatest lever for improving economic and environmental performance is the return rate. The more times a cup is used, the less impact it has, both environmentally and financially. Appropriate infrastructure, proper engagement of fans, stadium employees, concessionaires, and successful post-game waste sorting are all key elements of achieving and maintaining a high return rate.

Case Study: CPKC Stadium

When considering the potential to implement reuse programs in the 11 US-based stadiums hosting the 2026 FIFA World Cup, the research team sought to gauge what other successful reuse programs have worked for similar venues. The CPKC Stadium, which is shown in Figure 15 and opened on March 16, 2024, is located in Kansas City, Missouri, and is the home of the Kansas City Current of the National Women's Soccer League.

Figure 15. CPKC Stadium (Source: CPKC)

Figure 16. Signage at CKPC stadium encouraging proper disposal of cups (Source: Chandler Precht)

Figure 17. Cup designs are aligned with collection bin designs (Source: Chandler Precht)

Figure 18. Collection bins are placed alongside other waste stream receptacles (Source: Chandler Precht)

CPKC is the world's first dedicated women's professional sports stadium and the first to fully implement a reuse system since its opening. Implementing reuse is an integral part of the stadium's aim to be the first with zero waste by design. To achieve this, CPKC Stadium partnered with Bold Reuse to design, manufacture, and implement the cups for the reuse system (Kansas City Current, 2024). The stadium also invested in its marketing materials for the reuse system, using avenues like marketing on the jumbotron, having reuse directions written on collection bins and cups, and posting signs throughout the stadium (Figure 16). These marketing materials focused on the fan behavior of putting the cup in the correct collection bin, which has similar coloring to help associate the cups with the collection bins (Figure 17). The location of the collection bins themselves was also highly accessible to patrons, with the bins being placed next to other waste receptacle bins like compost and recycling (Figure 18). The cups are collected after every event and taken to an offsite wash facility, which washes, sanitizes, and performs quality checks before returning them to the stadium for the next event.

While CPKC and other stadiums have implemented proven reuse systems with the support of reuse service providers, hospitality partners, concessionaires, and fans, many stadiums and venues have not been compelled to invest in the transition to reuse. The following sections provide an analysis that will be helpful in making a business case for reuse.

THE BUSINESS CASE FOR REUSE AT STADIUMS

Based on interviews with stadium operations personnel and reuse service providers, switching from single-use to reusable cups will likely present a significant additional cost for stadiums. It will take time to prepare a proper business case for this transition. The research team chose to use the cost-benefit analysis (CBA) methodology to address this challenge. In general, the purpose of a CBA is to forecast how the present and future economic benefits generated by a project compare to the costs incurred (Boardman et al., 2018). In this context, the CBA examined a stadium's potential net economic benefit from replacing its single-use drinkware inventory with a reuse system.

The research team completed a CBA model for a “average” stadium reflecting attributes of the 11 stadiums proposed for the 2026 FIFA World Cup in the US. In keeping with standard practice for CBA modeling, the research team chose the stadium ownership to have standing, as defined below. The completed CBA model (in Microsoft Excel format) is available upon request.

Assumptions for the CBA were informed by a thorough review of economic literature and a series of interviews with real stakeholders hypothetically represented by the model. Notably, much existing academic research has focused on food containers rather than beverages. Nonetheless, this existing research was highly valuable in guiding the methodology and establishing the boundaries of the analysis. In accordance with best practices outlined by the compiled literature, a discount rate of 4.5% was used to calculate the net present value (NPV) of future costs and benefits (Lu et al., 2022). Interviews with cross-industry and cross-functional stakeholders, from reuse service providers and stadium representatives to local governments tasked with managing municipal waste, were greatly helpful in providing primary input information and shaping the final CBA model.

Scope and Inputs

The point of view from which a CBA is carried out depends on which stakeholders are of the highest priority. Keeping with best practices, a CBA must identify one and only one stakeholder group as having “standing” in the CBA model to prevent double-counting of costs and benefits (Boardman et al., 2018). The stakeholder with standing is the body from which perspective the model is constructed. As previously discussed, reuse systems require consistent collaboration between several parties, making the question of who has the most significant standing in the project hard to answer. With this in mind, the perspective or standing of this CBA was limited to the stadium owners/operators. Reuse service providers, concessionaires, sponsors, and other entities engaging with the reuse system were omitted from this perspective because the benefits and costs associated with them appear to be indirectly related to the stadium’s cash flow.

For example, a reuse service provider's revenue is represented by the price (nominal cost, in USD ($) for this report) paid by a stadium to purchase its inventory. Alternatively, local governments may offer grants to cover capital expenditures for reuse service providers rather than stadium operators. The Arizona Department of Environmental Quality (ADEQ) provided grant funding of $208,000 toward Bold Reuse's construction of a new washing facility in support of the Arizona Diamondbacks' reuse system at Chase Field (Lynch, 2024). While this benefitted the system as a whole, the stadium operators were not the direct recipients of the grant. The effect of grants and similar awards would be, indirectly, on the cash flow of the stadium (possibly reduced purchase and/or service costs for the reusable cups.) Thus, these parties were excluded from the standing of the CBA to avoid double counting.

As noted in the Introduction of this report, the 2026 FIFA World Cup presents a unique opportunity for widespread reuse expansion in larger stadiums. The research team developed the CBA model by leveraging capacity data from the 11 US stadiums hosting FIFA World Cup soccer matches and beverage consumption statistics gathered during research to create a profile of the "average FIFA World Cup stadium." Within this geographical boundary, the operational boundary of this analysis spanned from the procurement of reusable cups to their return to the stadium from an assumed-offsite washing facility. In the US, it is most common for stadiums to implement reuse in partnership with a reuse service provider rather than in-house. Therefore, activities beyond this operational boundary of the stadium, such as cup manufacturing and retirement, are featured in a separate analysis of this report (see Section V).

Considering the implementation time frame, the CBA model assumed that the "average FIFA World Cup stadium" implementing a reuse system will run a pilot phase for the first year. This pilot would allow the stadium to test the reuse system at a small scale, identify best practices, and prepare for 100% reuse adoption over time. The pilot phase in the CBA was modeled after the Portland Trail Blazers' reuse system at Moda Center, which initially included only alcoholic beverages before introducing Coca-Cola fountain drinks to the system after two years (Portland Trail Blazers, 2024). Per academic recommendations, a gradual increase in return rate was also modeled as the system matures, eventually reaching 90% (Lu et al., 2022). The overall lifespan of the reuse system was modeled as five years, with costs and benefits calculated per quarter (20 time periods overall). The model begins with the pilot phase starting in the first quarter of 2025 (Q1 2025), with the FIFA World Cup occurring in Q2 and Q3 2026, corresponding to periods 6 and 7 in the model. As ideally the project would continue past the five-year duration modeled, administrative or disposal costs at the end of the project lifespan are considered negligible and not included.

The model identified sponsorships and vendor fees as key benefits of a stadium reuse system (Figure 19). Sponsorships, like Pepsico®'s partnership with the Arizona Diamondbacks, provide a great deal of financial support to their sporting venue partners while also helping these brands achieve their sustainability goals through the implementation of reuse systems. Meanwhile, vendors looking to take advantage of concession space within stadiums indirectly buy into the reuse scheme.

Another benefit category was the avoided costs of single-use cup inventories, which include both procurement and waste management (Figure 19). Eliminating the need to constantly replace this inventory and engaging with local governments or independent waste managers may relieve stadiums of a large subset of fixed costs.

However, the procurement of reusable cups remains a major expense. Reuse service providers typically offer two distinct models for cup procurement and associated services: rental and ownership. Some lease an inventory to venues, while others allow them to purchase their fleet of cups. In either instance, these providers charge stadiums a per-unit price that can cover the cup by itself or include baked-in compensation for services like washing, transportation, and product customization. Given insights provided by prominent reuse service providers and concessionaires, this analysis assumed a venue-owned reusable cup model (Interviewee 1, personal communication, October 8th, 2024; Interviewee 10, personal communication, October 28th, 2024; Interviewee 11, personal communication, November 21st, 2024; Interviewee 8, personal communication, November 4th, 2024; Interviewee 9, personal communication, November 6th, 2024).

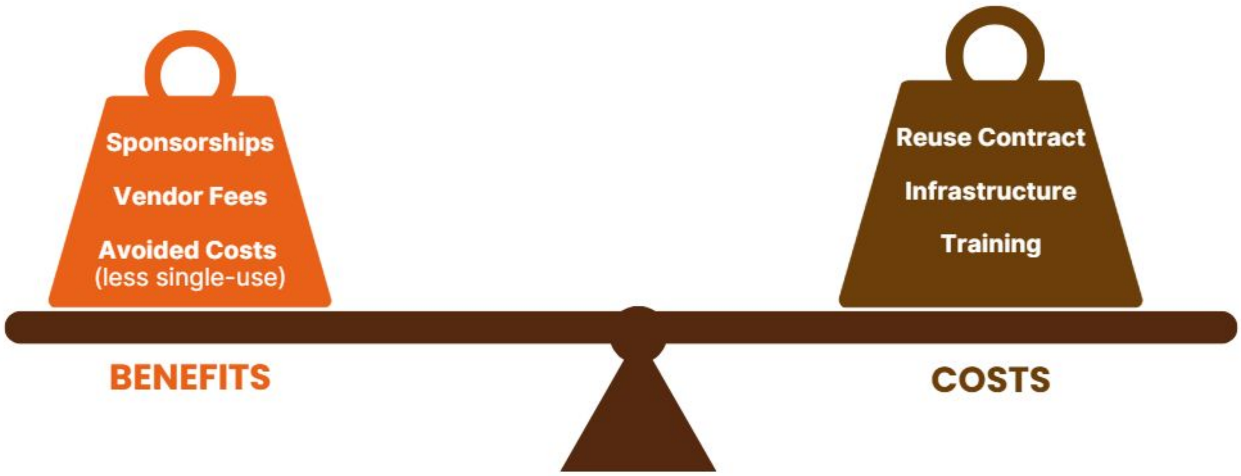


Figure 19. Overview of benefit and cost inputs for CBA model

Capital expenditures are also necessary for infrastructure that supports the reuse system (Figure 19). Examples of required assets include collection bins, water refill stations, soda fountains, and draft beer systems. Signage for fan education is another critical infrastructure component that ensures the convenience of disposal and boosts return rates. The model incorporated the additional capital costs of these items and assumed the entire purchase was paid up-front (as opposed to financed), for simplicity. Employees also require proper training to build an understanding of the system and ensure functionality behind the scenes – such costs were expressed as a product of hours trained and hourly lost time due to training rates (Figure 19).

Results

Table 3 and Figure 20 on the following page summarize the CBA model results. Net benefits over the assumed first five years of reuse implementation amounted to -$3.49 million. While less than favorable, these results reflect the nominal financial impact to a modeled average stadium and therefore may not apply directly to each stadium's unique context.

T**able 3.** Summary of cost-benefit analysis results

Present Value of Costs (USD)	$6,064,566.18
Present Value of Benefits (USD)	$2,704,379.59
Net Present Value	**-$3,360,186.59**
Benefit-Cost Ratio	**0.45**

The research team modeled a series of alternate scenarios to identify major drivers of the cost-benefit gap. One of these replaced the pilot phase with an initial full-scale reuse launch, as seen in the case of CPKC Stadium. Another scenario redirected government grant funding toward stadiums rather than reuse service providers, potentially to be put toward refill infrastructure improvements or to cover procurement costs. A third introduced a plastic tax aligned with recent proposed regulations like the REDUCE Act, which would place a $0.10 tax on all newly-produced plastic goods—including cups (Ward, 2023). While each of these scenarios had insignificant effects on the NPV, they point to the cost of an individual reusable cup as a major determinant of the final net cost.

These results also reiterate the value of corporate sponsorships in improving the financial viability of stadium reuse systems. A challenge the research team faced in preparing the CBA model was a lack of transparency surrounding certain data points, with some interviewees providing cost ranges rather than specific estimates and other stakeholders disclosing no data at all. Where this challenge impacted the model most was with respect to sponsorships. While several reuse service providers indicated that these partnerships were key to unlocking critical financial support for stadiums, sponsorship dollar amounts or contract details with individual stadiums were not publicly available (Interviewee 1, personal communication, October 8th, 2024; Interviewee 10, personal communication, October 28th, 2024; Interviewee 11, personal communication, November 21st, 2024). One potential figure that remains unconfirmed by the sponsor itself was a $3 million annual sponsorship of the Chicago Bears by Keurig Dr. Pepper (KDP) in 2012 (Long, 2012). The Bears' stadium, Soldier Field, recently announced its upcoming reuse system in partnership with Bold Reuse, but KDP's financial contributions remain undisclosed (Keurig Dr. Pepper, 2024). While including the $3 million estimate from the 2012 contract in the CBA model could strongly influence the final NPV, it remains speculative from unnamed sources and may not reflect the partnership as it exists today.

This analysis is limited to a specific period of a reusable cup's life cycle and reflects the direct, nominal impacts of reuse on stadium operators. These limitations raise additional, complicated questions: What kinds of impacts exist beyond the stadium and its attendees? What sort of hidden external costs from plastic manufacturing, use, and disposal are not accounted for in this analysis? Can impacts on the climate, local environments, and human health be quantified in economic terms? How can investors, governments, and other financial stakeholders account for these hidden costs?

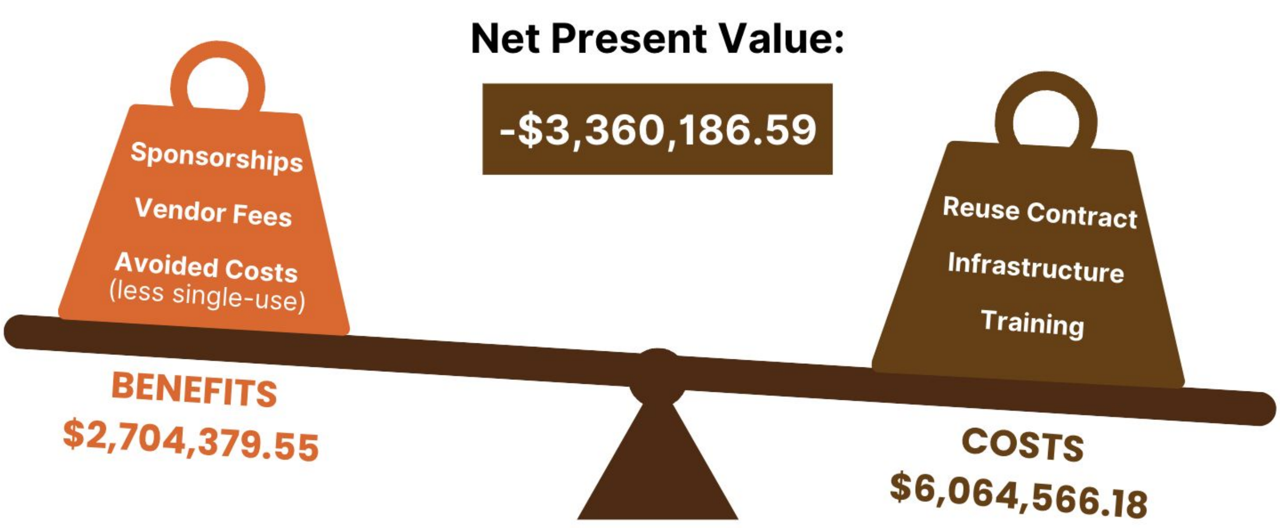


Figure 20. Graphic summary of cost-benefit analysis results

HIDDEN COSTS OF BEVERAGE CUPS

Chandler Precht

Plastic beverage cups add to the overall demand for plastic, which generates substantial negative externalities on the environment and society. Furthermore, these "hidden costs" are not reflected fully in the nominal price paid for a plastic cup, but are generated at every step of a plastic cup's life cycle. Building upon the nominal CBA model, this section adds an additional layer of economic analysis by identifying major externalities of plastic production, consumption, and disposal and quantifying their negative impacts on the environment and society.

Costs and Benefits Over the Life Cycle of a Plastic Cup

A plastic beverage container has five primary life cycle stages, outlined below in Figure 21.

Across all stages, issues such as resource extraction, energy consumption, environmental pollution, waste management, and resultant negative public health effects all present additional burdens on the environment and society. The "nominal" costs of single-use and reusable cups outlined in previous sections do not fully account for these externalities. However, plastic beverage cups are widely used due to benefits including low (nominal) initial cost, manufacturing efficiency, design flexibility, durability, transportation efficiency, and recyclability. Use of reusable plastic food and beverage containers, notably beverage cups, in a well-managed system can reduce the overall demand for single-use plastic and mitigate some of the associated negative health, pollution and climate effects. The following sections present data and provide analysis to quantify, where possible, the benefits of avoided negative social and environmental impacts from single-use plastic.

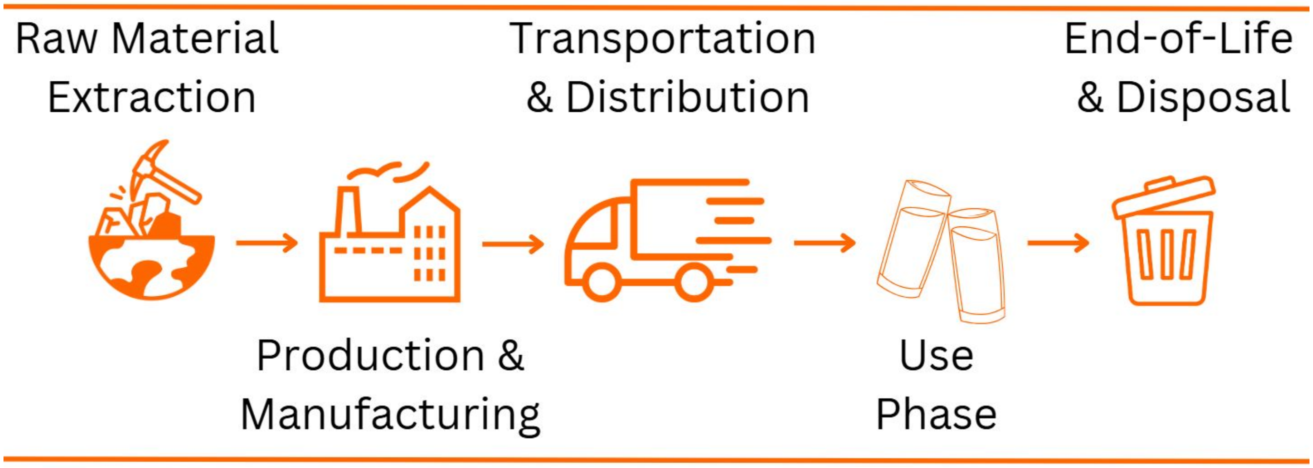


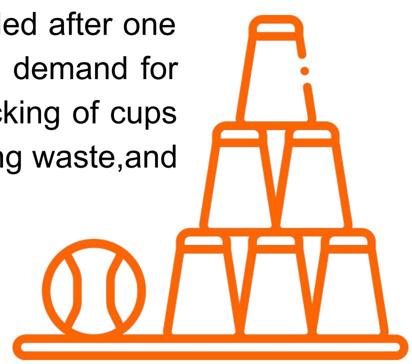
Figure 21. Life cycle stages of a plastic beverage container

The "True Cost of a Cup": Emissions Accounting of a Single-Use Cup's Life Cycle

There are notable differences between the raw material extraction costs and benefits of single-use and reusable cups. Single-use cups require a relatively low amount of raw materials per unit, making them nominally cheaper to produce, by unit, than reusable cups (Evans, 2023). However, these cups are made from petroleum-based plastics, contributing to resource depletion and negative environmental impacts during extraction. Oil and natural gas extraction for plastic has rapidly increased in the past several decades to approximately 368 million tonnes globally in 2019 (Jankowska, 2022). A typical reusable cup will require more raw material by mass (and hence lead to more extraction) than a single use cup due to its increased thickness and durability. Although the initial resource consumption is higher for reusable cups, this cost is spread over many uses, increasing long-term material efficiency. These cups are designed for repeated use, therefore most reusable cups compensate for the increased raw materials per cup (Garrido & Castillo, 2007). When reusable cups are used multiple times, they reduce the need for additional raw material extraction over time and mitigate the associated long-term environmental impacts. Thus, while single-use cups have lower externalities per cup from resource extraction, reusable cups overall offer greater resource efficiency and sustainability in the long term.

In terms of production and manufacturing, single-use cups generally have lower upfront costs but come with greater environmental and resource inefficiencies. Single-use cups benefit from economies of scale and are typically produced in high volumes to keep per-unit production costs low (Vercalsteren, 2010). However, the manufacturing process for single-use cups can be energy-intensive, and the high production volume often leads to excess waste and pollution. Producing reusable cups requires complex and energy-intensive manufacturing processes due to their greater durability and weight. However, because reusable cups are designed to last, the initial higher manufacturing costs per cup are spread over multiple uses. Therefore, while single-use cups cost less per unit to produce, reusable cups have the potential to reduce long-term environmental and social damage due to their longevity and reduced need for overproduction of plastic.

When comparing transportation and distribution costs, single-use cups have the advantage of being lightweight and stackable. Compared to reusable cups, single-use cups are therefore more efficient for transportation purposes, increasing mass distribution and large-scale production. However, because they are discarded after one use, the constant demand for newly-made cups leads to more demand for logistics and associated emissions overall. The constant restocking of cups contributes to ongoing transportation needs, additional packaging waste,and increased transportation-related emissions.



On the other hand, reusable cups are usually bulkier and heavier, which increases transportation costs per unit. Fortunately, since new reusable cups are reused multiple times, a customer (e.g. a stadium) will require fewer units over time, reducing transportation demand in the long run. While single-use cups may offer immediate transportation cost savings, reusable cups can provide longer-term benefits by requiring fewer shipments and reducing the environmental impact of transportation and distribution.

While some single-use cups are recyclable, many are thrown into trash cans or sorted incorrectly, making recycling difficult and inefficient. As a result, these cups often end up in landfills or as litter and contribute to global solid waste pollution. Single-use cups can take hundreds of years to break down once in a landfill, releasing harmful microplastics into ecosystems in the process (Su, 2022). Reusable cups also have the same associated solid-waste environmental issues, but as fewer cups are used overall, there is less waste generated along a similar timescale to multiple single-use cups. Overall, reusable cups offer a lower environmental cost at the end of their life than single-use cups, making them a more sustainable choice.

Additional Plastic Externalities

Worldwide, plastic production has reached over 350 million tons annually, with approximately 40% being single-use and destined for landfill (Wright and Kelly, 2017). Dependence on single-use plastic cups has significant hidden impacts on the environment and society, most notably on human health, labor, ecosystems, and waste management. Scientists have researched links between plastic exposure and adverse health outcomes for decades. One of the key issues surrounding plastic and human health is microplastics, as humans around the world are starting to show evidence of microplastics in their blood and urine (Xu et al., 2024).

Human Health and Labor

A 2023 study on plastic cup use showed that the longer a beverage remains in the cup, the more microplastics the user ingests (Zhou et al., 2023). While scientists have confirmed the presence of microplastics in humans and many common household products, their effects on human health are still being studied. Some studies have shown that polyethylene terephthalate (PET), the main component of many single-use cups, is likely to yield endocrine-disrupting phthalates, which leach from the plastic and end up in the beverage (Sax, 2009). These endocrine disruptors can have a variety of adverse health consequences, including developmental delays, cancers, decreased fertility, and more.

On the other hand, polypropylene (PP), the main component of the proposed reusable cups, has been found to exhibit low levels of cytotoxicity at most concentrations (Hwang et al., 2019). While plastic-related health outcomes are still unclear, some researchers estimate that the annual healthcare costs of plastic exposure are well over $200 billion USD, as of 2018 (Trasande et al., 2024).

While most humans are exposed to the negative side effects of plastics, workers consistently exposed to plastic during its production are much more likely to experience adverse health outcomes. Studies have shown that aerial inhalation is one of the leading causes of microplastic ingestion and can lead to long-term lung inflammation and decreased lung capacity (Campanale et al., 2020). Long-term plastic exposure has also been proven to directly impact blood metabolites, with workers in plastic factories showing significant differences in blood styrene levels, urinary mandelic acid level, and chromosomal makeup as a direct positive correlation with exposure time (Helal and Elshafy, 2012). Personal protective equipment (PPE) can effectively lower exposure rates, but plastic production workers are still much more likely to experience these health consequences than the average person. By implementing a reuse system and phasing out single-use cups, stadiums can help to lower single-use plastic demand, thus alleviating negative health outcomes for workers.

Ecosystems and Waste Management

Dependence on plastic has also had detrimental impacts on land and marine ecosystems. As plastic degrades in landfills, microplastics are released into the air and soil and can travel throughout the ecosystem. Similarly to human health, scientists have yet to discover the toxicological and ecological repercussions of microplastics fully. Preliminary research indicates that chemical degradation in landfills can negatively impact the environment (Wojnowska-Baryła et al., 2022). As microplastics and chemicals leach out of plastics in landfills and make their way into waterways as effluents, they adversely affect water pH and aquatic life. While the economic impacts of marine environmental degradation due to plastic are not widely understood, some researchers anticipate a 1-5% reduction in marine economic output as a direct consequence of marine plastic, equating to an annual worldwide revenue loss of over $500 billion (Beaumont, 2019).

Due to society's dependence on single-use plastics, landfills around the world receive tens of millions of tons of plastic annually (EPA, 2024). Much of this waste is due to both finished plastic goods and product loss during production. As of 2021, the UN Environment Program estimated that the global value of plastic waste during production was over $80 billion (UN, 2021).

While many waste management strategies are in place to lessen the landfill burden of plastic, many are not widely implemented, with only an estimated 9% of worldwide plastic being recycled annually (EPA, 2024). Stadiums could divert thousands of tons of plastic from landfills annually by transitioning from single-use to reusable cups.

Stadium-Specific Plastic Impacts

The research team sought to quantify the negative externalities associated with the demand for single-use plastic versus use of reusable plastic, for the specific use case of plastic beverage cups within a large sports stadium.

The calculations below represent a "modeled" stadium using single use and reusable beverage cups, and real-world impacts may vary. Due to the lack of data on quantification of other impact categories (health, solid-waste, pollution, etc.), only societal external costs associated with greenhouse gas (GHG) emissions are accounted for below.

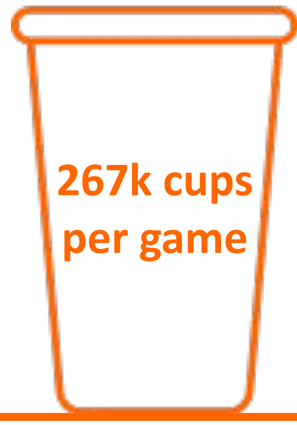
Stadium Model and Cup Quantity

In order to estimate the quantity of single-use and reusable plastic cups representing stadium demand, the total number of cups is calculated as:

(*stadium capacity*) * (*game attendance*) * (*cup use*) = total cups per game

- ***Stadium capacity*** represents the total capacity of the stadium, in the number of people per game.
- ***Game attendance*** represents the amount of stadium capacity filled per game on average, in percent of stadium capacity.
- ***Cup use*** represents the number of drinks sold to each attendee per game, with each attendee acquiring a new cup with each drink purchase.

Calculations were based on the stadiums designated for the 2026 FIFA World Cup in the US, averaging a capacity of 72,000 people per game (Martínez, 2024). With an average game attendance of 88% and each attendee using an estimated 4.4 drinks per fan, and accounting for a 5% discount to accommodate fans in suites (not considered for analysis, were determined to result in an average of 267,000 cups per game (Martínez, 2024).



72,000 capacity x 88% attendance x 4.4 drinks/fan - 5% discount factor = 267,000 cups per game

The calculations here assume that each time an attendee purchases a new drink, they receive a new cup, in both the single-use and reusable cup cases. In the single-use case attendees receive a newly manufactured cup, while in the reusable cup case attendees receive a reusable cup which has been previously washed.

Cup Materials

The calculations assume the reusable cups are made of polypropylene (PP). As noted in previous sections, estimates of the lifespan of a reusable cup vary and range from 10 to 300 uses; however, the higher end of this range is based on the durability of reusable cups rather than the number of uses that occur in practice based on the return rate of a given system. For example, a 90% return rate achieves an average of 10 uses per cup, and a 95% return rate achieves an average of 20 uses. The research team estimates approximately 50 uses per reusable cup over its lifetime, with the cup being washed after each use. The single-use cups are assumed to be made of polyethylene terephthalate (PET) (Wentz, 2021). An average of 50 uses per cup is possible with a 98% return rate; while reuse systems are not typically seeing this high of a return rate today, the research team chose to estimate based on the potential a reuse system has once it has been effectively scaled.

System Boundaries and Locations

This section defines the boundaries of the research team's calculations, including location assumptions and phase omissions where applicable - detailed in Table 4.

Table 4. System boundaries, locations, and definitions for economic analysis of single-use and reusable cup impacts

Phase	Single-use	Reusable
Raw materials formation	Included Location: Saudi Arabia	Included Location: China
Raw materials transport to manufacturing	Included	Not included, assumed negligible
Manufacturing	Included Location: China	Included Location: China
Transport finished goods to use port of entry	Included Port of entry: Los Angeles, CA, US	Included Port of entry: Los Angeles, CA, US

Table 4. System boundaries, locations, and definitions for economic analysis of single-use and reusable cup impacts (cont.)

Phase	Single-use	Reusable
Transport port of entry to distribution center	Included	Included
Distribution	Included Location: Kansas City, MO, USA	Included Location: Kansas City, MO, USA
Transport distribution to use location	Included	Included
Use location	SoFi Stadium, Los Angeles, CA	SoFi Stadium, Los Angeles, CA
Use	Not included	Included
Wash location	N/A	Los Angeles, CA
Transport use location to wash location (round-trip)	Not included	Included
Disposal/end-of-life	Included	Included
Disposal location	Los Angeles, CA	Los Angeles, CA

Social Cost of Carbon

To quantify the societal cost of GHG emissions, the research team used a social cost of carbon of $50 per metric ton, utilizing emissions factors from the Environmental Protection Agency (EPA) GHG Emissions Factor Hub (Environmental Protection Agency, 2024). As social cost of carbon is inherently a socioeconomically rather than scientifically defined value, considerable debate exists regarding an appropriate level. The EPA and other government agencies have considered values as low as $1 - $7 per metric ton (Bledsoe, et. al, 2024) to nearly $100 per metric ton (Auffhammer, 2018). More recent academic studies have indicated a cost of $250 per metric ton as being more representative (Kerlin, 2024). The research team selected a value of $50 per metric ton as noted above and on the advice of an environmental economic expert they consulted (Interviewee 19, personal communication, November 19th, 2024).

Single-Use Cups

For single-use cups, the analysis assumed three different cup sizes, ranging from 4.0 to 13.0 grams per cup. Considering an average of 267,000 cups per game, the plastic requirement was calculated as 1.75 - 3.13 tons of PET per game.

Considering one PET cup, the impact from raw material extraction accounts for 0.21 kg CO_2e per cup.

The production and manufacturing stage has an estimated impact of 0.056 kg CO_2e per cup.

Transportation emissions were also assessed for sea freight from Guangzhou, China to California (12,084 km), with an emission output of 0.00006 kg CO_2e/kg-km and the subsequent truck transport from the port to distribution center and then to the stadium (5,254 km) producing 0.00012 kg CO_2e/kg-km (Fluent Cargo, n.d.). Consequently, the total emissions for the transportation stage amounted to 0.013 kg CO_2e per cup.

At the end-of-life stage for these cups, emissions were calculated based on landfill disposal. 100% landfilling was assumed because recycling rates and levels of infrastructure vary across the US, and not all disposable cups used at stadiums are recyclable. Cups are transported an estimated 32 km to the landfill and landfilling is associated with 0.02 Mt CO_2e/ton. This resulted in estimated emissions of 0.000039 kg CO_2e per cup.

The total estimated emissions over the life cycle of a single-use cup, including raw material extraction, manufacturing, transportation, and end-of-life sum to 0.28 kg CO_2e per cup. Using the $50 per ton social cost of carbon, this equates to $0.015 per cup, meaning 1.5 cents per cup of hidden costs is associated with emissions.

Multiplying by the average 267,000 cups per game estimates a total of 81 tons CO_2e per game, equivalent to about $4,050 per game of hidden costs. Extrapolating this to the 78 World Cup games to be hosted in the US in 2026 concludes the following:

The total emissions for single-use cups at the World Cup would equate to **6,320 tCO_2e,** which makes up the total emissions cost of **$316,000** using a $50 per ton social cost of carbon (Environmental Protection Agency, 2024).

Reusable Cups

In calculating the required plastic for reusable cups, the analysis assumed three different cup sizes, ranging from 20.0 to 29.1 grams per cup. Considering an average of 267,000 cups per game, the plastic requirement for a set of reusable cups to serve drinks for one game is calculated as 4.6 - 8.2 tons of PP plastic. Since these cups will be reused, this tonnage of plastic must be divided by the number of uses. Assuming a 98% return rate resulting in an average of 50 uses per cup, this results in 0.09 - 0.16 tons of PP per stadium per game. This is nearly a 95% reduction in plastic use compared to single-use per beverage sold.

Considering the raw material extraction for one PP cup, this life cycle stage accounts for 0.28 kg CO_2e per cup.

The production and manufacturing stage has an estimated impact of 0.060 kg CO_2e per cup

Transportation emissions were also assessed for sea freight from Guangzhou, China to Los Angeles, California (12,084 km), with an emission output of 0.00006 kg CO_2e/kg-km and the subsequent truck transport from the port to distribution center and then to the stadium (5,254 km) producing 0.00012 kg CO_2e/kg-km (Fluent Cargo, n.d.). It should be noted that this distance represents a scenario in which the transport distances between the port, distribution center, and and stadium are large in order to be conservative in our estimates. Consequently, the total emissions for the transportation stage amounted to 0.029 kg CO_2e per cup.

For reusable cups, impacts from the use stage consider transportation to and from a dishwashing facility, washing of the cups, and return transport to the stadium. The washing facility is assumed to be located 10 miles from the stadium. Total transport and washing emissions in the use phase were calculated as 0.0029 kg CO_2e per cup per use.

Ideally reusable cups are reused as many times as possible; however, they are not infinitely reusable. The final life cycle stage is end-of-life which assumed transportation to a landfill 20 miles away from the washing facility. The final emissions per landfilled cup amounted to 0.00040 kg CO_2e per cup.

The total estimated emissions over the life cycle of a reusable cup, including raw material extraction, manufacturing, transportation, distribution, use, and end-of-life, sum to 0.37 kg CO_2e per cup for one use, which does not account for a reusable cup being used multiple times.

In order to compare this result to the emissions from a single-use cup, the stages of the life cycle that only occur once per reusable cup (i.e., non-use stages) must be divided by the number of uses. Non-use stages include raw material extraction, manufacturing, transportation, and end-of-life. The use stage occurs for each use of the cup and therefore are not divided per use. Thus, the emissions per use of a reusable cup can be calculated as:

$$\frac{\textit{emissions from non-use stages}}{\textbf{number of uses}} + \textit{emissions from use stages} = \textbf{emissions per cup per use}$$

Assuming a high return rate of 98% resulting in an average of 50 uses per cup, the emissions per reusable cup equate to 0.010 kg CO_2e per cup per use. Using a $50 per ton social cost of carbon, this equates to $0.0006 per cup, meaning less than one-tenth of a cent per use of a reusable cup of hidden costs is associated with emissions.

Multiplying by the average 267,000 cups per game estimates a total of 3.0 tons CO_2e per game, equivalent to about $150 per game of hidden costs. Extrapolating this to the 78 World Cup games to be hosted in the US in 2026 results in an estimated 230 tons CO_2e, which makes up the total emissions cost of $12,000, using a $50 per ton social cost of carbon (Environmental Protection Agency, 2024). Comparing this to single-use concludes the following:

If reusable cups are implemented at the World Cup in well-designed reuse systems with high return rates, **over $300,000 in hidden costs could be saved** through avoided emissions.

All calculations and assumptions were documented in a comprehensive spreadsheet, which is available upon request.

Beyond the Stadium: Global Plastic Costs

A number of studies have outlined the qualitative effects of the demand for single-use plastic.

One study attempts to provide a comprehensive estimate of the hidden costs that are not reflected in plastic's low market price throughout its life cycle by illustrating the economic, health, and ecological costs of plastics, pushing for a global response to holistically address these issues (WWF, 2021). The report found that in 2019 alone, the cost of plastic production exceeded $3.7 trillion (WWF, 2021). The market price of plastic considered in the report does not account for hidden costs of plastic, including the cost of greenhouse gas (GHG) emissions, health outcomes, and waste management, which burden societies and governments.

Other studies examine and determine which phases of the plastic lifestyle have the greatest negative impact. The WWF report used total GHG emissions across the plastic life cycle where emissions concentrations are dominated by the production and conversion process of plastics, accounting for 90.9% of the total life cycle emissions (WWF, 2021). Utilizing a $100 social cost of carbon, the cost of GHG emissions across the plastic life cycle is estimated to exceed $171 billion globally across the entire plastic production industry. The second cost considered is the cost of managing plastic waste, which was estimated to reach $32 billion (WWF, 2021). This accounted for the costs imposed by the collection, sorting, recycling, and/or disposal of municipal solid waste by both the formal and informal sectors. In addition, the study considered how informal waste pickers are more susceptible to significant health risks throughout the plastic waste processing cycle than formal waste pickers. Informal pickers' prolonged and frequent exposure to faecal matter, medical waste, and hazardous substances from plastic processing puts them at greater risk of chronic health conditions such as respiratory disorders (WWF, 2021).

The plastic produced in 2019 is projected to cause $3.1 trillion in damages to marine ecosystem services due to degradation and loss over the next 100 years. The estimate is derived from the effect of plastic waste on the value that people can derive from the ocean; this value includes marine habitats from aquatic farming, regulating services such as carbon sequestration and flood control, and cultural services like recreation. If current trends continue, the combined hidden costs are projected to more than double, reaching an estimated $7.1 trillion by 2040 under a business-as-usual scenario (WWF, 2021).

Another report quantifies the hidden social costs and corporate liabilities associated with plastic pollution, with a focus on the liability risks plastic pollution poses to businesses and insurers (Merkl & Charles, 2022). The findings reveal staggering social costs from plastic pollution, amounting to hundreds of billions of dollars annually using the approach of potential litigation risks for corporations, especially within industries linked to plastic manufacturing, distribution, and waste management. The report also suggests that legal claims will likely increase as scientific and legal frameworks evolve, allowing for more accountability for plastic-related harms (Merkl & Charles, 2022).

A third report details how to shift from the existing linear plastics economy to a circular economy through cost estimates associated with plastic pollution, and attempts to quantify the economic burden it places on various sectors using the “global plastic stock take” of 2019. The report estimates the cost of CO_2 emissions from plastic production and incineration at $60.5 to $180 billion annually, the cost of air pollution from plastics between $31.3 and $211.8 billion, and the cost of plastic waste in the ocean from $0.7 to $1.4 billion per year (UNEP, 2023). Several health impacts are also evaluated such as the impacts from toxic chemicals such as bisphenols and phthalates at $130.8 billion annually and from microplastics through ingestion and inhalation at between $10 billion and $100 billion per year (UNEP, 2023). Contrary to WWF’s estimate of $3.1 trillion, this report’s evaluation of the cost of plastic-related harm to marine biodiversity and ecosystems is estimated at only $70.2 to $143.7 billion annually (WWF, 2021; UNEP, 2023).

Several common themes emerge from review of the reports described above. One theme is the need to have a globally coordinated approach, ideally through a legally binding treaty on plastic pollution. Such a treaty would harmonize regulations, close accountability gaps, and drive actors toward sustainable practices. A treaty would incentivize a shift to responsible plastic management by aligning financial incentives with environmental goals. The reports unanimously agree that adopting a circular economy approach to plastics is essential for mitigating the extensive costs associated with plastic pollution and promoting global sustainability (WWF, 2021; Merkel & Charles, 2022; UNEP, 2023). For example, the system change scenario in one report highlights the potential for substantial economic savings, enhanced public health, and reduced environmental impact, providing a strong case for an integrated, globally coordinated strategy (UNEP, 2023).

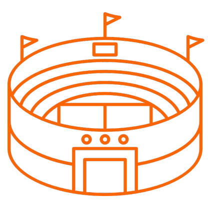
LOOKING FORWARD

Reuse at the 2026 FIFA World Cup: Single-Use Plastic Reduction

The US is slated to host 78 FIFA World Cup games in 2026. Assuming high attendance rates (greater than 95% per game) which have been seen at past World Cups, this international event has the potential to eliminate approximately 250 tons of single-use plastic by implementing reusable cup systems.

Well designed reuse systems can achieve return rates in the 90th percentile range. Assuming an idealistic return rate of 98%, one reusable cup can replace 50 single-use cups leading to this significant reduction in single-use plastic usage.

Reuse Beyond the World Cup: Stadiums as Anchor Venues



Partnerships between stadiums and reuse service providers can be mutually beneficial and can be a pathway to allow reuse systems to become available to the businesses surrounding stadiums' in nearby urban areas and neighboring communities. Some reuse service providers noted to the research team that in order to set up a washing facility in a community, they need “anchor” clients who can provide sufficient regular flow of containers to both justify the initial investment and to keep the facility in operation (Interviewee 1, personal communication, October 8th, 2024). Stadiums are an ideal anchor partnership due to their large capacities and consistently high cup demand. For example, during the development of CPKC Stadium, the stadium owners wanted to implement a reuse system, but there were no reuse service providers with washing facilities already in the area. However, due to the consistent business that CPKC would generate, Bold Reuse agreed to set up a washing facility in Kansas City (Kansas City Current, 2024). While the washing facility was initially intended to primarily serve the CPKC Stadium, smaller businesses around Kansas City now have access to Bold Reuse services that would not have existed without the stadium's involvement. Smaller venues such as theaters and arenas may want to set up reuse programs, but if they are located in an area without an existing reuse company's washing facility, it may be challenging to find partners to help implement the program.

Suppose more high-capacity stadiums nationwide (such as the 11 US stadiums hosting the 2026 FIFA World Cup) transition to reuse programs utilizing reuse service provider partnerships. In that case, these businesses would be incentivized to open up more washing facilities, thus making it easier for smaller venues and businesses in the community to implement reuse systems.

Scaling for Reuse: Need for Regulatory Intervention

As reuse systems across the US are in their infancy, there is a need for regulatory intervention to support the initial development of these systems so that they may scale and become financially viable solutions for businesses. Key players, including policymakers, industry leaders, and financial institutions, have a key opportunity to collaborate to drive regulatory actions that mandate and support corporate responsibility, the reduction of plastic waste, and investment in innovative solutions. These interventions can take various forms, such as grant funding, subsidies, or plastic taxes.

The US has recently been preparing a plastic tax through the REDUCE Act, but it unfortunately remains in committee and is likely to require reintroduction to move forward. However, a future plastic tax in the US is not outside the realm of possibility as other countries are passing similar laws. For example, The United Kingdom (UK) introduced a plastic packaging tax in 2022, charging £200 per tonne on plastic packaging with less than 30% recycled content (UK Government, 2022). This policy incentivizes manufacturers and industries operating in the UK region to use recycled materials and reduces reliance on virgin plastics. Additionally, aligning incentives with environmental and social goals can catalyze systemic change, facilitating the transition to a circular economy.

CONCLUSION

Chandler Precht

To assess the issue of single-use waste, the research team first turned its attention toward academic observations of both disposable and reusable plastic cups through a gap analysis of relevant LCAs. This analysis found that a lack of consistent assessment methods has been a critical pitfall in understanding the environmental effects attributable to a single cup, and the research team has provided guidance for future research based on this finding.

The focus was then pivoted to reuse in practice, examining the design considerations and implementation strategies necessary for sports stadiums to employ successful reusable cup systems. Best practices from stadiums and their reuse service providers, such as "ugly" cup design and fan education, offer valuable insights to stadiums interested in transitioning away from single-use drinkware.

With this qualitative background in mind, the research team prepared a series of economic analyses highlighting the sizable value attached to the reuse concept. Comparing the nominal costs and benefits of stadium-wide reuse illustrated the short-term financial implications of this transition. Revealing the hidden societal costs of plastic production outside the stadium expanded on these implications, demonstrating that the nominal costs of plastic goods do not tell the entire story. In terms of greenhouse gas emissions, the team found that reusable cups can substantially reduce the negative impacts of relying on single-use plastic cups when return rates are well-managed.

The research team views the 2026 FIFA World Cup as an opportunity to address single-use dependence quickly and at scale. A novel venue like CPKC Stadium is an exciting proof of concept, with fans, athletes, and stadium owners eager to get involved. The stadiums hosting the 2026 FIFA World Cup are an ideal setting to elevate reuse further and step forward as sustainability leaders among professional sports venues.

Owners, operators, and financiers of these stadiums could contribute to massive social and environmental change by buying into reuse— both as an idea and an operational advantage.

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PR3

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