

Piloting an immersive XR environment for Plastic Reduction Practices and Behaviours in Kitchen Operations



Colofon

Title publicatie

Extended Reality for Single-Use Plastics Reduction in Hospitality: Piloting an immersive XR environment for Plastic Reduction Practices and Behaviours in Kitchen Operations

Publicatiedatum

Juni 2025

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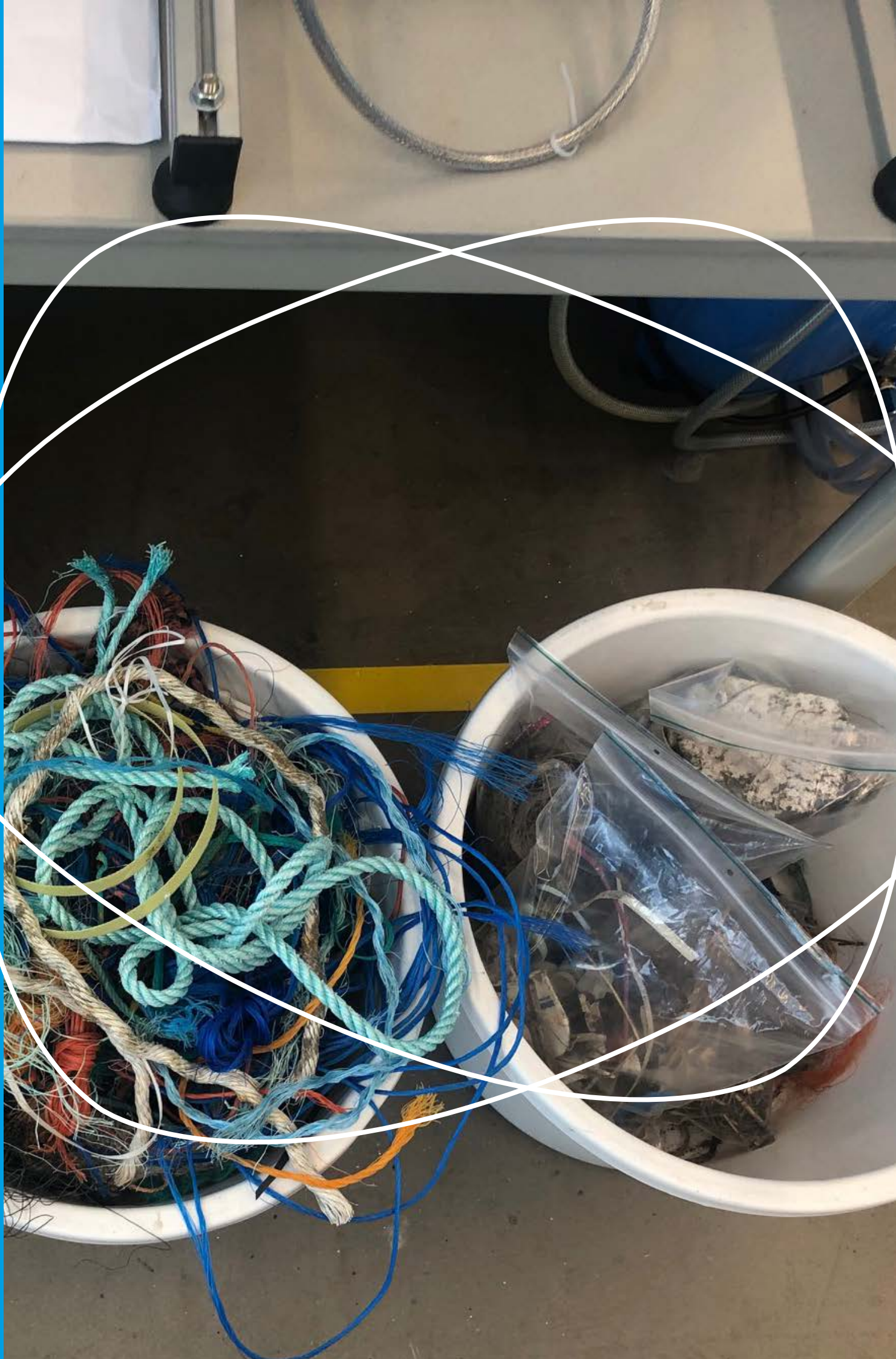
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1. EXECUTIVE SUMMARY

- **The project “Extended Reality for Single-Use Plastics Reduction in Hospitality” set out to address the urgent global challenge of single-use plastics (SUPs), focusing on their prevalent use in small hospitality firms (SHFs). These businesses, often constrained by limited resources and high operational pressures, struggle to implement sustainable practices despite their willingness to reduce environmental impact. Our initiative aimed to co-create innovative, design-based interventions that help SHFs reduce SUP usage in kitchen operations without disrupting their workflow.**

This project pioneered the use of Extended Reality (XR) technologies within hospitality settings. By capturing kitchen operations through multi-camera systems and generating immersive XR environments, we enabled SHFs to observe and redesign their practices collaboratively. Co-creation sessions held within these virtual kitchen environments facilitated the identification of practical interventions aligned with the 3R principles (Refuse, Reuse, Recycle) and behavioral nudging strategies. The collaboration brought together NHL Stenden, Zuyd University of Applied Sciences, and Breda University of Applied Sciences, alongside nine SHFs across Friesland, Limburg, and North Brabant. The joint effort combined expertise in sustainability, circular plastics, immersive technologies, and hospitality operations. Participating students contributed through plastic-use inventories, intervention design, and pre/post-intervention assessments, ensuring strong integration with educational programs. Key deliverables included video records of kitchen operations, an immersive XR setting hosting co-creative sessions, co-created plastic reduction interventions, and dissemination outputs such as academic publications (e.g. book chapter), industry reports, webinars, and presentation in conferences. The project demonstrated that XR can be a powerful tool to foster sustainable practices, with outcomes designed for replication in hospitality firms across regions. This project not only supported SHFs in reducing their plastic footprint but also provided the wider hospitality sector with scalable, innovative solutions for environmental stewardship.

2. INTRODUCTION

- **Single-use plastics (SUPs) represent one of the most pressing environmental challenges of our time. With over 150 million tons of SUPs consumed globally each year, their polluting effects on ecosystems, marine life, and human health are widely documented.**

The hospitality sector plays a significant role in this issue, particularly through its kitchen operations where SUPs are extensively used in food storage, preparation, packaging, and service. Despite increasing awareness and regulatory pressures to reduce plastic waste, meaningful progress in this sector—especially among small hospitality firms (SHFs)—remains limited. SHFs, including independent restaurants, cafés, hotels, and hostels, constitute a large proportion of the hospitality landscape in the Netherlands and beyond. However, they often face substantial barriers to adopting sustainable practices. Unlike larger hotel chains or international brands with dedicated sustainability teams and resources, SHFs typically operate under tight economic constraints and acute time pressures. These businesses frequently lack access to the knowledge, tools, and financial means required to effectively address SUP usage. Furthermore, the daily operational demands of kitchen environments leave little room for experimenting with new practices or redesigning workflows in ways that might momentarily request changes in workflows and lower efficiency. Kitchen operations, in particular, are hotspots of SUP consumption. From cling film and vacuum bags to disposable gloves and single-use packaging for ingredients, plastic use is embedded in standard culinary practices. In many cases, these materials are relied upon for reasons of food safety, hygiene, convenience, or cost-effectiveness. As a result, any meaningful reduction in SUP use must account for the complex interplay between operational needs, regulatory compliance, and sustainability ambitions.

Recognizing these challenges, this project aimed to support SHFs in exploring innovative pathways to reduce SUP consumption within kitchen operations. The project was driven by an urgent call from SHFs in Friesland, Limburg, and North Brabant, who expressed their need for practical guidance and effective interventions that could be implemented without disrupting their core activities. The participating SHFs highlighted their eagerness to contribute to environmental sustainability but also voiced concerns over their capacity to independently identify, test, and integrate solutions that address SUP use. To address these needs, the project leveraged a novel combination of methodologies centered on design-based action research, co-creation, and extended reality (XR) technologies. Inspired by successful applications of XR in sectors such as healthcare, retail, and automotive industries, the project introduced this technology into hospitality kitchens for the first time. Through the creation of immersive XR experience of SHF kitchen environments, we provided stakeholders with a powerful platform to reflect on existing practices, identify opportunities for improvement, and collaboratively design interventions aimed at reducing SUP reliance. Central to this approach was the principle of minimal disruption to normal kitchen operations. By capturing real kitchen operations through multi-camera systems and translating this data into XR environments, the project enabled SHFs to engage in meaningful exploration and redesign of practices without interfering with their day-to-day service. The use of XR allowed teams to experience a realistic simulation of their kitchens, observe habitual plastic-use patterns, and consider alternative behaviours and materials in a safe, controlled virtual space.

This project was delivered through a collaboration between NHL Stenden University of Applied Sciences, Zuyd University of Applied Sciences, and Breda University of Applied Sciences, working alongside several SHFs across three Dutch regions. The interdisciplinary team combined expertise in hospitality management, circular plastics, sustainability transitions, and immersive technology. Together, the consortium sought not only to deliver practical interventions for participating SHFs but also to generate insights, tools, and methodologies that can be scaled and adapted across the wider hospitality sector.

In summary, this report documents the journey of applying XR technology and collaborative design to the challenge of SUP reduction in hospitality kitchens. It outlines the processes followed, the interventions co-created and tested, and the lessons learned about enabling sustainability transitions in small-scale hospitality contexts.



3. THE PLASTIC CHALLENGE IN HOSPITALITY AND XR POTENTIAL

- The extensive use of plastics and SUPs has been widely acknowledged as a global problem with several environmental consequences. The United Nations Environmental Programme (UNEP) in the platform #Beat-PlasticPollution (www.unep.org/interactive/beat-plastic-pollution) stresses that “around the world, one million plastic drinking bottles are purchased every minute, while 5 trillion single-use plastic bags are used worldwide every year. In total, half of all plastic produced is designed to be used only once — and then thrown away”. Moreover, “plastic waste is now so ubiquitous in the natural environment that scientists have even suggested it could serve as a geological indicator of the Anthropocene era” (ibid.).

At a global level, on an annual basis, we produce about 400 million tons of plastic waste. That is nearly equivalent to the weight of the entire human population. The urgency of and ambition for plastic reduction is well testified by several international and national initiatives, policies, and campaigns aiming at tackling this global challenge. To exemplify, think about the Plastic Atlas 2019 published by The Henrich Böll Foundation with facts and figures about the world of synthetic polymers (www.boell.de/en/pasticatlas), the Plastic Soup Foundation (www.plasticsoupfoundation.org), and the Global Commitment, Plastic Pact Network lead by UNEP (<https://www.unep.org/new-plastics-economy-global-commitment>). Moreover, the Ellen MacArthur Foundation gathers a growing number of organizations under the common vision of a circular economy in which plastic should not be wasted. Despite the relevance of such global challenge and the ambition of the agendas linked to it, there is either no or only scant data on the plastic types, their amounts, and the practices connected to their use in the different industry sectors. Looking at hospitality, which is at the center of this project, despite the aggregated data of 150 million tons of SUPs used per year (Green Hospitality, 2020; UNESCO Sustainable Travel Pledge, n.d.), specific details and information about the drivers of their use are missed. This information gap should be closed if we wish to stimulate action and measure the impact of the actions taken. In the last decades several sectors (e. g. healthcare, retail, automotive industry) - inside and outside Netherlands - have been using XR as a safe, effective, and reliable environment for product development and prototyping, training, practice, simulation, and behavioral testing. Conversely, the use of XR is still at a preliminary stage within the hospitality sector where training, practice, prototyping, and behavioral testing take place in the physical space with all its constraints. As such, the hospitality sector largely misses the opportunities of XR to prompt further innovation and development in areas like plastic reduction, which is the focus of this project.

Plastic pollution is a global problem that requires local solutions (CGTN Europe, n.d.; Earth5R; IUCN, 2019). Therefore, this project adopts a funnel approach: it is grounded into the plastic global problem while focusing on the Dutch hospitality sector, and more specifically on the provinces of Friesland, Limburg, and Noord Brabant. The Dutch Government has embraced the European Union Directive 2019/904 (<https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:32019L0904>) to reduce plastics by both regulatory and non-regulatory means for businesses using SUPs (<https://business.gov.nl/regulation/rules-single-use-plastics/>). The interest in plastic reduction is growing in the Dutch hospitality sector as proven by the MVO Tourism Plastic Pledge (<https://www.mvonderland.nl/en/case/tourism-plastic-pledge-150-businesses-sign-up-to-cut-plastic-pollution/>). However, hospitality is largely unprepared to cope with new measures and regulations on SUPs. Specifically, small hospitality firms (SHFs) mostly lack the economic and human resources as well as the knowledge to effectively act. Moreover, they are constrained by the time pressure of their operations. In this context, SHFs in Friesland, North Brabant, and Limburg reached out to knowledge institutions in their region and asked support in developing measures for SUPs reduction.

3.1. Extended Reality (XR) environments

Immersive technologies (e. g. augmented reality (AR) and virtual reality (VR)) and their employment into Extended Realities (XR) have developed strongly in the last years. Their development has provoked much debate inside and outside the scientific community, particularly about their use in tackling challenges and limitations in our current environment (Rauschnabel et al., 2022). Several studies have discussed implications of Metaverse infrastructures for marketing (Dwivedi, et al., 2022), hospitality (Han et al., 2022), and the generation of new food experiences to stimulate sustainable consumption behaviour (Han et al., 2022). The use of XR environments for, e.g., trainings, is common in sectors like healthcare, retail, and automotive industry. XR environments offer solutions to enhance physical settings with digital computer-generated augmentations in an overlaid format (augmented reality), as well as blended format (mixed reality) that aims to interrelate the physical and virtual realities. In the case of Virtual Reality (VR) the user is transported into a complete computer-generated environment allowing the user to be visually completely immersed in VR. However, whilst being able to offer enhanced experiences for individual users, such immersive solutions are limited in their capacity to involve multiple users simultaneously (Dionisio et al., 2013). This is particularly relevant for contexts, like hospitality, where the social aspect is highly influential for the overall evaluation of the experience. To tackle this shortcoming, several studies have explored the use of immersive VR Caves. VR Caves are based on 3D projections that collectively create an immersive XR environment to enhance a dedicated physical space. In the Eat & Travel concept used by Dionisio et al. (2013), it was found that such spaces could create the perception of guests being transported to a different location during the consumption of food and drinks and engage guests to interact and explore the environment. More specifically, guests perceived a sense of presence in the virtual environment that allowed for meaningful connections between the guests and the space. Similar findings were reported in a different study that used a multisensory immersive XR environment setting to provide sensory and cognitive engagement in an immersive dining experience (Qvist et al., 2016). We propose that such XR solutions can be expanded to facilitate co-creative multistakeholder sessions by engaging the group in an immersive environment. By taking real-life video footage from a kitchen and the use of SUPs within, immersive scenes can be created that facilitate a sense of presence and foster better understanding and empathy of stakeholders involved in the co-creative process.

4. METHODOLOGY

- This project adopted a design-based, participatory research methodology aimed at co-creating and piloting innovative interventions to reduce single-use plastics (SUPs) in small hospitality firms (SHFs). The approach was grounded in action research, with a strong emphasis on stakeholder engagement and minimal disruption to daily kitchen operations.

Preliminary interviews to validate and enrich existing baseline & SUPs inventory [November 2024]

Before starting with the project activities, a set of preliminary interviews were conducted with 4 SHFs to validate a preliminary baseline and inventory of SUPs in hospitality conducted by a Circular Plastics NHL Stenden master student. The aim was to increase the limited knowledge about which specific plastic items are used in hospitality settings. These interviews with SHFs entrepreneurs permitted to validate and discuss the existing SUP baseline and inventory as well as its enrichment and the exploration of the reasons behind their use of SUPs. Moreover, the interviews also covered the locations and types of operations where SUPs were most often used.

The project drew on the results of a master’s thesis research on Single-Use Plastics (SUPs) in hospitality, specifically focusing on kitchen operations and cleaning. The research was conducted by a student at the Circular Plastics Professorship - NHL Stenden. The baseline and inventory developed through this master’s thesis (Fig. 1) formed the foundation for a series of preliminary interviews conducted in November to December 2024 with entrepreneurs from three regions: Friesland, North Brabant, and Limburg. Consequently, four entrepreneurs (Om de Dobben – Burgum; Paddy O’Ryan Pub and Restaurant – Leeuwarden; Sibelicious Restaurant – Breda; Restaurant L’Étoile – Maastricht; and a Breda’s restaurant who asked to remain anonymous) were interviewed to discuss, validate, and expand upon the SUP baseline and inventory (Tab. 1 and 2). These interviews also aimed to identify other potential SUPs (Fig. 2) and offer insights into the processes and locations where SUPs are most prevalent. This information then guided the subsequent multi-camera participant observations.

	Plastic application	Explanation	Example photo
1	Bottle	A portable container for holding liquids, characteristically having a neck and mouth and made plastic.	

2	Box	A container, case, or receptacle, usually rectangular, often with a lid or removable cover.	
3	Bucket	A deep, cylindrical vessel, with a flat bottom and a semicircular bail, for collecting, carrying, or holding water, sauces, fruit, etc.	
4	(Spray)cap	Something that protects, closes, or covers a different product such as a bottle. Usually opened/closed by a rotational movement.	
5	Jar	A broad-mouthed container, usually cylindrical.	
6	Jerrycan	A flat-sided can with a large capacity used for storing or transporting liquids.	
7	Lid	A removable or hinged cover for closing the opening, usually at the top, of a pot, jar, etc. Usually pressed onto the other part of the packaging product (e.g., a box or jar).	
8	Flexible packaging	Flexible plastic packaging include items like plastic bags, food wrappers, plastic film and pouches.	

Fig 1 - Types and uses of SUP to be discussed and validated with the interviewed entrepreneurs

Where	What	By who	Why	Picture number	Interviewees's replies (aggregated)
Kitchen	Bottle	Chef, Cleaning staff & Kitchen staff	Cooking & cleaning	1	Outsourced, so out of control & most commonly this is how the supplier offers it
x	Small container	x	x	2	Supplier brings fruits & veggies without plastic wrapping; only reusable plastic crate
Kitchen	Bucket	Chef & Kitchen staff	Cooking	3	Repurposed for cleaning or reuse;
					Problem: They can't take them all back because of the printing - Levo
Kitchen & Restaurant	Lid of cleaning material	Service staff + Cleaning staff & own staff	Cleaning	4	They refill the bottles from jerrycans into bottles;
					This is how the supplier offers it; Outsourced, so out of control + To keep things fresh; This is how the supplier offers it
Kitchen	Jar	Chef	Cooking	5	Reuse; mainly they have glass jar that they refill from big plastic bags
Kitchen & Restaurant	Jerry Can	Chef & Service staff	Cleaning & cooking	6	Used to refill small bottles; This is how the supplier offers it, + sometimes they can take them back
Kitchen	Lid of container	Chef	Cooking	7	Reuse; Hygiene: everything needs to be closed with lids because of mice – HACCP mainly they have glass jar that they refill from big plastic bags ; This is how the supplier offers it
Kitchen	Bags	Chef	Cooking	8	This is how the supplier offers it
x	Tray	x	x	9	Not used, has their own slicing machine so buy a whole cheese or ham + This is how the supplier offers it & Convenience

Tab. 1- Validating Master student research

Where	What	By who	Why	Picture number	Notes
Kitchen & Restaurant	Clingfilm/ wrap & Slagersfolie	Chef & Service staff	Keeping things fresh by covering them with it or put it in between (e.g. ham) so that it won't stick together after cutting it	New	Hygiene standard, needed for transporting catering after preparations
Kitchen	Vacuum bags	Chef	Keeping things fresh in the fridge/ freezer – portioned	New	Hygiene & best practice to avoid food waste. To conserve fresh products in smaller portions
Kitchen & Restaurant	Sprays	Chef & Service staff	Cleaning	New	This is how the supplier offers it
Kitchen & Restaurant	Plastic foil around containers (wrapped by producer)	Chef & Service staff	Keeping things clean/ separate during production in factory	New	This is how the supplier offers it

Tab. 2- New identified SUP in kitchen operations



Fig 2- Overview of SUPs present in kitchens added to the preliminary list during the interviews

Multicamera participant observation and video recording [January 2025]

The project followed with a multicamera participant observation in one selected SHF kitchen in Breda. A multi-camera system was installed to record the kitchen locations and operations identified as pivotal during the preliminary interviews, focusing specifically on SUP use across key processes such as food delivery, storage, and preparation. This footage provided insights into the frequency, context, and rationale behind

SUPs use. The data collected formed the foundation for a collective immersive experience of the kitchen operations in the extended reality (XR) environment.

Development of XR immersive experience [February-March 2025]

The recorded footage was transformed into a set of video loops to be used for an immersive experience based on the XR technology at the Food Experience Lab of Zuyd University of Applied Sciences. The immersive XR environment reproduced the physical kitchen space and operations with high fidelity, enabling stakeholders to experience a virtual representation of the use of plastics in a kitchen environment. This XR setting provided a shared, realistic context for watching and discussing plastic-use practices. As such, by providing a common scenario and context, it facilitated co-creation and eye-to-eye reflection among the different participants and stakeholders without interrupting actual kitchen activities.

Co-creative XR session [April 2025]

In this XR environment a participatory co-creative session was organised inviting SHFs representatives and kitchen staff as well as research lecturers and students. Together, participants watched the video shooting of the kitchen operations and the presence and use of SUP during delivery, storage, and food preparation. During the session, a double diamond model was followed to explore ideas and refining it into a solution. The immersive setting helped stakeholders better visualize challenges as well as opportunities and habits collaboratively discussing possible interventions and sharing best practices.

On the 16th of April 2025, a co-creative session in the XR environment of the Future of Food Lab at Zuyd University of Applied Sciences, was held. The video recordings of kitchen operations and hot spots for SUP use and storage were projected in the lab prompting discussion among participants (Fig. 3 and 4). The co-creative session involved 16 participants ranging from entrepreneurs and kitchen staff till research lecturers and bachelor students in practice (Tab. 3).



Fig 3- Overview immersive XR environment hosting the co-creative session



Fig 4- Co-creative session tables of discussion

	Participant	Organisation	Role
1	Dai-in Danny Han	Zuyd UAS	Professor Future of Food
2	Malu Boerwinkel	Zuyd UAS	Researcher Future of Food
3	Silvia Gabriela Abreu e Silva	Zuyd UAS	Practitioner Future of Food/ former chef
4	Luc Bosch	Zuyd UAS	Lecturer Hotel Management School Maastricht/ former chef
5	Elena Cavagnaro	NHL Stenden UAS	Professor Sustainability in Hospitality & Tourism
6	Lucia Tomassini	NHL Stenden UAS	Researcher Sustainability in Hospitality & Tourism
7	Andrew Mzembe	BUAS	Researcher Sustainability Transitions
8	Ilse van Ipenburg	BUAS	Researcher Sustainability Transitions
9	Baukje de Vries	Paddy O'Ryan, Leeuwarden	Hospitality Entrepreneur
10	Sjef Kerckhoffs	Restaurant Refresh Hotel Management School Maastricht	Chef Hotel Management School Maastricht
11	Boris Spauwen	Restaurant Refresh Hotel Management School Maastricht	Chef Hotel Management School Maastricht
12	Iris Charlier	3rd year Bachelor student BUAS	Practice in kitchen
13	Kevin Eikelenboom	3rd year Bachelor student BUAS	Practice in kitchen
14	Jens Jongen	3rd year Bachelor student BUAS	Practice in kitchen
15	Martin Studeny	3rd year Bachelor student BUAS	Practice in kitchen
16	Ton Vermeulen	CELTH	Communication

Tab. 3 - XR co-creative session participants

Follow up validation and discussion results XR session [May 2025]

The results and possible interventions as well as the constraints and opportunities for reducing SUPs in kitchen operation that emerged during the co-creative XR session were organised in a presentation and presented to a different set of participants (e.g. research lecturers, kitchen staff, and SHFs representatives) at NHL Stenden University of Applied Sciences in Leeuwarden. During this meeting the results were discussed, validated, and enriched by sharing ideas, first-hand experiences, and best practices. Moreover, priorities and short-, medium-, and long-term scenarios and possible goals have been discussed as possible project spin-off initiatives. Throughout, the project integrated contributions from an interdisciplinary team and participating SHFs, ensuring that outcomes were relevant, actionable, and scalable to other hospitality contexts.

On the 15 of May 2025, a follow up session was organised at NHL Stenden University in Leeuwarden (Fig. 8). In this session, a new group of practitioners and kitchen staff was invited to discuss and validate the key results of the XR co-creative sessions. This follow-up session consisted of a presentation of the results from the previous session, insights about plastic materials and films from Judith Ogink – NHL Stenden Circular Plastic Research Lecturer and HMSL PD candidate. This was followed by a roundtable of discussion (Fig. 8 and 9) and a visit to the Circular Plastic Laboratory at NHL Stenden (Fig. 10 and 11). The session counted on 12 participants among research lecturers, chefs, and practitioners from Notiz Hotel Group, Leeuwarden and Firda, Sneek.



Fig 8- Overview of round table discussion



Fig 9- Overview of round table discussion

	Participant	Organisation	Role
1	Dai-in Danny Han	Zuyd UAS	Professor Future of Food
2	Malu Boerwinkel	Zuyd UAS	Researcher Future of Food
3	Elena Cavagnaro	NHL Stenden UAS	Professor Sustainability in Hospitality & Tourism
4	Lucia Tomassini	NHL Stenden UAS	Researcher Sustainability in Hospitality & Tourism
	Marie Hartman	Notiz Hotel Group (NHG) and NHL UAS	Researcher Sustainability in Hospitality & Tourism and NHG Supervisor Stewarding Department
5	Judith Ogink	NHL Stenden UAS	Researcher Circular Plastics
6	Andrew Mzembe	BUAS	Researcher Sustainability Transitions
7	Ilse van Ipenburg	BUAS	Researcher Sustainability Transitions
8	Veronica Mal	Notiz Hotel Group	Head of Food & Beverage
9	Erwin Hendriks	Notiz Hotel Group	Chef Campus Kitchen
10	Tristan Delstra	Notiz Hotel Group	Practice Instructor and Chef Canteen
11	Eelco Bleeker	Firda	MBO Chef
12	Douwe van der Lei	Notiz Hotel Group	Former restaurant owner and NHG employee

Tab. 4 - Follow up session participants



Fig 10- Visit at the Circular Plastics Lab at NHL Stenden UAS



Fig 11- Visit at the Circular Plastics Lab at NHL Stenden UAS

5. RESULTS

- The results of this project revealed deep-rooted challenges, perceptions, and opportunities surrounding the use of single-use plastics (SUPs) in hospitality kitchens. Drawing from video observations, participant reflections, and co-creative discussions, the findings are grouped into four main themes: emotional responses and awareness, root causes of SUP use, target items for intervention, and proposed solutions and opportunities for change.

5.1. Results and key themes emerging from the 16th of April 2025 Co-creative XR session

Emotional responses and awareness

Initial exposure to video footage of kitchen operations was eye-opening for participants. While some were already aware of the extensive use of SUPs, others were struck by the sheer volume of plastic waste, especially disposable gloves, cling film, and plastic containers. The footage highlighted improper waste separation — often attributed to time pressure — and significant quantities of unnecessary packaging from suppliers, such as plastic crates wrapped within additional plastic. These observations triggered strong emotional reactions. Participants expressed frustration over the perceived overuse of plastics and questioned the necessity of certain practices. Feelings of guilt were common, as individuals recognized their contribution to the problem. Many also reported a sense of powerlessness, feeling trapped in a system where plastic use is normalized and alternatives seem difficult to implement. Despite these negative emotions, participants showed a genuine willingness to explore change, albeit acknowledging that shifts in mindset, behavior, and structural systems would be required (Fig. 5).

Key insights

- **Emotional Responses:** frustration, guilt, powerlessness among staff.
- Kitchen footage showed **high volumes of plastic waste** (gloves, plastic wrap / cling film, containers).
- **Improper waste separation** due to time pressure.
- SUPs used for **hygiene, convenience, and regulation compliance**.

Fig 5- Overview of the key participants insights and reflections

Root Causes of SUP use

The dialogue and analysis identified a range of intertwined factors driving SUP use in kitchens. First, habitual practices and learned behaviors have entrenched plastic use as the norm. Convenience and efficiency also emerged as key drivers: plastics facilitate rapid operations, help conserve food, and minimize cleanup effort. Hygiene and regulatory compliance were repeatedly cited as justifications for plastic use — for example, wearing gloves to prevent cross-contamination, meeting health code requirements, or presenting a hygienic appearance. However, discussions revealed that some of these practices may result from over-interpretation of regulations or a culture of excessive caution. The hierarchical structure of kitchens further compounds the issue; staff are often expected to follow the head chef's directions without questioning the environmental impact of certain routines. Additional root causes included lack of education on alternatives, perceived cost efficiency of plastic solutions, and systemic factors such as supplier practices and packaging standards (Fig. 6). Notably, participants highlighted that plastic use is often overlooked during kitchen evaluations, where hygiene and operational flow take precedence over sustainability concerns.

Root Causes of SUP use

- Plastic use is **normalized** in kitchens.
- **Lack of education** on sustainable alternatives.
- Regulatory **over-interpretation** and confusion.
- **Kitchen hierarchy** challenges behavioral change.
- **Target items** for intervention:
 - **Plastic wrap | Cling film**
 - **Disposable gloves**
 - **Containers**

Fig 6- Overview of discussed root cause of SUPs use

Target Items for Interventions

Participants identified specific SUP items where intervention could have an immediate impact. These included:

- **Cling film:** widely used for wrapping and storage, often without standard guidance. In most cases, lids can replace cling film to preserve food stored in a container.
- **Disposable gloves:** used for hygiene, convenience, and cosmetic reasons, but sometimes unnecessarily.
- **Plastic containers:** prevalent in food storage, transport, and sampling, with opportunities to switch to reusable alternatives.

While some uses of plastic — such as vacuum bags for food preservation — were seen as harder to replace at present, the group agreed that focusing on these three items offered a practical starting point for waste reduction.

Proposed solutions and opportunities for change

The results pointed to multi-level interventions spanning short-, mid-, and long-term horizons (Fig. 7).

- **Short-term actions** include the creation of Standard Operating Procedures for glove and cling film use, improving access to handwashing stations to reduce glove dependency, and exploring reusable lids and containers.
- **Mid-term strategies** focus on building awareness and changing behaviors. Suggested actions involve developing training and educational programs (e.g., through hotel schools), using positive nudges such as team competitions and visual waste tracking, and promoting local procurement to reduce packaging.
- **In the long-term**, participants envisioned a systemic shift led by universities of applied sciences, which could set new sustainability standards, act as testing grounds for best practices, and foster partnerships with suppliers, designers, and industry bodies. Supply chain collaboration, including renegotiated contracts with suppliers to reduce unnecessary packaging, was seen as critical to success.

Overall, the results highlight both the complexity of SUP use in kitchens and the readiness of stakeholders to engage in meaningful change when supported by clear guidelines, education, and structural incentives.

Proposed Interventions & Opportunities

Short-Term Actions:

- Create Standard Operating Procedures for glove and cling film use.
- Explore reusable lids and containers.
- Improve access to handwashing facilities to reduce glove dependency.

Mid-Term Strategies:

- Develop training & awareness programs (e.g., in hotel schools).
- Use positive nudges (e.g., team competitions, visual waste tracking).
- Promote local procurement with minimal packaging.

Long-Term Vision:

- Universities of Applied Sciences to set sustainability standards.
- Foster cross-sector partnerships (e.g., suppliers, Horeca Nederland, designers).
- Leverage pilot kitchens to test and scale successful practices. Plastic wrap | Cling film
- Disposable gloves
- Containers

Fig 7- Overview of the Short-, Mid-, Long-term interventions and opportunities

5.2. Results and key themes emerging from the 15th of May 2025 follow up session

a) Plastic use in kitchen and role of the supply chain

Across the supply chain, plastic is deeply ingrained in daily operations. Suppliers typically deliver fresh food in plastic boxes or gas-filled bags, similar to supermarket packaging. To speed up kitchen processes, sliced vegetables are often purchased, which invariably come in plastic. Even sustainable alternatives, like eco-friendly cups, arrive wrapped in plastic. Suppliers cite hygiene regulations, preservation of freshness, and portioning standards as reasons for this dependency. For example, organic produce must not contact non-organic items, necessitating packaging. Suppliers are sometimes open to reuse ideas, such as transporting sliced onions in reusable buckets. Yet, logistical challenges—like the inefficiency of transporting round containers—and hygiene concerns limit progress. Furthermore, suppliers find it hard to scale client-specific requests and rarely change practices mid-contract unless financial incentives align.

b) Challenges balancing operations, sustainability, and cost

There is an ongoing tension between operational efficiency, sustainability, and cost control. Daily fresh deliveries often mean accepting produce in plastic, as this is seen as the only way to meet tight timelines. From a life cycle assessment (LCA) perspective, plastic can sometimes be justified if it prevents food loss—for instance, extending the shelf life of cucumbers. Cultural expectations and shopping habits also play a role. In countries like Italy or Mediterranean countries, daily grocery shopping reduces reliance on plastic packaging, but in many other contexts, plastic use is normalized and expected. Internally, practices like using vacuum bags for portioning and storage are popular due to their convenience, though efforts are underway to reduce reliance through improved planning and alternative techniques such as fermenting seasonal produce.

c) Influence on suppliers and the tendering process

The current tendering and procurement processes often lock in packaging practices for years, leaving little room for change unless sustainability requirements are embedded from the outset. There is a need to involve chefs, sustainability experts, and other key stakeholders when drafting contracts to ensure balance between operational needs and environmental objectives. Suppliers are unlikely to innovate unless sustainability contributes directly to the business case or is contractually required. Moreover, consistency of supply and system limitations sometimes restrict flexibility, even when chefs are willing to adapt.

d) Educational and cultural dimensions

The discussion with chefs and practitioners highlighted how hospitality students today often have less familiarity with fresh, unprocessed produce, making it harder to shift towards practices that minimize packaging. There's a broader challenge in reconnecting future managers with the environmental context of food production — from soil health to pollution impacts. Within kitchens, reliance on single-use plastic items (e.g. plastic wrap) is habitual, and knowledge about alternatives is limited. Initiatives like reducing waste bag use by ensuring bins are filled before disposal have shown promise, as have trials with paper wraps in place of foil.

e) The role and potential of co-creation using XR environments

The XR co-creative session experience provided a valuable platform for shared reflection. The short film produced from the lab experiment created a common reference point, helping stakeholders understand each other's perspectives — what one saw as normal plastic use, another saw as excessive. This transparency facilitated deeper conversations and collaborative solution-building. Co-creation sessions like these are seen as essential for future progress, alongside engagement with packaging manufacturers, suppliers, and cross-sector experts. There is growing interest in involving finance professionals to assess long-term costs, and in forming coalitions of willing universities and businesses to drive supplier change through collective action.

f) Looking forward

Next steps will involve layered strategies: short-term actions within direct control (such as reducing plastic bag use) and long-term efforts to influence suppliers and packaging industries. Testing bioplastic alternatives within the facilities, exploring collective procurement, and sharing findings at industry events are planned. There is agreement on the importance of involving policy makers at the right stage and selecting partners carefully to ensure credible, scalable solutions.

5.3. Future Interventions

Short-Term (Inside Circle of Influence)

- Reduce plastic waste bag usage: fill to capacity before disposal.
- Replace plastic wrap with butcher paper or alternatives.
- Improve kitchen planning to reduce vacuum bag use.
- Use the XR experience (film, shared reference point) to deepen stakeholder understanding and co-create solutions.

Long-Term (Outside Circle of Influence)

- Build supplier partnerships to co-develop alternative packaging solutions.
- Embed sustainability clauses in supply contracts (balance specificity with flexibility).
- Collaborate with packaging producers, policymakers, and cross-sector experts (e.g. circular plastics).
- Foster seasonality in menu planning (reduces reliance on imported, plastic-packed goods).

Co-creation & Collaboration

- Expand co-creation sessions to include:
 - *Packaging manufacturers*
 - *Food distributors*
 - *Finance experts (lifetime cost assessments)*

- *Policy makers (determine ideal stage for involvement)*
- Explore collective procurement as UAS (act as distribution hub to influence supplier packaging choices).
- Test bioplastics (e.g. cups, foils) within facilities.
- Leverage cross-sector professorships (e.g. circular plastics).

Next Steps

- Organize layered follow-up:
 - *Inside circle: coalition of the willing (internal ops, faculty, engaged suppliers)*
 - *Outside circle: suppliers, packaging industry, policy influencers*
- Seek funding and assign writing agents to support project development.
- Share learning and progress at Internal and external stakeholder meetings, conferences, and symposiums
- Carefully select partners for alternative solution trials.

6. CONCLUSIONS

This project provides valuable insights into the practical challenges and opportunities for reducing plastics, particularly single-use plastics, in kitchen operations. It highlights that plastic use is deeply embedded in food safety, freshness preservation, and operational efficiency, making reduction efforts complex and requiring a balance between sustainability and daily operational demands. The project reveals that kitchen staff often face constraints such as supply chain packaging, hygiene regulations, procurements and logistical limitations, which complicate plastic refuse and reduction.

A key novelty of this project is the use of Extended Reality (XR) as an innovative tool to engage stakeholders and create a shared understanding of plastic use issues. The immersive XR experience enabled diverse participants—chefs, students, and lecturers—to visualize and reflect on plastic use patterns together, fostering collaborative dialogue and generating actionable solutions. This XR approach represents a pioneering method for sustainability engagement in hospitality and food service education and operations and future (long-term) tool for education and training.

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