Rigid plastic: A wasted opportunity?

Scaling non-packaging rigid plastic recycling through practical system design

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This document contains the *Rigid plastic: A wasted opportunity? Scaling non-packaging rigid plastic recycling through practical system design* for the TREASoURcE project (Grant Agreement No. 101059491).

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Project Details			
Project acronym	TREASoURcE	Start / Duration	June 2022 / 48 months
Topic	HORIZON-CL6-2021-CIRCBIO-01-01 – Circular Cities and Regions Initiative (CCRI)'s circular systemic solutions	Grant Agreement No	101059491
Type of Action	Innovation Action (IA)	Coordinator	VTT Technical Research Centre of Finland Ltd
Contact person	Ugur Kaya, ugur.kaya@vtt.fi		
Website	https://treasource.eu/		

Deliverable Details			
Deliverable No	N/A		
Deliverable Name	Rigid plastic: A wasted opportunity? Scaling non-packaging rigid plastic recycling through practical system design		
Work Package	WP2, WP3, WP5, WP6		
Dissemination level	PU	Type	Report
Due Date (M)	30.4.2026	Submission date	30.4.2026
Lead Beneficiary	FVH	Responsible Author	Kaisa Sibelius

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Document History			
Date	Version	Name	Changes
26.04.2026	1	Rigid plastic: A wasted opportunity? Scaling non-packaging rigid plastic recycling through practical system design	First draft
07.05.2026	2	Rigid plastic: A wasted opportunity? Scaling non-packaging rigid plastic recycling through practical system design	Reviewed and final version

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Acronyms and abbreviations

Acronym	Full name
ARL	Australasian Recycling Label
AWCS	Automated Waste Collection Systems
CE	Circular Economy
EPR	Extended Producer Responsibility
FVH	Forum Virium Helsinki Oy
HSY	Helsinki Region Environmental Services Authority
IDBM	International Design and Business Management

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Executive Summary

The transition toward a circular economy has increased the need for more efficient systems for collecting, sorting, and recycling plastic waste. While packaging plastics are relatively well addressed through existing regulatory and infrastructure frameworks, non-packaging rigid plastics remain a largely underdeveloped waste stream, with low recycling rates resulting in significant material losses through incineration and mixed waste disposal.

This report presents the outcomes of a research project conducted in collaboration with the Aalto University International Design Business Management (IDBM) programme and TREASoURcE project together with the use case of the mentoring company Syklo Oy (Syklo). It explores how rigid plastic collection could be improved in ways that are practical, scalable, and aligned with real market conditions, while directly supporting the objectives of the TREASoURcE project by addressing challenges related to plastic recognition at the consumer level. This report is an additional research study related to WP3.

The research follows a systemic thinking approach and combines desk research, stakeholder interviews, and international field observations, including a comparative case study in South Korea.

Based on our research, we identified two key bottlenecks:
(1) the high cognitive burden placed on consumers in sorting complex materials, and
(2) the lack of accessible and convenient collection infrastructure.

To address these challenges, we developed and evaluated four design visions. However, stakeholder feedback and feasibility analysis revealed that no single solution is sufficient in isolation. As a result, we propose a combined system built on three key elements:

- **local collection hubs** with assisted sorting,
- **seasonal collection models** aligned with waste generation patterns, and
- **reverse logistics** leveraging existing urban delivery networks.

This integrated approach reduces the burden on households, improves material quality, and enables scalable collection by utilizing existing infrastructure and behavioral patterns.
Ultimately, the proposed model shifts rigid plastic recycling from an individual responsibility to a system-supported process, improving both participation and efficiency while creating a foundation for future data-driven optimization and policy development.

This report is an additional deliverable within the initial project plan, it directly contributes to the project's core strategic goals. By documenting and analysing plastic recycling and treatment processe, it serves as 'replicable practices', which was established as key objectives of the TREASoURcE project to ensure long-term impact and scalability.

1. Introduction

The transition toward a circular economy has increased the need for more efficient systems for collecting, sorting, and recycling plastic waste. While packaging plastics have received significant regulatory attention and infrastructure investment across Europe, non-packaging rigid plastics remain an underdeveloped waste stream with comparatively low recycling rates. As a result, large quantities of valuable plastic material continue to be lost through mixed waste disposal, incineration, or inefficient recovery systems.

The expert on the challenge presented by the TREASoURcE project was circular economy company Syklo is preparing a new processing solution intended to strengthen rigid plastic recycling in Finland. The company is currently developing one of the largest rigid plastics recycling facilities in the country, creating an important opportunity to increase domestic material recovery capacity. However, recycling infrastructure alone is not sufficient to ensure success. Without effective collection systems, clear sourcing channels, and active stakeholder participation, only limited volumes of rigid plastics will reach the facility.

This industry project was carried out as part of the IDBM programme at Aalto University. The interdisciplinary project team consisted of students from business, technology, law, and design backgrounds, enabling a broad and systems-oriented approach to the challenge. Working in collaboration with Syklo, the team was tasked with exploring how rigid plastic collection could be improved in ways that are practical, scalable, and aligned with real market conditions.

The project is particularly relevant in the Finnish context, where ambitious sustainability targets and circular economy goals require stronger material circulation and improved resource efficiency. Increasing the recovery of rigid plastics can reduce waste, decrease reliance on virgin raw materials, and create new economic value through recycling. At the same time, successful implementation depends on solutions that consider both operational feasibility and consumers' readiness to participate in recycling systems.

This report presents the project process and outcomes, focusing on opportunities to improve the sourcing and collection of non-packaging rigid plastics for Syklo's upcoming facility. It outlines the project goals, research findings, concept development process, and final recommendations. These results are also part of the TREASoURcE project replicable practices and publicly available beyond the end of the project.

1.1. Project Collaboration and TREASoURcE Alignment

The collaboration with the Aalto University International Design and Business Management (IDBM) programme was designed to directly support the objectives of the TREASoURcE project by addressing challenges related to plastic recognition and bio-waste sorting at the consumer level. The outcomes of the studies will be beneficial for consumers, whose everyday waste-sorting behaviour and access to effective systems are critical for improving circular material flows.

Executing this task within an established and internationally recognised academic programme ensures the application of the latest research knowledge and methodologies. This is critical for ensuring the quality, credibility, and impact required by an EU-funded project. The defined challenge is connected to the target areas of TREASoURcE's WP2 (consumers and stakeholder engagement demos), WP3 (the circulation of non-recycled plastics), WP5 (biobased side and waste streams), and WP6 (transferable practices and exploitable results). In addition, WP8 (communication) disseminates the results to various stakeholders.

The participating company, Syklo Oy, has contributed to the project primarily in the role of industry expert, challenge provider, and mentor for the student team. It has introduced real-world challenges based on its expertise in waste management and circular economy solutions. The company's role has been to ensure that the student work is grounded in practical relevance and reflects current industry needs, while keeping the focus on broader societal impact.

The selected student project focuses on rigid plastic collection logistics**.** The challenge is highly relevant from a consumer perspective, as inefficiencies in sorting systems and unclear practices at the household level lead to significant losses in recycling quality. By developing new concepts, insights, and system-level improvements, the project aims to make waste sorting more intuitive, accessible, and effective for consumers. In this way, the work contributes to enabling better environmental outcomes in everyday life.

Importantly, the results of this student project are public and openly available, ensuring that the knowledge generated can be widely utilised beyond the immediate project context. This openness reinforces the role of the TREASoURcE project as a driver of shared learning and scalable solutions, maximising its impact across sectors and regions.

1.2. Acknowledgements

We would like to express our sincere gratitude to all the organizations and individuals who generously shared their time and expertise during our field research in South Korea.

We especially thank Envac Korea for providing detailed insights into automated waste collection systems and for arranging site visits that allowed us to better understand technical and operational aspects. We are also grateful to AETECH for introducing innovative smart collection technologies, and to Associate Professor Jooyoung Park of Seoul National University (Department of Civil and Environmental Engineering) and Hanyang University Global Circular Economy Center (Department of Global Climate Environmental Studies)'s researchers, for providing academic insights into Korea's waste management system and policy framework.

Their openness and willingness to engage in discussion greatly enriched our understanding of the Korean recycling ecosystem and contributed significantly to this research.

2. Project Goals and Scope

The primary goal of this project was to identify practical solutions that could support the scaling of rigid plastic recycling in Finland and beyond by increasing the supply of non-packaging rigid plastics for recirculation and material recovery. Syklo's upcoming hard plastic processing facility in Hyvinkää, Finland, was utilised as a case study to ground the research and provide a practical context. The project sought to address both supply-side and participation-related challenges, recognising that successful recycling systems depend on efficient operations as well as stakeholder engagement.

More specifically, the project aimed to understand the current barriers limiting the collection and sourcing of rigid plastics, and to develop concepts that could improve the flow of materials from waste generators to recycling processes. In line with the project brief, particular attention was given to economic realities, implementation feasibility, and consumers' willingness to participate in recycling systems.

The key objectives of the project were to:

- analyse the current ecosystem for rigid plastic collection and recycling in Finland;
- identify inefficiencies, bottlenecks, and missed opportunities in existing sourcing channels;
- understand the needs, behaviours, and incentives of relevant stakeholders, including consumers, waste management operators, businesses, and municipalities;
- generate innovative concepts that could increase collection volumes and improve system performance;
- evaluate proposed concepts based on desirability, feasibility, scalability, and potential impact.

The scope of the project focused specifically on non-packaging rigid plastics within the Finnish market context. Although wider European circular economy frameworks informed the work, the recommendations were developed primarily for conditions relevant to Finland and were refined in the context of Syklo's operational environment. To get real life perspective and understanding to the industry project. The goal is that the results can be shared and give insight for replicability of the case.

The project did not include technical design of recycling machinery, detailed plant engineering, or full financial investment modelling. It also did not involve full-scale implementation of the proposed concepts. Instead, the emphasis was placed on opportunity identification, stakeholder insights, and concept development that could support future strategic decisions and pilot initiatives. Through this scope, the project aimed to contribute actionable recommendations for increasing rigid plastic recovery rates and strengthening circular material flows in Finland.

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3. Background Information and Analysis

This report is based on comprehensive research divided into three preliminary sub-reports covering project planning stage, desk research, and empirical observations. The collective findings of the underlying research, which took place between November 2025 and April 2026, are brought together in this background section.

3.1. Planning Stage

After initial consultation with the key stakeholders (Forum Virium Helsinki and Syklo), and aligning with them on the research brief, our team decided to adopt a systemic, stakeholder-centred approach in attempt to identify novel, creative, and transferable solutions to hard plastic recycling. The approach was deemed appropriate, as it is tailored for understanding interconnectivity of human centric phenomena and the complexity of problems produced, and utilises pluralist methodology to produce insights into management of "organised complexity" and "wicked problems" for decisionmakers (Jackson, 2024).

With the view of conceptualising the complex, systemic problem of recycling of household rigid plastics, the lifecycle of rigid plastic and its journey through waste management system was mapped first. Based on the mapping, initial surface level research, and key stakeholder consultation, two significant bottlenecks in the waste stream flow were identified – sorting and disposal on the consumer side propagated by the lack of awareness and convenience, and the logistics of collection and transforming the waste to Syklo's recycling plant in Hyvinkää, Finland at low cost. Identification of these bottlenecks early was crucial for the following stages of deck research and empirical observations, as they served to frame and focus our work. Concurrently, we identified and mapped the stakeholders of the focal company (Syklo), with the aim of pinpointing the key actors and their level of influence and interest in rigid plastic recycling. This led us to focus particularly on stakeholders with high interest and influence levels, namely key public and commercial actors. In addition, attention was given to consumers, who are at the centre of rigid plastic material flow, as well as abstract stakeholders such as society and environment.

To facilitate critical and introspective approach, we further outlined the potential risks and constrains on the research, as well as ways of mitigating them. Most importantly, we identified that the present research could be affected by conflicting stakeholder interests. While the focal company of our research needs material flow of sufficient quality for low cost to ensure the profitability of its factory, households prioritise convenience and effortlessness of waste sorting. On the other hand, TREASoURcE is interested in solutions that can be widely utilised beyond the immediate project context. Therefore, coming up with a logistically perfect system tailored to the needs of Syklo (strict sorting rules and no expenses) may fail if other stakeholders are not ready to shoulder the financial or practical sorting burden, or if the solution lacks broader applicability. To address this issue, we adjusted our design approach to be user centric, with the aim of ensuring wide participation. In addition, we frame our solution in wider EU and international context to satisfy broader applicability.

3.2. Desk Research

The desk research took place within diverse disciplines, with the aim of establishing a sufficient theoretical foundation based on the prior, relevant literature, and taking full advantage of the diverse expertise of the research team. This research was conducted utilising semi-systematic literature review as a methodology, which allowed us to approach the topic flexibly and produce a wide overview of the research area (Snyder, 2019; Wong et al., 2013).

3.2.1. Historical Background

The historical development of waste management in Finland followed a similar development path to the rest of the Europe, moving from early urban sanitation and waste dumping in the mid-19th century to a high-tech circular economy. At the end of the 1990s, following its membership in EU in 1995, Finland produced 65–70 million tons of waste annually. Although two-thirds of industrial waste was already being recycled, municipal waste still ended up mainly in landfills (Melanen et al., 2002). The solution was to introduce extended producer responsibility (EPR) in 1997 following gradual adoption by other EU member states, which obliged companies to take responsibility for the life cycle of their packaging (Mallick et. al., 2024).

The current Waste Act (646/2011), updated in 2021, requires all housing companies in Finland with at least five apartments to provide separate waste bins for biowaste, plastic, metal, and cardboard (Finland.fi, 2021). Despite this, the plastic recycling rate was only 31% in 2022. As a result, the EU has initiated legal proceedings against Finland for failing to meet the 50% target by 2025 (Finnish Government, 2025). To remedy this, Finland is investing in new industrial projects, including the focal company of this research – Syklo, which will be launching a rigid plastic reception and recycling service nationwide for waste management operators in 2026 (Syklo, 2025).

3.2.2. Rigid Plastics

Rigid plastics are solid materials that are very stiff and resist deformation until they break. Unlike flexible plastic films, thin wrappers, or single use drinking bottles, rigid plastics are typically used to make durable goods and long-lasting products. Common household examples include toys, buckets, and garden furniture. (Wong M. B., 2009). In Finland, solid plastic products such as crates, buckets, toys and larger containers are not normally covered by packaging recycling scheme. Only plastic packaging, for which there is an EPR-system in place are specifically collected from households' centralized recycling shelters. Citizens can also recycle packaging waste through Rinki recycling points free of charge. For non-packaging rigid plastics, Finland has historically lacked a comprehensive nationwide recycling infrastructure, meaning that most rigid plastics have ended up incinerated or downcycled (Espoo, 2026).

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Figure 1: Rigid plastics collected at Syklo's new recycling facility in Hyvinkää

Currently, people in Finland are encouraged to separate rigid plastics from general waste and packaging streams. Non-packaging hard plastics can be taken for example in Helsinki region to Sortti Stations (municipal sorting and recycling stations operated by Helsinki Region Environmental Services Authority HSY), which receive all plastics marked with code 02, 04 and 05. These are generally items like plastic garden furniture, freezer containers, chopping boards, winter sleds and toys. Citizens are asked to pay by the volume of recyclables (10,20 € / m3 / 1000 litres). To give an example, two plastic bags of plastic items (0,05 m3) cost 0,51 € (HSY, 2026). Sortti Stations are usually located on the outskirts of the cities.

3.2.3. International Benchmarking and Initiatives

At the EU level, Finland's municipal waste recycling rate stands at 44.8%, slightly below the EU-27 average of 47.7%. Germany and Austria are the leaders in municipal recycling, with rates over 60% (Waste recycling in Europe, 2025). Their waste sorting systems are comparable to the Finnish one and distinguish between paper and cardboard, glass, metal (only in Austria), bio, plastic packaging, and residual waste (Abfall Trenn-ABC, 2019; Mülltrennung, 2026). Recently some German municipalities have implemented "Werstofftonne" (*eng. recycling bins*), which combine multiple recycling materials (such as metals, plastic packaging, and rigid plastics) in one bin. These municipalities report increased household convenience and claim this approach can raise recycling volumes by approximately 8 kg per household per year (Die Wertstofftonne, 2026).

Another recycling leader in Europe is Belgium with a municipal recycling rate of 55,8% and a recycling rate of plastics of 54,2%, partially attributable to the national ban of landfills and a high cost for burning waste, incentivizing recycling. Substantial investments in sorting infrastructure, together with the nationwide "blue bag" system combining plastic packaging, metals, and drink cartons, further contribute to these outcomes (Waste recycling in Europe, 2025). In contrast, France relies on a more simplified collection system, typically consisting of one glass container and two additional bins. As a result, its municipal recycling rate was 40.3% while the recycling rate for plastic packaging was only 25.2% in 2022, the lowest in Europe (Plastic Waste and Recycling in the EU: Facts and Figures, 2024; Guide to Waste and Sorting, 2026). Overall, despite comprehensive and increasingly harmonised EU legislation, significant differences persist among Member States in both waste management practices and plastic recycling performance.

Outside Europe, Australia provides an example of a system focused on simplifying complex sorting rules through highly visual and intuitive guidelines. As noted in the City of Sydney's waste services, a primary strategy is the "Scrunch Test," which serves as an easy tool for residents to distinguish between hard and soft plastics. If the items "bounce back" when squeezed, such as milk bottles, shampoo containers, and biscuit trays, they can be recycled as hard plastics. On the other hand, plastics that can be easily scrunched into a ball (e.g., bread bags, confectionery wrappers, and plastic film) are currently sorted in general waste. This approach is complemented by the Australasian Recycling Label (ARL), which uses standardised icons to indicate the recyclability of items and applicable instructions. Together, these tools reduce confusion and contamination, highlighting the value of simple physical tests and clear visual cues that could be adopted to promote hard plastic recycling.

In the United States, the recycling system is highly decentralized, with the recycling system varying significantly by state and municipality. Curbside collection and recycling is the most widespread mode of collection of household recyclables, which operates through two main models: single-stream and dual-stream collection. In the single-stream collection the residents combine all recyclables in one bin. This method is widely considered to be more convenient but also increases risk of contamination. On the other hand, in the dual-stream system, the residents separate fibres (paper and cardboard) from containers (plastics, metal, glass), which produces streams of recycled material of better quality, but also is more costly due to separate collection (National Academies of Sciences, Engineering, and Medicine, 2025). Private, complementing initiatives include for profit companies such as TerraCycle, which operates corporate sponsored as well as commodified collection models for materials commonly excluded from curbside recyclables collection.

South Korea represents a contrasting model characterised by household and community collection point separation as well as strict recycling rules. Citizens recycle rigid plastics separately from general waste. Transparent PET bottles are collected separately from other plastics to improve purity of the recycled stream. For larger and non-packaging rigid plastic items, citizens purchase their own recycling bags, which are then collected on the curbside on specific days. Historically, EPR in Korea has applied only to plastic packaging, but from 1 January 2026, the system has been expanded to include 18 categories of toys, although products containing batteries require separate handling (Eco-Business, 2025). In parallel, South Korea has introduced mandatory recycled content requirements for PET bottles, starting at 10% in 2026 and expected to increase to 30% by 2030, reinforcing demand for high quality recycled plastics (City of Sydney, n.d.).

3.2.4. Findings from Adjacent Fields

On a legislative level, the EPR in EU is based on the Directive 2008/98/EC, which sets up the general waste framework of the Union. Among else, the directive establishes the so-called waste hierarchy, requiring Member States to adopt measures to encourage waste management methods that deliver the best overall environmental outcome in the following order: prevention, reuse, recycling, recovery, disposal (Article 4). According to Article 8, Member states may take measures to ensure that the producers of products take financial responsibility for re-use, the prevention, recycling and other recovery of waste associated with their products. This may include, for instance, acceptance of returned products or remains of a used product, management of subsequent waste, financial responsibility for these activities, as well as provision of information to the public on the recyclability of their products.

From a technical point of view, owing to the variety of different types of plastic, sorting of rigid plastics presents various technical challenges, which places the burden of separation on households. Nonetheless, recent technological advancements (for instance, near-infrared spectroscopy, visual / RGB sorting, and Terahertz (THz) separation) have led to improvements in identification of different polymers and removal of contaminants based on the transparency and colour of the plastic, combination of which could potentially leading towards automated sorting in the future and reduce the burden on individual households (Okubo et al., 2025). In addition, recent developments in Machine Learning and Artificial Intelligence (AI) have shown significant promise. For instance, AI-powered waste-sorting robots can recognize and classify many types of waste with high accuracy allowing for more effective sorting of rigid plastics and other recyclables in recycling facilities (AETECH 2026).

Rigid plastic recycling is also affected by behavioural elements. Some studies show that people may engage in recycling because they feel an expectation from community members to be responsible (Vining and Ebreo, 1992). Another trigger can be altruistic concern for the better future, which however requires a belief that one's actions have widespread harmful consequences (Awareness of Consequences) and that a person is personally responsible for these consequences (Ascribed Responsibility) (Valle et al., 2005). Furthermore, research suggest that perceived convenience of recycling might weigh more than general environmental attitudes of a person when it comes to participation (De Young, 1988-1989), and that while monetary incentives can initiate recycling, the behaviour frequently stops once the incentive is removed (Vining and Ebreo, 1992). Overall, research indicates that individual’s belief in the impact of their actions, satisfaction with the frequency and location of collection, and a clear, localised moral obligation as a part of community seem to be the most significant driving forces of participation.

Insights from marketing field corroborate the behavioural findings. The research by White and Simpson (2013) indicates that messages work better when they focus on the immediate community rather than a broader general group. Accordingly, consumers do not respond to prompts stating that the whole country or the whole world recycles. Instead, marketing message stating that a person’s own neighbourhood or city recycles creates a stronger desire to join the movement. Furthermore, according to a study by Kronrod, Grinstein, and Wathieu (2012), the level of assertiveness in green marketing plays a significant role. According to the study, demanding or forceful language is effective only when a behaviour is already a well-established social norm, whereas for new or unfamiliar behaviours it provokes irritation and resistance. This is particularly relevant in the Finnish context, where hard rigid plastic collection is novel for most households, indicating that communication should be framed in a gentle, inviting, and encouraging manner rather than through aggressive or obligatory messaging.

3.3. Empirical Research

The Empirical research employed a qualitative, exploratory case-study research design, combining learnings from desk research, field observations, and semi-structured interviews. Following a comparative pre-study of international cases, South Korea was selected due to existing rigid plastic collection initiatives, advanced logistics and automation, clear contrast with European systems while providing sufficient similarities, and due to difficulty to collect data on the country through secondary sources alone due to a language barrier.

The objective was to understand how household-level rigid plastic collection and recycling systems are designed and operated in practice, with particular attention to logistics, citizen engagement, and technological infrastructure, and to identify transferable insights for the Finnish context. Our observation focused primarily on user behaviour at collection points, clarity and complexity of sorting instructions, infrastructure design and accessibility, contamination or misuse, and the waste journey from disposal to sorting and transportation.

3.3.1. Interview with an Infrastructure and System Operator (Envac Korea)

Envac Korea – a manufacturer of automated waste collection systems (AWCS) – was chosen as one of the facilitators of empirical research in order to collect information on household behaviour in response to advanced waste collection and transporting systems, and to investigate how much responsibility can be shifted from users to systems. The AWCS itself operates through a series of pneumatic pipes connecting separate bins and households in an area. Once the waste enters the pipes, it travels to the waste collection station and enters a compressor, which then moves the waste into special containers for collection (Envac, 2025).

From the user's perspective, the system has been made easily accessible and clear. A flyer or a poster informs residents about what can be disposed of in the AWCS (see Figure 2). In South Korea, residents only pay for the garbage they produce, so the door only opens with an individual key card, and waste is weighed before disposal. Waste that cannot be processed in the AWCS is sorted in a dedicated area, with labelled bins, sometimes including photos demonstrating types of waste. In addition, oversized waste or unsuitable waste can be scheduled for pickup through an app for an additional fee.

Our findings indicate that convenience, accessibility, and discreetness, are highly appreciated qualities by consumers for which they are ready to pay, whether it is through the AWCS system or a mobile app, through which one can order collection on bulky waste without the necessity of bringing the item to recycling centre. We further observed that pay-as-you-throw system implemented in South Korea creates more awareness of individual waste production, as it is directly connected to the amount of money paid by the consumer. Contrary to the Finnish system, where waste management fees are collected from the housing collectives, consumers are therefore more likely to pay attention to the amount of waste generated by themselves. In addition, we noted the collective waste collection areas featured a significant number of visual and textual instructions on waste separation facilitating clarity and efficient recycling.

Figure 2: Envac's automatic waste collection system with disposal instructions

3.3.2. Interview with a Sorting Technology Provider (AETECH)

AETECH Co., Ltd. – a company specialising in AI and robot-based material recovery technology – was in turn chosen to be one of the facilitators of empirical research in order to assess how much technological solutions compensate for or depend upon high-quality household sorting. Indeed, according to AETECH, the sorting in households is ineffective, with recycling rate of household waste processed by recycling centres in South Korea being only around 30%. Furthermore, the material recovery and waste management centres also suffer from a lack of workforce for manual conveyor belt-based sorting, which in addition poses various safety risks for the employees. To address these issues the company has been developing AI-powered solutions to automate the sorting process through the application of robotics (AETECH, 2026).

Specifically, as an alternative and as a complement to manual waste classification, AETECH has developed ATRON operating interface (or an 'AI sorting robot'), which utilises a robotic arm operating on air pressure. This robot is able to grab objects of various sizes and shapes through suction and incorporates RGB and AI based visual recognition systems, which identify the waste, its shape, and position in real time. The visual recognition system is supported by the AI-database, which enables the recognition and classification of various waste types based on their shape, colour, label, and material. AI-database, known as WAI-KOR (Waste AI Korea) has been developed to address the problem of difficult-to-identify waste, such as food packaging with significant food residue. By training the AI database with examples of such packaging, it becomes possible for the robot to classify and sort such waste which is normally difficult to distinguish visually, as well as dismiss it if it is too contaminated.

Our empirical findings indicate that the technological landscape in waste management is rapidly evolving. Due to development of highly sophisticated recycling robots and waste identification techniques, it is possible to imagine that recycling might not rely in the future on the efforts of households to accurately separate the waste. In fact, in future it might be more efficient to conduct waste separation outside households through automated means. We also noted that AI-databases are highly customisable to different use cases and may be adapted to different countries and cultures to better understand the local waste stream.

Figure 3: Model of AETECH's technology, presented at the AI conference held in Seoul

3.3.3. Interview with an Academic Expert (Seoul National University)

Associate Professor Jooyoung Park from the Department of Civil, Urban, and Environmental Engineering of the Seoul National University provided our empirical research with a critical perspective of the waste management system in South Korea, how it functions, and is perceived. Our discussion confirmed our previous observation on the impact of pay-as-you-throw practise on the behaviour of individual consumers. Indeed, since the implementation of Volume-Based Waste Fee (VBWF) in 1995, waste generation in Korea has steadily dropped and has remained low for decades. This seems to indicate that consumers have internalised the impact of waste generation. Nonetheless, paradoxically the plastic consumption in Korea is high particularly due to the rise of single-person households and the perceptions of hygiene. Therefore, we observed that even an excellent recycling infrastructure struggles to keep up with the culture of hyper-consumption.

We also considered the tensions inherent to complex sorting rules and ease of disposal. According to study by Tonjes, D. J. et al. (2018), when a community switches from a complex sorting system to a simple single-stream system the amount of waste recycled by people increased by 25.8 percent. In addition, 25 percent less recyclable material ends up by mistake in the regular trash bin, which makes the recycling process more effective. However, the simplicity and convenience might also lead to people throwing normal thrash into the recycling bin thus causing a heavier bin and potential contamination of recyclables. Therefore, we observed that simplification of the recycling system might lead to an increase of material flow but can also reduce its quality.

Our discussion further revealed cultural differences between commercial value of recycled materials. While being green has become a significant salespoint in EU, producers in Korea might not see the same value in transitioning to recycled materials. The producers might not be inclined to change their designs if virgin materials are cheaper and if the consumers are not inclined to buy recycled materials, for instance due to hygienic concerns. Consequently, Dr. Park emphasized the significance of strong EPR system, which would drive transition despite the lack of voluntary action by the industry. In addition, Dr. Park challenged the notion that recycling materials is always safe. Indeed, if recycling plastic repeatedly can potentially lead to concentration of certain toxic substances. This can lead to materials becoming hazardous over time and create a risk if they are reinjected into the market. Finally, Dr. Park also offered a critical view on upcycling, stating that it does not solve the root cause of plastic waste, and can even make it harder to recycle it.

3.3.4. Interview with an Academic Expert (Hanyang University)

In addition, we had the opportunity to speak with researchers from the Hanyang University Global Circular Economy Center, Department of Global Climate Environmental Studies at the International School. The interview provided valuable insights into the circular economy system of Jeju Island, Korea – an island province that cannot export all of its waste and is therefore strongly incentivized to develop highly efficient recycling systems. The discussion highlighted several differences compared to mainland Korea. Notably, Jeju has introduced unique measures such as a deposit system for beverages in disposable cups. The island has also embraced cutting-edge waste separation technologies, including systems for rigid plastics, and has already implemented AI-based sorting robots at the Jeju Resource Recovery Center, which began operations in June 2023. One particularly interesting feature is Jeju's waste collection model, which combines door-to-door collection ("Clean Houses") with centralised hub-based collection ("Recycling Assistance Centers").

While door-to-door collection is similar to that in Finland and uses neighborhood-based sorting and disposal points, the Jeju's system covers a significantly wider range of categories accepting 11 types of waste, including recyclable plastics, PET bottles, and vinyl. In addition, the province has established 164 Recycling Assistance Centers across the island. These centers function as centralized points where residents can dispose of waste at any time of day. They accept up to 17 types of waste and also facilitate the direct sale of recyclables to companies. Importantly, Jeju's recycling system also contributes to social inclusion by creating employment opportunities for groups that face barriers to entering the labor market. As of August 2024, a total of 1,258 senior workers are employed across the Clean Houses and Recycling Assistance Centers. This demonstrates that a circular economy can advance not only environmental sustainability but also meaningful social objectives.

3.4. Summary of Background Research

This research combined desk research with empirical insights to assess how rigid plastic recycling could be advanced in the Finnish context. Historically, waste management has evolved in response to public health concerns, industrialisation, and growing environmental awareness. Today, Finland operates within a mature legislative framework aligned with EU directives, including the waste hierarchy and EPR. Despite this progress, both desk and empirical research confirm a persistent structural gap, as non-packaging rigid plastics lack a comprehensive recycling infrastructure and are therefore often incinerated rather than recovered. International comparisons further show that, despite shared regulatory ambitions, significant differences remain in how rigid plastics are treated globally.

The empirical review further supports the desk research finding that recent technological developments, particularly the integration of multiple sorting methods and AI-based solutions, make higher quality recycling of rigid plastics increasingly feasible. However, the findings equally confirm that technology alone is insufficient. Behavioural research demonstrates that recycling participation depends heavily on perceived convenience, clear local norms, and accessible infrastructure, while marketing insights highlight the importance of localised, supportive, and ease-focused communication when introducing new recycling behaviours.

At the same time, the empirical research adds important critical depth by challenging some commonly held assumptions. While desk research frames recycling as a generally positive outcome, expert insights caution that repeated plastic recycling can lead to the accumulation of hazardous substances, and that upcycling may obscure rather than address systemic waste issues. Overall, the transition toward effective rigid plastic recycling requires balancing material purity with user convenience. Success depends on aligning regulation, infrastructure, technology, and consumer behaviour into a coherent and practical system.

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4. Concept Development

This section describes our concept development process. To overcome the systemic challenges households face regarding rigid plastic recycling, our team initially developed four different design visions. After presenting these to various stakeholders and receiving thorough feedback and insights, we decided to move from separate visions to a combined concept. In our final solution, we have combined the most feasible elements of our original visions into a cohesive, phased system.

4.1. Defining the Systemic Gap

To develop a credible practical application of our concept, we first had to demonstrate the shortcomings of the current system. Studies shows that currently 65 percent of Finland's plastic waste consists of plastics other than packaging and construction plastics (Uusiouutiset 2024). Of this massive amount, however, only 1 percent of non-packaging plastics is recycled. As a result of the system's flaws, approximately 5 kilograms of hard plastic waste per person ends up in mixed waste each year (Uusiouutiset 2024; TREASoURcE, 2024.).

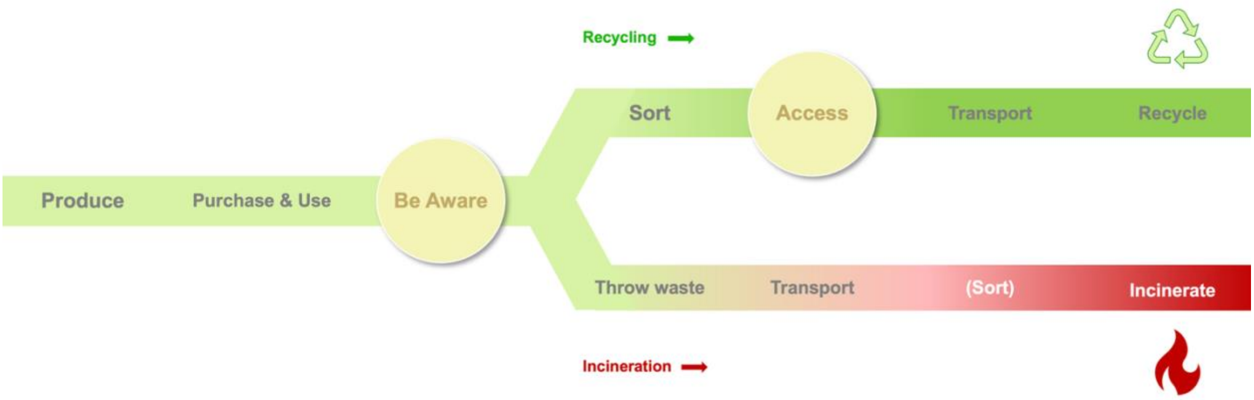

Figure 4: Bottlenecks within the current waste journey

Based on our research, we found that there are two key bottlenecks hindering the recycling of hard plastics (see Figure 4). First, the cognitive burden on consumers is enormous. Thinking through what plastics should be disposed of and how involves a surprisingly large amount of effort, while the costs of this remain almost invisible to consumers. Second, the physical infrastructure is inadequate. Long distances to collection points that handle hard plastics are impractical for the average city dweller in their daily life.

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4.2 Evaluating the Four Visions

4.2.1. Vision 1 – One Bin Fits It All

In this concept, we prioritized consumer convenience by proposing a radical simplification of sorting, with a single bin for all types of plastic. However, feedback from our industry partners revealed that purity requirements are extremely strict. This is also where EPR comes into play, as in this solution, packaging plastic producers would effectively have to pay for the processing of rigid plastics as well. Furthermore, Syklo's processing plants are unable to handle mixed plastic streams without significant financial and operational consequences. Implementing this vision would shift the burden of manual sorting from households directly to the system's infrastructure. This change would result in high processing fees for Syklo, rather than generating a profitable return from high-quality raw materials, which is, of course, Syklo's goal.

4.2.2. Vision 2 – Reduce, Repair, Reuse, and Recycle

This model was based on the stages of the EU waste hierarchy that occur before sorting, such as repair and reuse. In this vision, we proposed easily accessible community spaces where citizens could repair broken hard plastic items, receive guidance on how to do so, and, as a last resort, recycle them. Although the model was theoretically ideal for maximizing the lifespan of materials and increasing their value, behavioral analysis and stakeholder feedback showed that consumer motivation for this would in reality be very low. It was considered unlikely that the general public would spend their own time repairing cheap everyday items. Furthermore, this approach would not be able to cover the massive amounts of raw materials needed to sustain Syklo's industrial operations.

4.2.3. Vision 3 – Data-Driven Product Design

The purpose of this vision was to shift the focus to systematic responsibility across the entire lifecycle by introducing a data passport for products. This would make product information transparent to everyone and thus serve as a radical tool for sustainability. By utilizing digital product passports and a transparent lifecycle, the system would shift the burden of recycling from customers to producers. Although this concept aligns perfectly with upcoming European Union regulations and would relieve consumers' responsibility, it does not solve the physical logistical challenges faced by local communities. This also requires long-term work with the entire life cycle chain. However, the ability and obligation to collect data may be crucial to the future of recycling. With that we can create a sustainable design feedback loop and produce transparent and reliable data for the public, government, consumers, and producers.

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4.2.4. Vision 4 – Waste Hitchhiking on Urban Logistics

To overcome the bottleneck caused by physical distance, this vision proposed a reverse logistics flow that leverages existing urban distribution networks. Because hard plastic products take up a lot of space and collection points are often located far away, people are reluctant and unwilling to store and transport these large individual items of waste for too long or too far. By utilizing the empty return space in couriers and retail delivery vehicles already moving around the city, we can bring the waste collection point directly to the user. This reverse logistics model significantly improves accessibility. However, this requires pre-sorted, clean waste from consumers to meet hygiene requirements, as well as clear financial incentives for couriers.

4.3 Formulating the Final Vision

A reality check revealed that none of the visions could function successfully in isolation from the others. Vision One failed due to Syklo's strict industrial process requirements, as well as the lack of an EPR. Vision two would fail due to people's passivity and a lack of consumer motivation. Taking these observations into account, our team adopted the data generation mechanism from vision three and combined it with the reverse logistics process from vision four. In addition, components such as the improved accessibility and convenience of vision one and two are incorporated. This combination creates a dynamic system that simultaneously addresses both the lack of consumer awareness and the lack of physical accessibility, without neglecting the industrial business model.

5. Evaluation and Testing

5.1. Development and Testing of Reverse Logistics

5.1.1. Courier and Transport Service Evaluation

A comparative assessment was conducted to evaluate the feasibility of integrating reverse logistics into existing service networks. The analysis considered multiple service types, including food delivery platforms, ride-based services, logistics providers, and public transport systems.
Evaluation is based on qualitative assessment using six criteria: spatial capacity, hygiene constraints, operational impact, additional distance requirements, benefit to service providers, and ethical considerations. Ratings (Low / Medium / High) reflect relative feasibility for integration into reverse logistics systems.

Table 1. Feasibility Assessment of Courier and Transport Services

Service Type	Space Capacity	Hygiene Constraints	Impact on Delivery Efficiency	Additional Distance Required	Benefit to Service Provider	Ethical Considerations
Wolt / Uber Eats	Low	High	Low	Medium	High	Low
Uber Drive	Medium	Medium	Medium	Medium	High	Low
Manufacturers (Trucks)	High	Medium	Medium	Low	Medium	High
Grocery Delivery Robot	Low	High	Medium	Medium	Medium	High
Grocery Delivery Truck	High	Medium	Medium	Medium	Medium	High
Securitas Van	High	High	High	Medium	Low	Medium
Posti	Medium	Medium	Medium	Medium	Medium	High
Public Transport	Low	High	Low	Medium	Low	High
Library Buses	Low	Medium	Low	Low	Medium	High

The results indicate that not all service types are equally suitable for integrating reverse logistics. While rigid plastics are generally not heavily contaminated at disposal, services involving food delivery (e.g., Wolt, Uber Eats) face significant hygiene constraints. Addressing these would require additional handling solutions, such as separate storage compartments, increasing operational complexity. Public transport systems were also found to be unsuitable due to limited storage capacity, as well as a lack of operational flexibility and compatibility with collection activities. In contrast, on-demand delivery services (e.g., Uber Drive) and delivery trucks (e.g., manufacturers' trucks) demonstrate higher feasibility due to available space, greater flexibility in routing, and a stronger alignment with transport and logistics functions, making them more adaptable to reverse logistics integration.

A key insight from the analysis is that economic and operational incentives are critical determinants of feasibility. Even technically viable services require minimal disruption to existing routes and workflows to ensure participation (Masorgo, 2023).
This insight informed the development of localized collection hubs, strategically positioned along delivery routes, and complemented by a seasonal collection model that concentrates waste volumes. Together, these elements create a system that leverages existing infrastructure and underutilized capacity, thereby improving economic feasibility while enabling scalable implementation.

5.2. Development and Testing of Local Collection Hubs

In addition to evaluating reverse logistics, the feasibility of localized collection hubs was assessed as a core component of the system. To further evaluate the feasibility of hub-based collection, insights from the recycling system in Jeju Island were used as a benchmark. In Jeju, residents are required to sort waste at designated recycling centers or local collection hubs, where materials are separated with on-site guidance. The system has demonstrated high levels of material recovery and improved sorting quality.

A key success factor for this case was the combination of: accessibility (localized centers within residential proximity), on-site assistance (reducing sorting errors) and economic incentives (cost differentiation with for example pay-per-weight biowaste encourages proper sorting). The Jeju case demonstrates that investment in localized collection infrastructure can significantly improve both participation and material quality.

Based on the benchmark and project analysis, localized hubs are considered a viable investment due to their ability to:

- Centralize material flows for efficient transport
- Improve sorting quality through assisted separation
- Serve as data collection points for future system optimization
- Reduce reliance on individual sorting knowledge

Collection hubs act as both operational and informational infrastructure within the system.

While the installation of collection hubs introduces upfront costs, these are offset by several downstream benefits. Improved sorting quality reduces contamination, increasing the recyclability and value of collected materials. This, in turn, lowers processing costs and reduces reliance on mixed waste treatment. At a system level, this can lead to cost savings for housing associations and reduced waste management expenditures for municipalities and governments.

As demonstrated in comparable systems such as Jeju, investment in sorting infrastructure enables long-term cost savings and higher recovery rates, justifying initial expenditure.

5.3. Development and Testing of Seasonal Collection Model

Rigid plastic waste is not generated continuously, but rather during specific events such as seasonal cleaning, relocation, or renovation. As a result, waste generation is irregular but occurs in concentrated volumes during peak periods.

In the current system, households primarily dispose of rigid plastics through mixed waste streams, which are typically associated with higher disposal costs and lower material recovery. This creates an opportunity for a more targeted collection approach. By introducing separate collection during peak periods, rigid plastics can be diverted from mixed waste, improving both recycling outcomes and cost efficiency. That is why we aim to engage housing companies as key stakeholders in enabling this model, as they are responsible for organizing waste management and bearing the associated costs. By implementing temporary, seasonal collection systems such as on-site containers or scheduled collection events, housing operators can reduce mixed waste volumes and associated expenses, while facilitating higher-quality material recovery.

5.3. Overall Evaluation

5.3.1. Economic Feasibility Assessment

The economic feasibility of the proposed system altogether was assessed through a qualitative cost–value analysis, focusing on key cost drivers and potential value creation across stakeholders.

The primary cost elements identified include:

- Infrastructure costs for installation and operation of pop-up and permanent collection hubs
- Operational costs for staffing (facilitators at hubs), sorting and temporary storage
- Transportation costs for transfer of collected materials to recycling facilities, potential compensation for reverse logistics participation

Having these costs in mind, the proposed system incorporates several mechanisms to improve cost efficiency such as the use of existing infrastructure, which reduces the need for new investments and capital expenditure while reducing detours and operational inefficiencies, even minimizing transport costs. Also, seasonal collection model concentrates volume and further improves transport efficiency.

Thereby, the system is designed to minimize additional costs by leveraging existing flows, infrastructure, and spatial resources, rather than creating entirely new systems.

5.3.2. Value Creation and Cost-Value Balance

The proposed system generates value by increasing the recovery of recyclable rigid plastics, reducing reliance on incineration, and improving the quality of materials supplied to recyclers such as Syklo. In addition, the system enables the generation of data, which can support future optimization and automation.

While additional costs are introduced at the collection stage, these are partially offset by improvements in material recovery and overall system efficiency. The model therefore represents a cost redistribution rather than a net increase, shifting value from waste disposal toward material recovery.

5.3.3. Evaluation Synthesis and Next Steps

Overall, the combined evaluation of localized collection hubs and seasonal collection models demonstrates that the system is both operationally feasible and economically justified. Evidence from benchmark systems such as Jeju Island highlights the value of accessible, assisted sorting infrastructure, while the seasonal model aligns with real waste generation patterns and household cost structures.
However, several aspects require further validation. These include the development of appropriate economic incentives for courier participation, the coordination between multiple stakeholders, and user adoption of hub-based disposal systems.

6. Results and Final Concept

The final concept is a hybrid that combines multiple components of the previous design visions. It aims to improve the identified bottlenecks of raising awareness of rigid plastic recycling and of increasing convenience by improving access to nearby disposal solutions. The proposed concept is split into two phases with an additional outlook into the future. In the first phase, we propose the installation of recycling pop-ups, which can lead to permanent collection hubs, and a seasonal waste collection of rigid plastics. If additional measures are needed, we propose to make use of existing logistics (reverse logistics) to enhance accessibility in a second phase.

6.1. Recycling Pop-ups and Permanent Waste Collection Hubs

The recycling pop-ups are intended to improve accessibility by placing them in convenient locations that are nearby, easy to reach on foot or by public transport, and ideally on the routes of many users, such as malls, areas next to the libraries, or in metro stations. By placing the pop-ups in visible locations, they also raise awareness of the rigid plastic recycling issue. At each pop-up, trained facilitators assist with sorting and can dismantle more complex items made from multiple materials. We also envision a process that tracks which items are recycled to automate and improve the sorting process in the future. If successful, these pop-ups can be transformed into permanent collection hubs. To make use of existing infrastructure, we propose placing them near existing recycling touchpoints such as malls, second-hand stores, and Rinki stations or reuse centers (e.g. Kierrätyskeskus in Helsinki region). We see this as a shared-value system, where costs are distributed across stakeholders who benefit. In the early phase, public funding and pilot support, such as through projects like TREASoURcE, would enable implementation. As the system scales, costs can increasingly be supported by industry actors, such as recyclers and producers, especially as regulatory frameworks like EPR evolve. At the same time, logistics actors can participate through new service models built on existing delivery networks. Furthermore, we envision the pop-ups being operated through a public–private collaboration. Municipalities or waste authorities would act as system owners, while partners such as Syklo would support material handling and processing.

Visually, the collection hubs are visioned as welcoming and not exactly traditional recycling center style. Instead, we are connecting a strong visual, colorful and inspiring space that catches your attention and makes people want to pop-in. The mood is combination of vintage and contemporary styles that allows the location to be next to second hand or any other retail stores. The use of rigid plastic made products and rigid plastic materials for surfaces and furniture enhances the circular economy aspect.

Figure 5: Visual mood board for recycling pop-ups and permanent waste collection hubs

6.2. Seasonal Waste Peak Collection

Through our research, we noticed that waste, especially long-lasting items made of rigid plastics, is discarded in seasonal spikes, such as spring and autumn cleaning. Therefore, we propose seasonal peak-based collection in local neighborhoods, in addition to or alternating with the recycling pop-ups. A similar system is already in place; however, it is not for rigid plastics, which is a missed opportunity, and many rigid plastics end up in the mixed waste. Further, we mapped out other holidays or events that can be leveraged (see Figure 6). Regarding financing, we propose a similar multi-stakeholder engagement that also includes housing complexes. The housing complexes are already paying for waste collection, and the mixed waste is among the most expensive. Thus, there is a financial incentive to implement a less expensive collective rigid plastic container in the neighborhood, with the potential to decrease mixed waste. We would place these container bins to strategic locations, for great efficiency together with indoor collection hubs. Style wise these containers should pop up visually compared to other collection points. We will use this attention for marketing purposes with educational aspect about how the recycled materials will be used for products.

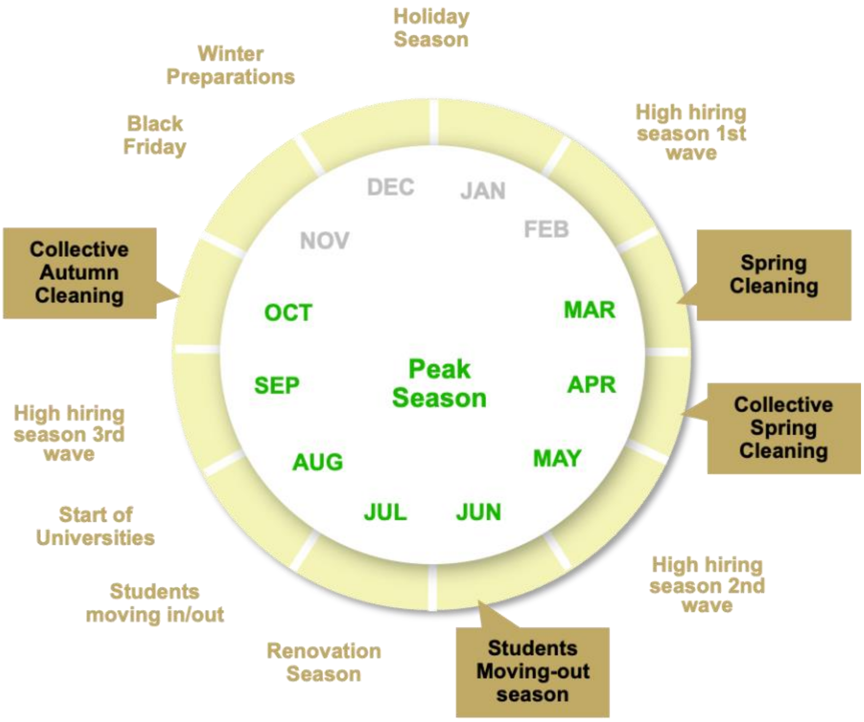

Figure 6: Seasonal waste peak model

Visually, the collection hubs are visioned as welcoming and not exactly traditional recycling center style. Instead, we are connecting a strong visual, colorful and inspiring space that catches your attention and makes people want to pop-in. The mood is combination of vintage and contemporary styles that allows the location to be next to second hand or any other retail stores. The use of rigid plastic made products and rigid plastic materials for surfaces and furniture enhances the circular economy aspect.

Figure 7: Visual mood board for seasonal waste peak collection bins

6.3. Reverse Logistics

In case phase one of the recycling pop-ups and seasonal waste collection proves to be underutilized due to inconvenience, we propose to enhance accessibility through reverse logistics in phase two. The idea of reverse logistics is to utilize the existing courier delivery network, which brings goods from local shops, restaurants, or postal stations to the user and leaves the user empty-handed. We propose that users can give couriers their rigid plastics for a small fee. Previously collected data can be used to aid the work of the couriers through an automated app that detects rigid plastics. However, the detailed process and type of courier service would strongly depend on the learnings of the previous phase regarding types of rigid plastics and user behavior.

We would place these container bins to strategic locations, for great efficiency together with indoor collection hubs. Style wise these containers should pop up visually compared to other collection points. We will use this attention for marketing purposes with educational aspect about how the recycled materials will be used for products.

6.4. Future Outlook

In the future, we see great potential in using collected data to improve sorting by automation, as well as influence that products are designed with recycling in mind. Nonetheless, we acknowledge that a regulatory framework such as EPR for rigid plastics has the potential to accelerate the systematic shift toward recycling them.

8. Conclusion

In accordance with the objectives set for this project, this research explored the current ecosystem for rigid plastic collection and recycling in Finland. The research showed that there is a persistent structural issue, as non-packaging rigid plastics lack a comprehensive recycling infrastructure and are therefore often incinerated. Consequently, large amount of potentially valuable material is presently lost, due to non-packaging rigid plastics falling outside the current EPR scheme and being effectively excluded from municipal collection. Instead, the existing infrastructure relies on consumers being actively aware of existence of rigid plastics as a separate waste category, as well as them being knowledgeable enough to separate the material from complex compound products. Furthermore, any existing recycling centres in Finland that accept rigid plastics are inconveniently placed on the outskirts of cities, demanding significant time investment to access especially by means of public transport.

These observations led us towards identifying inefficiencies of the current system as well as bottlenecks affecting the material flow of household rigid plastics. Both the desk and empirical research demonstrated that, in addition to inadequacy of current recycling infrastructure, behavioural factors such as perceived convenience and localised values can play a significant role in recycling participation. Therefore, in order to access the previously missed material flow, it was necessary to design a solution that addresses both the user awareness and user perception of convenience. In addition, the research indicated that utilising the cutting-edge technologies in identification and separation of plastics could be leveraged for shifting the burden of separation from households to recycling centres.

To address the identified issues, we proposed four independent design visions with different strengths. These included a single plastics bin, developing local repair and recycling hubs, utilising reverse logistics for rigid plastic collection, and enabling data-driven product design. Nevertheless, based on stakeholder feedback and evaluation of feasibility, we came to a conclusion that none of the proposed visions design would be able to address the complex and systemic problem of rigid plastic recycling by itself. Consequently, we developed a final concept, which combined multiple components of the previous design visions into a one comprehensive intervention.

Our final proposal consists of two phases comprising a comprehensive intervention. In the first phase, we have proposed addressing the issue of accessibility through establishment of recycling pop-ups. In addition, due to the fact that rigid plastics are found in long-lasting products that are not frequently thrown, we have proposed a collection system utilising seasonal waste peaks. If a sufficient participation level is not reached after the initial phase, we have proposed to intensify the household engagement through introduction of waste collection by reverse logistics, which utilises existing delivery routes. Concurrently, during both phases, we have suggested to collect data about the thrown rigid plastics, their types, disposal frequency, and methods of separation from complicated compound products. This data could be leveraged in future to automate the separation process for refinement of high-quality material flow. In addition, the data could be used to guide decisionmakers to adopt more extensive product lifecycle legislation, which could lead to more sustainable product design, as well as eventual integration of non-packaging rigid plastics into the EPR-scheme. The proposed concept has been discussed and its potential validated with the mentor company Syklo. However, the need for further validation and adaptation to specific operational context was acknowledged.

We imagine that in our proposal, the recycling pop-ups could be organised and managed by public-private collaboration. At the same time, seasonal collection could be encouraged as a private initiative, as housing collectives and neighbourhoods already engage companies to supply containers for disposal of seasonal waste. In addition, as under the current system, facilities such as Syklo could partially offset transporting fees if the material is of sufficient quality, while a waste disposal fee would be paid if the material is of low quality. Risen transporting fees due to enhanced collection initiatives could be partially subsidised by the government during the pilot stage. Eventually, after the pilot phase, we imagine that rigid plastic recycling would be transitioned under EPR system.

Finally, we reiterate that the present research attempted to align several conflicting stakeholder interests. Therefore, we highlight that the report is drafted to provide a broad overlook and widely applicable insights beyond a single case-study. The solution can be further tailored to the interest of a specific company, such as Syklo, after a more detailed business centric validation.

9. REFERENCES

- Abfall Trenn-ABC. (2019, January). Retrieved from Bundesministerium für Nachhaltigkeit und Tourismus:https://www.bmluk.gv.at/dam/jcr:5bc56edf-daff-402c-b1f3-7f1b4705f85b/Abfall_Trenn_ABC_ua.pdf
- AETECH. Atron. Accessed 13.2.2026. https://www.aetech.co.kr/en/
- City of Espoo. Recycling rigid plastics – do you know how to recycle plastics other than packaging? Accessed on 12.2.2026. https://www.espoo.fi/en/news/2023/05/recycling-rigid-plastics-do-you-know-how-recycle-plastics-other-packaging?utm_source=chatgpt.com
- City of Sydney. (n.d.). Recycle household items. Accessed on 2.2.2026. https://www.cityofsydney.nsw.gov.au/waste-recycling-services/recycle-household-items
- De Young, R. (1988-1989). Exploring the difference between recyclers and non-recyclers: The role of information. Journal of Environmental Systems, 18, 341-351
- Die Wertstofftonne. (2026). Retrieved from Abfallwirtschaft Dithmarschen: https://die-wertstofftonne.de
- Eco-Business. South Korea to include plastic toys in recycling responsibility scheme from 2026. Accessed on 13.2.2026. https://www.eco-business.com/news/south-korea-to-include-plastic-toys-in-recycling-responsibility-scheme-from-2026/
- Envac Group. (2025, March 12). Envac Korea marks 30 years of pioneering smart waste management. Envac Group. https://www.envacgroup.com/news/envac-korea-marks-30-years-of-pioneering-smart-waste-management/
- Finland.fi. (2021). From bottles to molecules: Finland continues to reshape its plastic recycling. https://finland.fi/business-innovation/from-bottles-to-molecules-finland-continues-to-reshape-its-plastic-recycling/
- Finnish Government. (1993). Waste Act (1072/1993). https://www.finlex.fi/api/media/statute-foreign-language-translation/688952/mainPdf/main.pdf
- Guide to Waste and Sorting. (2026). Retrieved from Mairie de Paris: https://www.api-site.paris.fr/mairies/public/assets/2017%2F5%2FGuide%20to%20waste%20sorting.pdf
- HSY, Helsinki Region Environmental Services Authority. (2023). Waste management service fees 2024. https://www.hsy.fi/globalassets/jatteet-ja-kierratys/tiedostot/waste-management-service-fees-2024.pdf
- Jackson, Michael C. Critical Systems Thinking: A Practitioner's Guide, John Wiley & Sons, Inc., 2024.
- Kronrod, A., Grinstein, A., and Wathieu, L. (2012). Go green! Should environmental messages be so assertive? Journal of Marketing, 76(1), 95-102.
- Mallick, P. K., Salling, K. B., Pigosso, D. C. A., & McAloone, T. C. (2024). Designing and operationalising extended producer responsibility under the EU Green Deal. Environmental Challenges, 16, 100977. https://doi.org/10.1016/j.envc.2024.100977
- Melanen, M., Kautto, P., Saarikoski, H., Ilomäki, M., & Yli-Kauppila, H. (2002). Finnish waste policy—effects and effectiveness. Resources, Conservation and Recycling, 35(1-2), 1–15.
- National Academies of Sciences, Engineering, and Medicine (2025). Municipal Solid Waste Recycling in the United States: Analysis of Current and Alternative Approaches. Washington, DC: The National Academies Press. https://doi.org/10.17226/26.
- Okubo, K., Manago, G., Tanabe, T., Yu, J., Liu, X., & Sasaki, T. (2025). Identifying plastic materials in post-consumer food containers and packaging waste using terahertz spectroscopy and machine learning. Waste Management, 196, 32–41. https://doi.org/10.1016/j.wasman.2025.02.018

Funded by the European Union

- Plastic waste and recycling in the EU: facts and figures. (2024, June 25). Retrieved from European Parliament: https://www.europarl.europa.eu/topics/en/article /20181212STO21610/plastic-waste-and-recycling-in-the-eu-facts-and-figures.
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039.
- Syklo Oy. Circular Economy Pioneer Syklo Driving Waste Management Companies into a New Era of Rigid Plastic Recycling. Accessed on 12.2.2026. https://syklo.com/circular-economy-pioneer-syklo-driving-waste-management-companies-into-a-new-era-of-rigid-plastic-recycling/?utm_source=chatgpt.com
- TREASoURcE. (2024). Rigid plastic campaign: Collection & sorting. https://treasource.eu/wp-content/uploads/2023/06/TREASOURCE_Rigid_Plastic_Campaign_Collection_Sorting_11012024.pdf
- Uusiouutiset (2024). Pakkausmuovi kiertää pääkaupunkiseudulla ja Lahdessa kohtalaisen hyvin– Kovan muovin ja rakennusmuovin kierto edelleen heikkoa. https://uusiouutiset.fi/pakkausmuovi-kiertaa-paakaupunkiseudulla-ja-lahdessa-kohtalaisen-hyvin-kovan-muovin-ja-rakennusmuovin-kierto-edelleen-heikkoa/
- Valle, P. O. D., Rebelo, E., Reis, E., & Menezes, J. (2005). Combining Behavioral Theories to Predict Recycling Involvement. Environment and Behavior, 37(3), 364–396. https://doi.org/10.1177/0013916504272563
- Vining, J. and Ebreo, A. (1992), Predicting Recycling Behavior from Global and Specific Environmental Attitudes and Changes in Recycling Opportunities. Journal of Applied Social Psychology, 22: 1580-1607.
- Waste recycling in Europe. (2025, December 03). Retrieved from European Environmental Agency: https://www.eea.europa.eu/en/analysis/indicators/waste-recycling-in-europe?activeAccordion=ecdb3bcf-bbe9-4978-b5cf-0b136399d9f8
- White, K., and Simpson, B. (2013). When do (and do not) normative appeals influence sustainable consumer behaviors? Journal of Marketing, 77(2), 78-95.
- Wong, G., Greenhalgh, T., Westhorp, G., Buckingham, J., & Pawson, R. (2013). RAMESES publication standards: Meta-narrative reviews. BMC Medicine, 11, 20. https://doi.org/10.1186/1741-7015-11-20.
- Wong, M. B. (2009). Plastic analysis and design of steel structures. Elsevier. https://doi.org/10.1016/B978-0-7506-8298-5.00005-3

PHOTO CREDITS

Figure 5:
1. https://www.fyra.fi/reference/posti-helsinki-10/
2. https://www.counterproduction.co.uk/product/durat-p008-mint-julep/
3. https://syklo.com/products/recycled-plastic-pellets/
4. https://australianinteriordesignawards.com/gallery/2022/public-design/4Q01UOP9468
5. https://fi.pinterest.com/pin/300826450141957124/
6. https://www.instagram.com/p/DQUpW8EEtXN/?img_index=1
7. https://fi.pinterest.com/pin/300826450141957149/

Figure 7:
8. https://www.giulioiacchetti.com/?p=3900
9. https://materialdistrict.com/article/watch-ocean-plastic/
10. https://the-brandidentity.com/project/heydays-and-goods-partner-to-craft-a-software-led-identity-for-waste-management-company-carrot

11. https://syklo.com/products/recycled-plastic-pellets/
12. https://the-brandidentity.com/project/accompanys-zesty-brand-for-round-and-round-is-paving-a-path-for-a-circular-more-sustainable-future?utm_source=Pinterest&utm_medium=organic
13. https://www.indiamart.com/proddetail/industrial-heavy-duty-corrugated-boxes-2858517976630.html
14. https://brandlic.studio

Funded by the European Union