Circular Economy: Design for Recycling and Data Exchange for Plastic Packaging

Master’s thesis in Industrial Ecology

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Abstract

Circular economy is becoming a key way of addressing use of limited resources and environmental impact, but currently the use of plastic packaging is far from circular. One of the challenges that hinder a circular flow of plastic for packaging is that the packaging is not always designed to work with existing recycling infrastructure. Together with a literature review of recent scientific findings and policy documents, interviews were used to fulfil the aim of analysing the state-of-the-art and current data exchange practices of the plastic packaging value chain. Semi-structured interviews were conducted with 19 companies that produce and sell products with plastic packaging (product producers), and 10 complementary interviews were conducted to cover a larger part of the value chain. With the recently introduced EU Packaging and Packaging Waste Regulation (PPWR), the industry has an increasing focus in Design for Recycling (DfR). The main tool that product producers use for DfR today is DfR guidelines, but the study show that these can diverge in their assessments of products. The industry currently only have a small focus on traceability, but the PPWR will bring more focus to this as requirements for ensuring recycling at scale comes into affect. DfR and differentiated fees is a start but increased data exchange in the industry has the potential to improve circularity to a new level.

Keywords: Circular Economy, Plastic Packaging, Design for Recycling (DfR), Traceability, Producer, Sorting, Guidelines.

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A special thanks to Linnea Granström and Rickard Jansson at Swedish Plastic Recycling for showing us Site Zero in Motala and giving us their insights and sharing knowledge about the current and future plastic packaging recycling.

Also, a special thanks to all 29 companies that agreed to participate in an interview during the spring. The participation exceeded expectations both in terms of numbers and engagement. Every conversation provided valuable insights. It became clear that this is a topic of concern for many companies in the Swedish industry. Although this report cannot encompass all aspects discussed, we will carry the insights gained during our time at Chalmers with us, allowing them to guide us in our future careers

Thank you!

Oscar Ivarsson and Olliver Persson

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Definitions and acronyms

BoL. Beginning-of-Life. Refers to the initial stages of a product's lifecycle, including design, material sourcing, manufacturing, and distribution.

BMC. Business model canvas.

Brand owner. Here defined as a company that owns a product brand. Some brand owners are also the product producer for their product and some outsource production to a product producer.

Chemical recycling. Chemical recycling is the process of converting polymeric waste by changing its chemical structure and turning it back into substances that can be used as raw materials for the manufacturing of plastics or other products.

Circular economy. A system where waste is minimized and resources are kept in use for as long as possible. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting.

DfR. Design for recycling. Refers to a product's inherent potential to be reused at end-of-life (EOL), encompassing not only material recycling but also part reuse, remanufacturing, and energy recovery.

DLF. A trade organisation for companies that produce or import goods for the grocery or food-service market in Sweden.

DPP. A digital product passport is a set of information connected to a physical product using a unique identity.

EoL. End-of-life. Refers to the final stage of a product's lifecycle when it is no longer useful or functional and must be disposed of, recycled, or repurposed.

EPR. Extended Producer Responsibility.

GS1 Sweden. The Swedish part of GS1. GS1 Sweden is a non-profit organisation helping companies around the world identify, label and share information about everything that moves in their value chains and flow of goods.

High-quality recycling. Defined in the EU Packaging and Packaging Waste Regulation as: any recycling process which produces recycled materials that are of equivalent quality to the original materials, based on preserved technical characteristics, and that are used as a substitute to primary raw materials for packaging or other applications where the quality of the recycled material is retained.

Low-quality material recycling. Recycled materials that do not have equivalent quality to the original materials, and that are used as a substitute for other materials but cannot fulfil the same original purpose as the raw material.

Mechanical recycling. The processing of waste plastics by physical means (grinding, shredding, washing, drying and melting) back into a plastic product.

NPA. Näringslivets Producentansvar, a PRO in Sweden.

Packaging producer. Here defined as a company that produce and sell plastic packaging material to be filled by other companies.

PPW. Plastic Packaging Waste.

PPWR. Packaging and Packaging Waste Regulation.

PRO. Producer Responsibility Organisation.

Product producer. Here defined as a company that produces a product and puts it in packaging from a packaging producer.

Recyclability. Plastics must meet four conditions for a product to be considered recyclable. The four conditions are that the product must be made of plastic that is collected for recycling, have market value, and/or be supported by a legislatively mandated program. Secondly, the product must be sorted and aggregated into defined streams for recycling processes. Thirdly, the product can be processed and reclaimed/recycled with commercial recycling processes. Lastly, the recycled plastic becomes a raw material that is used in the production of new products.

SIS. The Swedish Standards Institute, SIS is a part of ISO and CEN and manages a network of experts who work to create international standards.

SPÅ. Swedish Plastics Recycling, a company operating the plastic packaging sorting facility 'Site Zero' in Sweden.

SVDH. Svensk Dagligvaruhandel, is the trade association for the food retailers in Sweden. The members are Axfood, Coop Sweden, ICA , Lidl Sweden and Livsmedelshandlarna.

TMR. Tailor-made Responsibility, a PRO in Sweden.

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1 Introduction

A circular economy is a concept originating from industry with an abundance of definitions currently being used within the academic literature, most of them with an emphasis on reducing, reusing and recycling to increase sustainability (Kirchherr et al., 2017). A common focus in a circular economy is to maximise and maintain the value of the extracted resources by reusing them, recognising that the resources on Earth are limited (Kalmykova et al., 2018). The use of plastics in packaging is currently far from circular. During the year of 2023, Swedish households sorted 128 000 tons of plastic packaging for recycling, leaving 107 000 tons unsorted in the general household waste (Landerdahl et al., 2024), although the unsorted waste could be even higher due to unreported volumes (Ljungkvist Nordin et al., 2019). Of the plastic packaging entering the recycling material stream in Sweden, 60 000 tons is likely rejected at Sweden's largest plastic packaging sorting facility in Motala (Ljungkvist Nordin and Boberg, 2019). There is, therefore, much potential in improving the end-of-life waste management system for plastic packaging. Moreover, Material Economics, 2018 argues that in the Swedish economy, as much as 8,7 billion SEK is lost yearly due to plastic leaving the economic system.

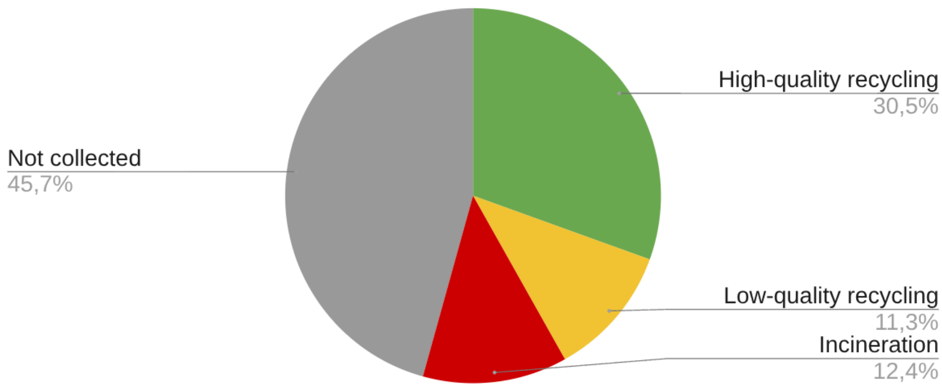


Figure 1: Waste management outcomes for plastic packaging in Sweden in 2023. The estimate is made from the composition of collected plastic, not sorting output data. (Data source: Landerdahl et al. (2024) and Näringslivets Producentansvar (2023))

The main challenges include waste not being sorted for recycling by consumers and that the sorted waste is not designed to be recycled over and over again (high-quality recycling), as seen in Figure 1. A considerable part of this design for recycling (DfR) problem can be traced to the wide variety of use cases that plastic has and the complexity coming from the wide variety of additives and colours included in the plastic (Material Economics, 2018). The circularity of plastic packaging can increase through either improved end-of-life processes or by adapting the design of plastic packaging, and both approaches need to work together (Mangers et al., 2023). Industry actors and government agencies also state that packaging design needs to consider recycling if circularity is to increase (Swedish Plastics Recycling, 2024, Naturvårdsverket, 2021). Ljungkvist Nordin et al. (2019) concludes that several initiatives are currently underway to increase the recyclability of packages in the design phase, but that information for designing recyclable packages needs to increase across the value chain.

Currently, the Swedish system and the Swedish extended producer responsibility scheme encourage recycling but does not distinguish between down-cycling/low-quality recycling and high-quality recycling, and in practice encourages down-cycling as this is cheaper even though the environmentally preferable option is high-quality recycling (Ekvall et al., 2025). The European Parliament introduced the new Packaging and Packaging Waste Regulation in early 2025 which mandates that all packaging should be recyclable by 2030 and is intended to increase the use of recycled plastics in packaging (European Commission, 2025), which means that high-quality recycling becomes necessary. There is asymmetric information in the plastic market regarding additives and other material properties which results in recyclable plastic risk not being prioritised over other non-recyclable options (Nordzell et al., 2021). Two of several barriers for the plastic market in general identified by Nordzell et al. (2021) is that (1) there is a lack of control and traceability between actors resulting in sorted plastic being incinerated and (2) products are not always recyclable as there is not enough consideration for recycling in the design phase. It is therefore important to increase the understanding of plastic packaging value chain to increase recyclability and circularity.

1.1 Aim and objectives

This thesis focused on ways to increase the recyclability of plastic packaging waste, specifically focusing on analysing data exchange between the end-of-life and beginning-of-life and how plastic packaging design can improve regarding recyclability. The aim was increasing circularity and reducing the environmental impact of the plastic packaging industry. The project was based on three research questions and objectives:

Research question one: What is the state-of-the-art for the plastic packaging supply chain in Sweden?

The first objective was to analyse the state-of-the-art practices in the plastic plastic packaging value chain from beginning-of-life to end-of-life in Sweden to assess current material, information and finance flows, as well as established and niche actors and technologies.

Research question two: What are the current data exchange practices across the value chain for plastic packaging?

The second objective was to, based on the state-of-the-art analysis, explore data exchange between actors in the beginning-of-life (BoL) and end-of-life (EoL) stages of plastic packaging. The project evaluated current data exchange practices in the plastic packaging value chain.

Research question three: How can potential data exchange methods address an existing gap in the plastic packaging value chain?

The third objective was to find potential improvements for how EoL and BoL can support each other through data and knowledge and explore business model ideas that connect the BoL and EoL stages of plastic packaging. With created or identified value throughout the process, scalable business models that fill gaps in the current value chain and market were evaluated.

1.2 Data statement

Interviews with actors across the value chain of plastic packaging has been conducted within this thesis. Due to the sensitive nature of some of the topics discussed in the interviews, the respondents were assured that the raw data would not be shared. Data on the material composition of 14 plastic packages was kindly provided by a large company to compare DfR guidelines. The company was assured that this data would remain confidential and can not be shared.

2 Method

This master's thesis primarily used a qualitative approach. Semi-structured interviews with actors across the plastic packaging supply chain was used to collect primary data. A literature review provided secondary data to summarise the scientific knowledge-base. The interviews and literature review together answer the first and second objective. The third objective was answered through a Triple Layer Business Model Canvas.

2.1 Literature review

A literature review allows for detecting themes and compiling the state of knowledge (Snyder, 2019), here focused on plastic packaging. Literature was gathered from the scientific literature database Scopus. Three search terms were used to cover literature that maps the state-of-the-art for plastic packaging design, collection, sorting and recycling, as well as traceability and information flows for plastic packaging. Searches were made in title-keywords-abstract. The first search was *' traceability AND plastic* '* with the keywords *"microplastic/s, animal/s, automotive industry, agriculture, fibre reinforced plastics, reinforced plastics, chemistry"* excluded to narrow down the search to the area of interest. The second search was *' "plastic* packaging" AND ("future foresight" OR scenario*) '*. The third search was focused on finding literature that connect the end of life with the beginning of life and the search string was *' ("beginning of life" OR BoL OR design OR development) AND ("plastic* packaging") AND ("end of life" OR eol OR recycling) '*. For the second and third searches, the keywords *"microplastic/s, chemical recycling, pyrolysis, chemistry, elastomer, biodegradable"* were excluded.

The literature results were filtered to only include articles or reviews published in 2010 and newer. It was deemed reasonable to assume that what is to be considered state-of-the-art in 2025 is included in this literature.

In the next step bibliometric data of the articles were exported from Scopus to Notion. The authors then independently classified the articles as "include" or "exclude" based on the criteria specified in Table 1 by reading the title, author keywords and abstract of the articles. The excluded topics are important but are outside the scope of this project. Articles that the authors had classified differently were discussed to reach a consensus with an emphasis on including rather than excluding. The included articles were read more in-depth and summarised in section 3.1 Results - Literature Review.

To provide a deeper European policy context of packaging and plastics, the EUR-Lex database was used as a complement the rest of the literature review. It is the official EU repository for EU legal documents. As the main focus of this article is not to analyse implications of legal decision, a simple approach of snowballing from the Packaging and Packaging Waste Regulation was used.

2.2 Interviews

Interviews with product producers and brand owners (of white-label products) were conducted under the label "product producer interviews". Actors across different parts of the value chain were also interviewed, which was named "complementary value chain interviews.

Table 1: Include-exclude criteria used for the literature review.

Include The articles needed to focus on one of:	
Plastic packaging	*Example: A study investigating how to make plastic packaging more circular.*
Plastics in general if it was not explicitly mentioned that some plastics application other than packaging was in focus.	
Exclude Articles was excluded when the main focus was:	
Microplastics/nanoplastics and/or litter.	*Example: A study investigating the amount of microplastics created from plastic packaging litering.*
Biodegradable plastics.	
Consumer patterns or behaviours.	*Example: The impact of labelling for at-home sorting.*
Chemical recycling.	
Chemistry and the chemical composition of plastics.	*Example: A study comparing different plastic molecular structures.*
Production and technical details of packaging.	*Example: A study comparing the strength of plastic packaging variants with different wall thickness.*
Medical applications of plastic.	
Articles that the authors were unable to reach were excluded.	*Access is determined by what the Chalmers Library provides access to for students as of April 2025.*

2.2.1 Product producer interviews

A semi-structured interview is a qualitative research method that combines pre-determined questions with the flexibility to explore new topics based on the respondent's answers (Castillo-Montoya, 2016). It follows an interview template but allows the interviewer to ask follow-up questions. This approach ensures consistency across interviews while providing room for open-ended discussions and unexpected findings.

Participants and questions

The semi-structured interviews focused on product producers, meaning companies that put plastic packaging on the Swedish market, as the other parts of the value chain contain less actors where all can be interviewed (see section 2.2.2). The two producer responsibility organisations in Sweden, NPA and TMR, had together in April 2025 around 8000 companies registered that put packaging on the market[1]. A selection of actors to interview was made using "the plastics initiative 2025", an industry initiative by the trade association DLF to increase the recyclability of plastic packaging —covered under the producer responsibility regulation— to 100% (Dagligvaruleverantörers Förbund, 2025), as the companies who participate in the initiative could be considered to represent the state-of-the-art among product producers.

The plastics initiative has been signed by 56 companies representing several different product

[1]Summarised by the authors from TMR, 2025 and Näringslivets Producentansvar, 2025.

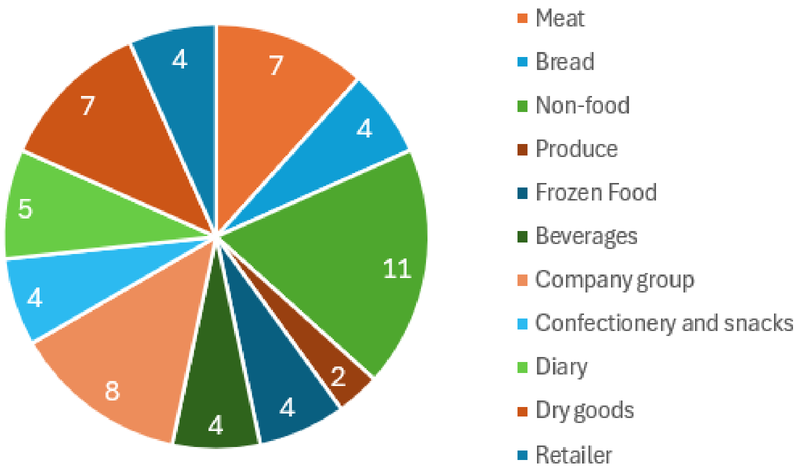


Figure 2: Interview Sampling: Categories of the selected companies

categories, all of which were contacted for interviews. Through email and phone contact, 15 of these 56 agreed to answer the interview. 13 of these 15 participated in either an audio/video call or face-to-face interview, and two answered the questionnaire by email. The interviews were conducted in March and April of 2025 and ranged from 30 to 45 minutes. The companies are mainly focused on food, and the selection can be seen in Figure 2. Companies that decided to participate are presented in Figure 3.

Four other companies were considered so important that they were also contacted. These were ICA, Axfood(including City Gross), Coop and Lidl, which are retailers representing 98.4% of the grocery store market by sales (DLF and DELFI, 2024). Of these 98.4% a share of the sold products are white-label products for the retailers. These are products they have not produced themselves by they own and control the branding (Axfood, n.d.). These companies do procurement for these products sold under their brands. All four participated in the product producer interviews, and the 60 who were asked are shown in Figure 2. The companies that participated in the interview study are presented in the results section.

A total of 13 questions, a warm-up question and an outro question were included in the interviews, divided into three sections. The first section was "plastic packaging and plastic types" to understand what packaging and plastic types the interviews cover. The second was "design and packaging development process" to understand how the producers work with packaging design and DfR today, and where changes are the most efficient. The third was "data exchange, traceability and future packaging" to understand the producers' views on data exchange and what they need. The interview protocol was developed and refined using the Interview Protocol Refinement Framework (Castillo-Montoya, 2016). The full interview protocol for the 19 (product producers and retailers) in the semi-structured interviews can be found in Appendix A.

The product producer interviews continued to, and slightly beyond, the point of data saturation, which is where no new meaningful themes or codings appear in the collected data (Fusch and Ness, 2015).

Coding of interview answers

During the product producer interviews, questions focusing on 'how,' 'which,' 'what,' and 'where' were included. These responses required coding and interpretation to generate a bar chart. The analysis followed Braun and Clarke's thematic approach, in a simpler form to fit the scope of this study. Thematic analysis by Braun and Clarke involves seven steps(Clarke and Braun, 2017). It begins with familiarisation of the data, where researchers immerse themselves in the content to gain a thorough understanding. This was made by grouping all answers question by question and writing first some joint bullet points and then a summary of the answers for each question.

The second step is initial coding, where important features of the data are identified and labelled. In the third step, generating themes, codes that are related to each other are grouped into potential themes. The fourth step involves checking the validity and reliability of themes to ensure they accurately reflect the data. This has been done in three ways (Clarke and Braun, 2017):

- Review the Data Again: Revisit the original data to confirm that all themes are grounded in actual content. Each theme should be supported by clear and relevant data extracts.
- Check for External Heterogeneity: Themes should be clearly distinct from one another. There shouldn't be significant overlap between themes.
- Reflexivity: Keep track of your assumptions and biases to ensure they haven't unduly shaped the themes.

Step five is defining and naming themes, where each theme is clearly described and labelled. For example, one theme that was a possibility was to code a yes/no question on mentioning HolyGrail 2.0 project, but the theme of traceability awareness with low, medium and high awareness was chosen. The sixth step is interpretation and reporting. It is here that the meaning and significance of the themes are explored (interpretation). The reporting part is how the results are presented in a structured and meaningful way, which in this thesis is by first showing all the graphs and a short explanatory text in the beginning to give an overview and then the question answers are also put into the relevant category.

Interview respondents

Of the 56 companies in the "plastics initiative" from DLF, 15 agreed to participate in the interviews. See Table 2 for a full list of participating companies. Both smaller companies with specific products for the Swedish market and larger companies with operations in several European countries participated. The four large grocery retailers in Sweden were contacted, and all of them participated in the interviews. All companies are brand owners in a sense, as all companies interviewed have products on the market under brands that they own, so the "product producer" label is used for companies that also have production facilities.

Table 2: Companies that participated in the product producer interviews.

Company	Category	Type	Interview
(1)	Retailer	Brand owner	Online
(2)	Dry goods	Product producer	Online
(3)	Non-food	Product producer	Online
(4)	Diary	Product producer	Online
(5)	Diary	Product producer	Online
(6)	Dry goods	Product producer	Face-to-face
(7)	Company group	Product producer	Online
(8)	Retailer	Brand owner	Online
(9)	Diary	Product producer	Online
(10)	Meat	Product producer	Online
(11)	Retailer	Brand owner	Online
(12)	Dry goods	Product producer	Online
(13)	Non-food	Product producer	Online
(14)	Meat	Product produce	Email
(15)	Retailer	Brand owner	Email
(16)	Company group	Product producer	Online
(17)	Frozen foods	Product producer	Online
(18)	Produce	Product producer	Email
(19)	Confectionery and snacks	Product producer	Online

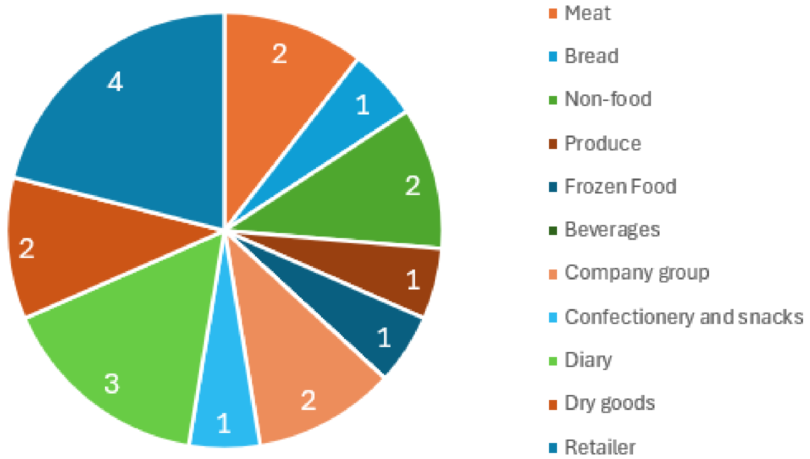


Figure 3: Categories of companies in the product producer interviews

Product producers and brand owners (meaning retailers acting in the role of brand owners for white-label products) were interviewed and will be referred to as product producer interviews. Ten other interviews, referred to as complementary value chain interviews, were conducted with actors with roles across the plastic packaging value chain in Sweden. These interviews were used as sources for the results and to confirm and broaden answers from the product producer interviews.

2.2.2 Complementary value chain interviews

Ten complementary interviews were conducted to get a broader view and more perspective. The trade association DLF was interviewed for a better understanding of the plastic initiative 2025, and SVDH, as a trade association with the corresponding role as DLF, but for the retailers. SVDH has a similar initiative to increase plastic package recyclability called "Fossil free and Recyclable plastic packaging to 2030" where it states plastic packages should be recyclable by 2022 (Svensk Dagligvaruhandel, 2023), which has been revised to 2025 (Svensk Dagligvaruhandel, nd).

As part of this thesis, a visit was made to the Swedish Plastic Recycling (Svensk Plaståtervinning, SPÅ) facility in Motala, known as 'Site Zero'. This facility manages the vast majority of Sweden's plastic packaging waste, operating on behalf of the largest producer responsibility organisation (PRO) in the country, Näringslivets Producentansvar (NPA). Interviews were conducted separately with both SPÅ and NPA. To cover the Swedish market, interviews were also conducted with the other PRO, TMR, and one of their sorting partners, Stena Recycling.

During both the complementary value chain interviews and the product producer interviews, standardisation and the new EU Packaging and Packaging Waste Regulation (PPWR) were recurring topics, particularly when discussing traceability and design for recycling. The European standards organisation CEN is actively developing standards in this area, with the Svenska Institutet för Standarder (SIS) representing Sweden in these efforts, making them a key interviewee.

GS1 Sweden also emerged as a significant player in these discussions due to its extensive experience in traceability and its influential role within the industry. They are the Swedish branch of the global GS1 network, and are also owned by DLF and SvDH (GS1 Sweden, 2025). They play a critical role in establishing and maintaining traceability standards. Given their expertise and industry reach, they were also included in the interviews.

Lastly, the industry supervisor for this master's thesis facilitated connections with industry experts from Circular Analytics and PreZero, allowing additional valuable interviews for this research.

Table 3 shows the interviewed companies together with the expertise of the interviewee. For some companies, several experts from the company participated and these were interviewed together.

Table 3: Companies that participated in the complementary value chain interviews.

Company	Category	Area of expertise of interviewee(s)	Number of interviewees	Interview
Circular Analytics/-Packaging Cockpit	DfR software provider	DfR & DfR software	1	Online
DLF	Trade organisation	Project manager	1	Online
GS1 Sweden	Traceability solutions provider	Traceability & Data Experts	2	Online
NPA	Producer responsibility organisation	Packaging specialist	1	Online
PreZero Polymers Austria	Sorter/Recycler	Sorting, Recycling	1	Online
SIS (Swedish Institute for Standards	Standardisation organisation	EU & national standardisation procedures	1	Online
Stena Recycling	Sorter	Sorting, Operations, Development	2	Online
SVDH	Trade organisation	Sustainability	1	Online
Swedish Plastic Recycling	Sorter	Packaging, Sorting, Environment, Climate	2	Online
TMR	Producer responsibility organisation	Packaging specialist	1	Online

2.2.3 Data management and security

The project included managing personal information, as defined by GDPR, to be able to conduct the interviews. This was managed in consideration of the Chalmers GDPR policy for thesis projects. This information was stored in one central location/app that only the authors had access to. There was also sensitive data regarding company operations as the interviews gave insights into several companies which was managed in the same way and deleted after the project finished.

2.3 Business Models Canvas

To answer the third research question and elaborate on gaps in the market and how these can be filled, the concept of a business model canvas (BMC) was used to present the findings. A business model can be seen as a description or translator of the rationale for how an organisation creates, delivers and captures value from there ideas. Which can be described using nine building blocks behind how a company makes money, presented in a BMC(Osterwalder and Pigneur, 2010). Joyce and Paquin, 2016 extends the business model canvas concept to form the Triple Layer Business Model Canvas that also integrates the sustainability dimensions of social, environmental and economic into a holistic picture, which was used in this thesis.

3 Results

This section presents the findings of the study. First, the literature review results are presented, followed by the interviews. These are compared in section 4 Discussion. Results of research questions one and two can be found in both the literature review and the interview study.

Section 3.1.2, 3.1.3, 3.1.4 and 3.1.5 from the literature review, and section 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.7 and 3.2.9 answer research question one about the current state-of-the-art for plastic packaging in Sweden.

Section 3.1.6, 3.2.1, 3.2.6 and 3.2.8 answer research question 2 about current data exchange practices. As DfR guidelines emerged as the main data exchange mechanism from EoL to BoL, a comparison and evaluation of it was conducted which is presented in section 3.3 and also corresponds to research question two.

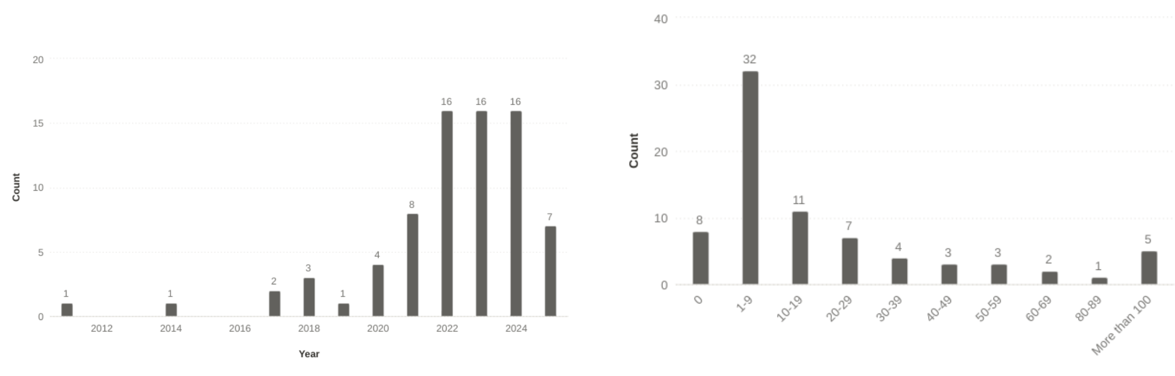
The Business Model Canvases in Section 3.4 correspond to research question 3 and are presented last.

3.1 Result from Literature review

The literature review is presented by first showing bibliometric information of the collected articles followed by summarising the findings in the subsequent subsections.

3.1.1 Bibliometric information

The three search strings presented in section 2 Method yielded a total of 247 results in Scopus from the three searches after removing 15 duplicates, with 75 remaining after applying the include/exclude criteria. Search 3, focusing on connecting the end of life and beginning of life yielded the most results, and after applying the include/exclude criteria, search 3 contributed to a majority of the articles. Only 11 articles from the traceability-focused search fulfilled the include/exclude criteria, which could indicate a lack of academic research on this topic.



(a) Publications per year.

(b) Citation count.

Figure 4: Bibliometric information for the literature review, after applying the include/exclude criteria.

For the articles that were included, Figure 4a shows that the number of articles related to the topic of this thesis grows dramatically after 2020 indicating a large increase in academic interest in the topic. Especially traceability for plastic packaging appears to be a new interest, as the first article on the subject was published in 2018. Figure 4b shows the citation count for the included articles. No article had between 90-99 citations, which is why this bar is excluded from the graph, and the maximum citation count was 293. Almost half of the articles have 1-9 citations, indicating a low impact (Donthu et al., 2021).

3.1.2 Policy landscape - Current and Emerging Frameworks

Steps towards a circular economy for plastics in the EU. The EU has long recognised the problem that plastic packaging, and introduced the Packaging and Packaging Waste Directive in 1994 to prevent waste and promote reuse and recycling of packaging waste (European Commission, 2022). "A European Strategy for Plastics in a Circular Economy" was introduced by the European Commission in 2018 and highlights that plastic is a very important material but that the current lack of circularity results in lost economic value and environmental harm (European Commission, 2018).

In 2019, the European Commission introduced the European Green Deal, which is a growth strategy for the EU with the goal of decoupling economic growth, prosperity and competitiveness from resource use and to address global warming, biodiversity loss and pollution with net zero emissions by 2050 (European Commission, 2019). The strategy sets out to achieve a circular economy in Europe with one of many action items focused on packaging. The "Circular Economy Action Plan", introduced by the European Commission in 2020, states that the EU needs to accelerate the transition to a regenerative growth model (European Commission, 2020).

Packaging and Packaging Waste Regulation - PPWR. Trade is hindered by unclear market signals, for example, PROs charge different fees for the same packaging at different markets that are similar (Pruess and Garrett, 2025). Industry actors like a level playing field so that not some actors bear the cost of sustainable packaging (Johnson et al., 2025). A part of the European Green Deal has been to revise the Packaging and Packaging Waste Directive to create a more even paying field across the EU as member states has diverged in implementation of the PPWD with sometimes contradictory measures caused by issues of understanding recyclability of packaging causing risks and uncertainties for producers (European Commission, 2022). Pruess, 2023 states that four main areas require harmonisation: (1) eco-modulation of fees, (2) better data collection of PROs, (3) PROs should cover treatment costs and (4) prosecution of free-riders.

The new Packaging and Packaging Waste Regulation (PPWR), which entered into force on 11 February 2025, will replace the old PPWD and harmonise the internal EU market, prevent and reduce packaging waste, and increase reuse and material recoverability (European Commission, 2025). The EU has introduced the PPWR to harmonise national measures across the EU and cover the entire life cycle of packaging (European Commission, 2025). A significant goal in the PPWR is that all packaging in the EU should be "reusable or recyclable in an economically feasible way" by 2030 (European Commission, 2022). In Figure 5 are four main steps from PPWR presented as a timeline.

Article 6 in the PPWR contains harmonised rules for design for recycling and differentiated packaging fees (European Parliament and European Council Regulation 2025/40, 2025). It states that all packaging put on the market should be recyclable by being designed to allow for (1) the waste packaging to be used to replace primary raw material from 2030 and (2) sorting at scale of the packaging from 2035.

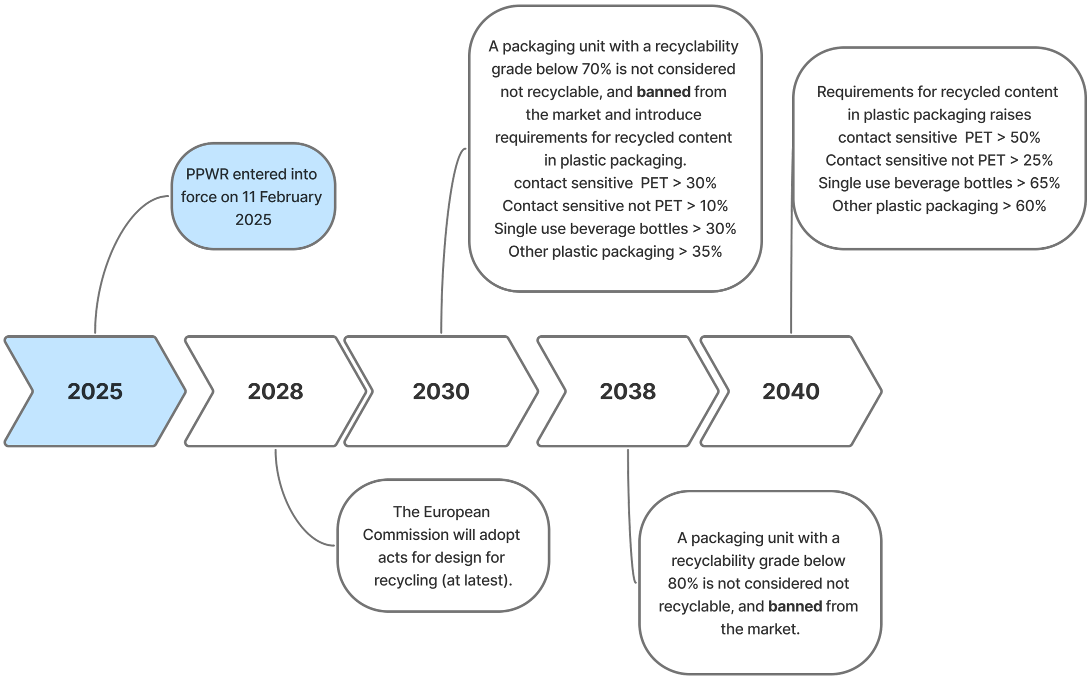


Figure 5: Short timeline of PPWR forward(European Parliament and European Council Regulation 2025/40, 2025)

On 1st of January 2028 at the latest, the European Commission will adopt acts for design for recycling (European Parliament and European Council Regulation 2025/40, 2025). The European Commission will send a standardisation request the European standardisation organisations to develop standards for design for recycling and will then take those into consideration when developing the criteria that will be mandatory from 2030 under PPWR (European Parliament and European Council Regulation 2025/40, 2025). The legislation already contains certain points that should be considered, such as the ability for the plastic packaging to be sorted and recycled into fractions that can be used to replace new raw material or substances that can negatively impact the reuse or recycling of materials (European Parliament and European Council Regulation 2025/40, 2025). By 2035, the criteria will also consider recycling at scale.

As of 2020, the European Union bases its recycling targets for plastic packaging on quantitative recycling rates which misses to evaluate the quality of the recycled material although quality based indicators are available (Roithner and Rechberger, 2020). In the new PPWR legislation, the EU has moved towards promoting high-quality recycling both through requirements regarding quality and through requirements for minimum recycled content of material recovered from post-consumer waste in new packaging (European Parliament and European Council Regulation 2025/40, 2025). Recycled plastic material needs to fulfil requirements from the EU regulation 2022/1616 on recycled plastic material to be considered save for being in contact with food, and as of 2022 only (1) post-consumer mechanical PET recycling and (2) recycling from closed or controlled product loops are approved, with the exception of novel recycling technologies (European Parliament and European Council Regulation 2025/40, 2022).

Extended Producer Responsibility. EPR plays an important part of European waste management for plastic packaging. The producer responsibility organisations plays a critical role in the system as they can absorb risks and have direct connections to all other actors (Andreasi Bassi et al., 2020). A lack of harmonisation among EU member states has led to a diverse set of implementations of extended producer responsibility across Europe (Pruess, 2023). The different implementations have both strengths and weaknesses although Germany ranks the highest in potential effectiveness (Pruess and Garrett, 2025).

In Europe, a wide variety of different EPR schemes exists with both non-profit and for-profit PROs, and PROs with monopoly positions and oligopolies (countries with a few PROs), and different levels of financial, operational and collection responsibility (Pruess, 2023). Volontary non-competing EPR schemes, as illustrated by Poland, has shown to be the least effective (Lorang et al., 2022). Most European countries allow producers to either take responsibility individually or collectively by joining a PRO (Pruess, 2023). EPR schemes does put producers on a path towards recyclable packaging and to reduce the amount of plastics (Lorang et al., 2022).

It is important that packaging fees reflect both the recyclability of the packaging and second market value of the material (Andreasi Bassi et al., 2020). Several countries have advanced disposal fees that encourage eco-design, a tool that has been shown to be effective together with take-back requirements (Lorang et al., 2022). In the Lybæk and Kjær, 2024 case study of the Danish Plastic Industry strengthening the EPR scheme and use fee-modulation like taxes/penalties is needed spur on the plastic industry to produce environmentally friendly products.

Large emerging economies are also working to manage plastic packaging waste. In India, steps are being taken towards formal plastic packaging waste management based on EPR (Pani and Pathak, 2021) and it has been suggested that this would be a viable method for China too (Yu et al., 2023).

An alternative to EPR schemes is deposit-refund systems which Lu et al. (2022) shows is beneficial for reuse packaging but not for singe-use packaging from a cost-benefit point of view. A deposit-refund system can be very effective at achieving high collection and recycling rates on well-defined packages such as PET-bottles as shown by both Germany and the Netherlands, and in these systems, DfR issues are quickly corrected (Picuno et al., 2021). These systems do allow for the recycled material to be used in food contact applications but it does not necessarily result in closed-loop systems (Picuno et al., 2021).

3.1.3 Packaging design - Integrating recyclability into the packaging design process

Recyclability. In 2018, the trade organisations Association of Plastic Recyclers (North America) and Plastic Recyclers Europe published a global definition of 'recyclability', namely the following (Association of Plastic Recyclers and Plastic Recyclers Europe, 2018):

1. The product must be made with a plastic that is collected for recycling, has market value and/or is supported by a legislatively mandated program.
2. The product must be sorted and aggregated into defined streams for recycling processes.
3. The product can be processed and reclaimed/recycled with commercial recycling processes.
4. The recycled plastic becomes a raw material that is used in the production of new products.

In the PPWR legislation, an new definition of recyclability is used which is: 'recyclability' means the compatibility of packaging with the management and processing of waste by design, based on separate collection, sorting in separate streams, recycling at scale and the use of recycled materials to replace primary raw materials" (European Parliament and European Council Regulation 2025/40, 2025). Design for recycling (DfR) can be seen as a set of design ideas that consider the recyclability of a product such as recovery value and recovery methods to improve recycling rates (Ding and Zhu, 2023). DfR is to design products that are recyclable.

Design deficiencies related to the recyclability of plastic packaging are one of the main barriers that hinder the flow of plastic material (Milios et al., 2018). Factors that influence the eco-design of packaging among companies include financial resources, recycling resources, regulation, internal collaboration/coordination, and customer demand (Flygansvær and Dahlstrom, 2024). This information needs to come from the recyclers in that they need to educate the designers, plastic producers and manufacturers on DfR (Hsu et al., 2022).

Several global companies have publicly made commitments to 100% recyclability and have made changes both to material, structure and design towards this goal (Ding and Zhu, 2023). In Sweden, the "plastics initiative 2025" from DLF has a similar goal with 56 that have signed the commitment and as of 2023, 9 of these had reached the target (Dagligvaruleverantörers Förbund, 2025). A majority of corporate sustainability reports for multinational food and beverage companies does not address plastic while around a fourth makes broad commitments regarding making their packaging recyclable. (Phelan et al., 2022).

However, recyclable packaging is not automatically the more environmentally friendly packaging solution, for example, light-weight non-recyclable multilayer plastic shrink films have a lower environmental impact than recyclable PE/EVOH films, although advancements in material science and recycling could change this (Pauer et al., 2020). Plastic packaging for meat also has a relatively low environmental impact compared to the meat it is used to protect (Pauer et al., 2020), indicating that it would be bad to replace packaging if food waste will increase.

Guidelines and tools. There have been a few attempts from an academic perspective to help companies with recyclability. Xu et al. (2025) proposes a preliminary decision-making tool for packaging designers based on packaging design factors summarised into a sustainability index that can help designers in the conceptual phase of development. Matos et al. (2024) suggests that the three micro-indicators Material Circularity Index, Value-Based Resource Efficiency Indicator and Circular Economy Indicator Prototype are the most relevant to evaluate the circularity of plastic packaging.

CEN, the European standardisation organisation, is developing DfR standards for plastic packaging (Pierri et al., 2024). These will be considered when the European Commission adopts delegated acts for the design for recycling criteria that will is a part of the PPWR (European Parliament and European Council Regulation 2025/40, 2025). The fact that it will be just considered and not adopted directly is a new way of working and can be seen as a dissatisfaction from the EU towards the industry [Interview, SIS].

The packaging development process. When plastic packaging design and sorting and recycling technologies are considered in an integrated way, increased material recovery can be achieved (Hahladakis and Iacovidou, 2018). Finding synergies between the beginning-of-life and the end-of-life will enable changes that increase material recovery and efficiency (Hahladakis and Iacovidou, 2018).

Hsu et al. (2022) conducted interviews throughout the value chain for plastic, not specifically packaging, in Europe in October 2019 to November 2020, and concluded that plastic developers lack understanding of recycling, both in terms of how to design for recycling and how to integrate recycled plastic.

3.1.4 Kerbside Collection – The Right Path Forward?

In Sweden, kerbside collection is expected to expand significantly in the coming years. Since 2024, municipalities have been responsible for the collection of packaging waste from both households and co-located businesses, with full implementation required by 2027 (Regeringskansliet, 2022). This policy shift aims to improve the accessibility of collection services, which is generally expected to enhance the quality of collected plastic waste, thereby supporting higher material recycling rates. This, in turn, can reduce the demand for virgin raw materials and lower the carbon emissions associated with the production of new plastic.

However, the economic and environmental efficiency of these systems can vary significantly depending on the collection method (Groot et al., 2014). In a comparison between kerbside collection, drop-off systems, and post-separation approaches within municipalities in the Netherlands a cost model indicates that kerbside collection is approximately 2.5 times more expensive than drop-off systems, though costs vary considerably depending on the degree of urbanisation (Groot et al., 2014). The higher costs are primarily due to the operational inefficiencies of frequent stops and short idling times, which increase both greenhouse gas (GHG) emissions and associated costs. In fact, these vehicle-related emissions accounted for approximately 15% of the total collection costs in their study.

In addition to cost considerations, the environmental impact of different collection methods is closely linked to the quality of the collected material, which is a problem Andreasi Bassi et al. (2020) also points out. The environmental performance is proportional to the amount of plastic recycled as flakes and granules, rather than the amount collected from households so simply increasing the quantity collected without ensuring quality may have limited environmental advantages. Groot et al. (2014) highlight though that post-separated PPW generally has higher contamination rates compared to source-separated waste, leading to increased processing costs during sorting. Something that favours kerbside collection.

On the basis that contamination is effectively managed has Roosen et al. (2022) demonstrated a Material Flow Analysis when extending the fractions instead of the collected volume. This MFA done in Belgium showed by expanding the collection portfolio from only PET, PE bottles (&PP) bottles to PET, PE rigid, PP rigid, PS rigid, Films and PET trays the overall collection rate of plastic packaging could increase from 33.6% to 64.4%, with 77.3% of the collected material simulated to be correctly separated into targeted waste fractions. In Andreasi Bassi et al. (2020), an increase in the source-segregated could achieve a 63% recycling rate and would reduce the environmental impacts. Andreasi Bassi et al. (2020) shows that the collection rate is simultaneously rising alongside the source-segregation. Another aspect to get it circular after collection is that additional recycling technologies and packaging design improvements are needed to further increase the plastic recycling rate (Roosen et al., 2022).

In the discussion of extending the collection Scriosteanu and Criveanu (2024), advocates for more behaviour extension of the citizen regarding the recycling activity. To consider the cultural differences as Hofstede's six dimensions, and factors like income, urbanisation, and lifestyle. differences when developing strategies. In Birgen and Becidan (2022), when looking at the potential in the mixed-household waste in Oslo, urbanisation was not included and only the assumption that whole Norway behave like Oslo when it comes to waste handling. A simplistic "one-size-fits-all" mindset that will not work, according to Scriosteanu and Criveanu (2024). Andreasi Bassi et al. (2020) point out that the whole EPR system is financially vulnerable to changes in plastic waste composition, for example, due to changes in consumer behaviour.

3.1.5 Sorting and Recycling – Barriers and potential

Large-scale recycling. In PPWR there is a requirement saying that product producers need to ensure that their plastic packaging is recycled at scale, and there are also requirements for using recycled plastic material in the packaging (European Parliament and European Council Regulation 2025/40, 2025). This puts a lot of pressure on the entire plastic packaging value chain as there are currently considerable challenges to overcome. For recycled plastic, both supply and demand are absent, which can be attributed to a fragmented market (Milios et al., 2018). Requirements PPWR hope can be solved with recycling at scale, as this will increase both the supply and demand of recycled plastics(European Commission, 2022).

To achieve recycling at scale, new and efficient recycling technologies, both in mechanical and chemical recycling, are also needed (Ding and Zhu, 2023). To reach the EU targets, Antonopoulos et al. (2021) has identified four areas across the plastics value chain that have much need for improvements, which are product design, recycling plants, collection systems and the market. One of the four areas is recycling plants, but at the moment, the average sorting efficiency among state-of-the-art sorting plants is not over 50% and maintaining high quality in recycling is still an issue (Lybæk and Kjær, 2024).

Barriers for recycling. In Ding and Zhu (2023), they listed influencing factors for higher recyclability. One category they list is labels, additives and inks that are essential parts of packaging, but can affect plastic recycling significantly. Labels are often applied with adhesives or shrink-wrapped around containers, which can interfere with automated sorting and material recovery. Label size should not exceed 40% of the container's surface area to maintain accurate near-infrared (NIR) sorting. In Keller et al. (2022), recyclability factors that can lower the result for single-use packaging include dark colour, material compounds, insoluble adhesives, and large labels. Particularly, carbon black poses significant challenges for NIR-based sorting technologies. Carbon black cannot be detected effectively, as it absorbs a substantial portion of the NIR light, preventing accurate identification (Jakobs and Kroell, 2024).

One design-related issue in the sorting process that reduces the recyclability of packaging is the use of multi-layer films (Jakobs and Kroell, 2024). These films often contain a mix of polymers with different melting temperatures, which can lead to quality losses during remelting, resulting in weaker and less valuable end products. Additionally, the presence of films and other problematic contaminants can significantly reduce recovery rates, as these materials are more likely to be rejected during the sorting process or degrade the overall quality of the recycled output (Antonopoulos et al., 2021). An issue that Koinig et al. (2022) saw as a Latent Recycling Potential of Multilayer in Austria's waste management.

Potential in recycling. Multilayer packaging is commonly used for dairy, coffee and meat products. If advanced detection and ejection technologies for multilayer films are integrated with dedicated recycling infrastructure, this could produce a cleaner feedstock, enhancing overall material recovery efficiency (Koinig et al., 2022) In Norway, the largest potential for increasing plastic packaging waste recycling instead lies in mixed household waste, which accounts for 66% of the total plastic packaging waste (Birgen and Becidan, 2022). This potential can be tapped through either post-sorting facilities for mixed household waste or increased source-based sorting by consumers. Callewaert et al. (2023) examine mixed waste and Material Recovery Facilities (MRFs), highlighting the need for centrally coordinated implementation to prevent adverse effects, such as inconsistent polymer separation, increased material losses, and reduced overall system efficiency.

Effective planning is crucial to fully realise the environmental benefits of improved waste separation and sorting. One approach, as proposed by Stallkamp et al. (2022), goes beyond centralised coordination by developing a comprehensive recycling network for plastic packaging waste in Europe. This network approach includes opening new MRFs, transporting waste to these facilities, and distributing plastic pellets from MRFs to plastic converters. Such a network could make the system more efficient, addressing one of the key challenges in recycling – the weak economic viability of sorting and recycling flexible plastics from mixed waste, a current barrier to profitability for recyclers (Andreasi Bassi et al., 2020).

Tracer-Based Sorting (TBS) is an emerging technology for plastic identification that uses embedded chemical or physical tracers, such as fluorescent markers, to enable automated sorting (Gasde et al., 2021). It addresses limitations of traditional near-infrared sorting, like handling black plastics and multi-layer packaging, potentially supporting a shift toward a more circular plastic economy. However, successful TBS implementation depends on material modification, regulatory approval, and integration into existing waste systems.

Although materials can be handled better and lower recyclability leads to a larger carbon footprint in all assessed scenarios, with 0.13 kg CO2-equivalent emissions at 100% recyclability and 0.21 kg CO2-equivalent emissions at 0% recyclability (Keller et al., 2022). It is crucial to consider that packaging contamination is not solely a matter of material choice. For instance, multilayer PET trays used for meat packaging can contaminate PET bottle streams, leading to a decline in the quality and value of the recycled PET material (Pambudi et al., 2025).

The challenge of food grade plastic packaging. The value of recycled PET material can be significantly reduced if contamination is present, which poses both economic and safety challenges. In the context of recycling plastics for new food-grade packaging, it is critical to prevent chemical contamination that could compromise food safety (Poças and do Céu Selbourne, 2023). Advanced technologies, such as sensor arrays and predictive models, have been developed to monitor processing lines in real-time, providing valuable data for contamination analysis and detecting operational deviations in wash plants (Davis et al., 2017). These systems can enable more precise quality control and support the production of safer recycled plastic materials.

However, it is important to consider the broader context of why transitioning to mono materials and reducing overall plastic use remains a priority. While these efforts aim to reduce plastic waste and environmental impact, it is essential not to overlook the critical role that packaging plays in minimising food waste. For instance, modified atmosphere packaging, often used to extend the shelf life of perishable foods, typically relies on complex multilayer films (Seier et al., 2023) and it is possible to recycle this but that it is currently hindered by insufficient purification methods. Achieving this balance, as highlighted by Poças and do Céu Selbourne (2023), relies on the development of reliable methods for measuring packaging-related food waste, which remains a critical aspect of evaluating sustainability of packaging systems. Finding balance is crucial to achieving a circular and sustainable economy within packaging. Lastly, to succeed with recycling at scale, an increase in communication between EoL and BoL to avoid packaging designs that are incompatible with recycling infrastructure will be needed (Ding and Zhu, 2023).

3.1.6 Data Exchange and Traceability: Insights from the Latest Research

Rumetshofer and Fischer (2023) illustrated how we are moving from a linear economy, where the process follows a straight path (produce, use, and dispose) to the recycling economy which is more interconnected and includes several actors (resin producer, application producer, retailer, consumer, waste handler, and recycler) all working together to recycle materials and reduce waste but limited information sharing among all actors in the value chain and the growing complexity of the system is problematic. Hsu et al. (2022) recommend stakeholders in the plastic value chain (including designers, plastic producers, and manufacturers) firstly to share data on product composition, secondary plastic quality and availability, secondly to provide clear recycling instructions and environmental impact information, and thirdly to codify and share knowledge on how to integrate secondary plastics into products.

One of four main barriers that hinder the uptake of recycled plastic is a lack of traceability, both through limited market communication and limited value chain coordination (Milios et al., 2018). Several definitions of traceability exist. A definition used by Rumetshofer and Fischer (2023) is to consistently follow material and information from feedstock to final product and beyond. The international ISO standard "Chain of Custody - General terminology and models" defines traceability as the ability "trace the history, application, location or source(s) of a material or product throughout the supply chain" (International Organization for Standardization, 2020).

PPWR requires packaging to be recyclable-at-scale by 1 of January 2035 and requires the European Commission to adopt implementing acts by 1 of January 2030 for establishing a "chain of custody"-mechanism to ensure that packaging recycled at scale (European Parliament and European Council Regulation 2025/40, 2025). This puts extra focus on traceability for the plastic packaging industry. Hsu et al. (2022) explored barriers related to data, information and knowledge that hinder the use of secondary plastics in several applications including packaging, and concluded that traceability-related barriers can be overcome through new digital technologies, new traceability technologies, improved industry coordination, regulation and new business models. This seems to be parts of what the new legislation is trying to address. The PPWR states that the new chain of custody mechanism (or traceability mechanism) needs include at least (1) technical documentation for the quantity of collected packaging waste and (2) a verification process so that plastic producers can receive data from sorters and recyclers ("downstream operators") to ensure that their packaging is recycled at scale (European Parliament and European Council Regulation 2025/40, 2025).

Four categories of traceability mechanisms for plastic packaging can be identified: physical markers, blockchain technology, digital product passports, and certifications/standards (Rumetshofer and Fischer, 2023). These are often used together and will be explored below.

The simplest form of physical marker is the well-known and well-used barcodes and the newer QR-codes, but more advanced solutions such as RFID tags could also be used (Rumetshofer and Fischer, 2023). RFID tags are electronic devices that consist of a high variety of materials such as silicon, copper and silver that could be attached to packaging for traceability purposes, and even though the introduction of new materials could potentially decrease the quality of recycled plastic, lab results show that no such impact can be proven at least on HDPE waste streams (Aliaga et al., 2011). Industry initiatives to use QR-codes invisible to the eye as a physical marker and so-called digital watermarks, are currently active under the project "HolyGrail 2.0" (Rumetshofer and Fischer, 2023).

Another category of traceability mechanisms is blockchain which is a transparent, decentralised ledger of transactions or activities throughout the value chain which promotes accountability between actors, and is integrated into packaging through physical markers such as QR-codes or RFID-tags (Bułkowska et al., 2024). Several solutions using blockchain technology have been developed and proposed independently to track and trace plastic for higher recyclability, although high energy consumption, lack of governance and false information are potential downsides to the technology (Rumetshofer and Fischer, 2023). Bułkowska et al. (2024) concludes that blockchain technology has the potential to improve plastic recycling by increasing traceability and automating tasks, but that further development and investments are needed. Overall, the technology is on a conceptual or early development stage.

The third category is digital product passport, which is a product-specific data set describing aspects such as material composition, recycling and origin that is retrieved digitally and several independent solutions are currently in development (Rumetshofer et al., 2024).

The fourth category of traceability mechanisms is certifications and standards which is provided through national and international collaboration bodies. Many certifications have been developed to improve traceability, such as Recycled Plastics Traceability Certification by RecyClass (Hsu et al., 2022), and these can contribute to trust through the value chain although it alone does not provide object level traceability which would be needed to also improve sorting (Rumetshofer and Fischer, 2023).

Rumetshofer et al. (2024) made a case study of converting bottle caps to 2192 frisbees to illustrate the usage of DPPs, including to disclose the mass balance for the entire process, and showed that GS1 standards can already be used for DPPs that follow a product. According to Gazeau et al. (2024), GS1 overlooks the need for integrated waste management and need to focus on integrating with physical markers such as RFID-tags and qr-codes, even though GS1 provides a robust framework for supply chain traceability.

3.2 Result from Interviews

This section presents the findings from the product producer interviews and the complementary value chain interviews. The answers were coded to more than one label in the figures corresponding to Q1, Q2, Q5, Q6, Q10, Q11 and Q13. In 3.2.5 to 3.2.9, figures and result from the semistructed interviews are mainly presented.

3.2.1 Material, information and finance flows

This section shows material, information and finance flows for the plastic packaging supply chain in Sweden as determined by the conducted interviews. Each figure has been given a letter, followed by a detailed explanation of each flow.

Material flows

Figure 6 shows the material flows of plastic packaging in Sweden from the packaging producer to exported sorted plastic waste.

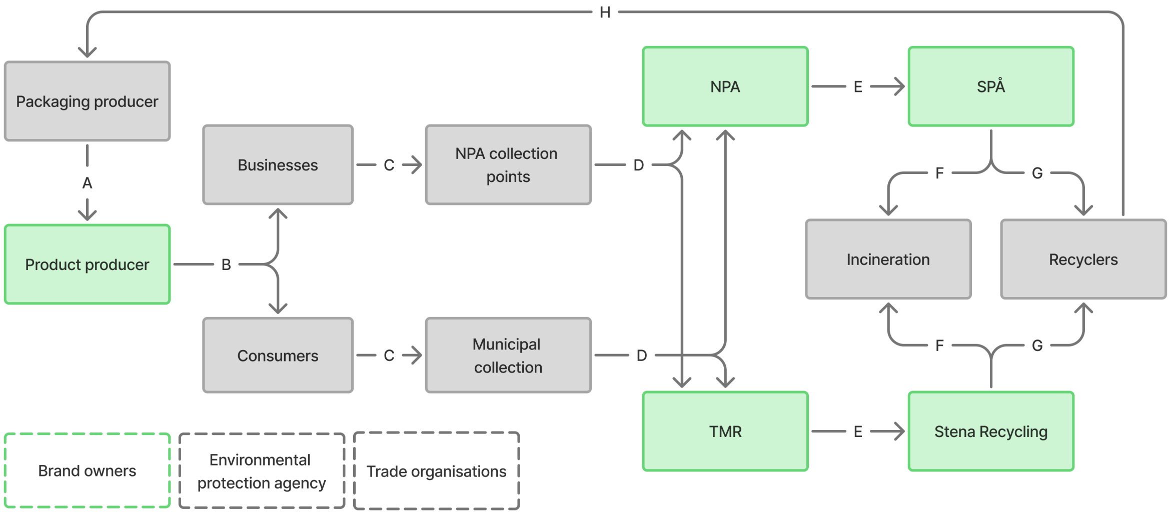


Figure 6: Material flow of plastic packaging in Sweden without mass/volume. Green have been interviewed within this project. Dashed are not a part of this flow.

A: Packaging producers sell packaging to product producers.

B: The product producers sell and distribute products to consumers and businesses through retailers. It is common that retailers also act as brand owners and buy products from product producers using white-label solutions.

C: From 1 of January 2024 the municipalities are responsible for the collection of plastic packaging waste from consumer/household waste. Business/commercial plastic packaging waste collection is handled by the largest PRO as determined by the environmental protection agency from plastic volumes reported by the PROs, which is NPA today.

D: The collected plastic packaging waste is split between the PROs (NPA and TMR) by mass according to market share.

E: NPA send their plastic packaging waste to the sorting facility Site Zero operated by Swedish Plastics Recycling (SPÅ) in Motala. TMR send their plastic packaging waste to Stena Recycling in Lanna.

F: Unsortable or low-value waste is sent to incineration plants.

G: Sorted fractions is sent to recyclers. No recyclers are currently established in Sweden so this arrow also represent exports.

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Information flows

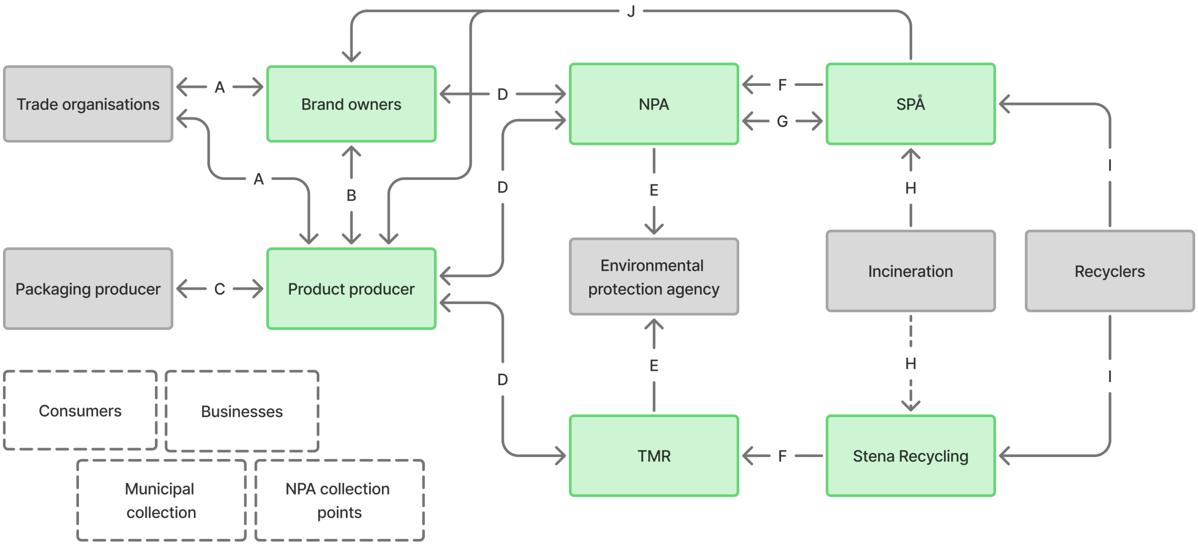


Figure 7: Information flow between actors in the plastic packaging value chain. Green have been interviewed within this project. Dashed are not a part of this flow.

Based on the interviews with actors across the plastic packaging value chain, 10 information flows have been identified between actors. These are shown in Figure 7. The flows are explained below:

- A: Trade organisations, which are DLF and SVDH for the companies that have been interviewed in this study, organise meetings and events. The trade organisations support their members in general topics like the PPWR and how it will affect them. They also have initiatives like the Plastic Initiative 2025 and help them to get interconnected with joint action plans.
- B: This flow represents the exchange between brand owners and product producers in the context of white-label products. The brand owners put some requirements on the product producer. The product producer sends material specifications to the retailer.
- C: Product producers often ask packaging producers for material specifications to be able to report on the recyclability of their packaging.
- D: DfR guidelines/packaging fee criteria are provided to brand owners/product producers from the PRO that they are connected to. Brand owners/product producers report the amount of packaging that they have used to the PRO they are connected to.
- E: The PROs report packaging amounts to the Environmental Protection Agency.
- F: The sorting facilities send updates on the amount of sorted plastics to the PROs.
- G: NPA have built their guidelines on case studies and RecyClass guidelines, and regular meetings with Swedish Plastic Recycling for updates. TMR does not have this type of exchange with its plastics sorter.
- H: Incineration plants assure sorting facilities that the correct amount of waste has been handled.

I: Recyclers assure sorting facilities that the material has been handled correctly and report how much of the sorted waste they were able to use.

J: Swedish Plastic Recycling provides a service to brand owners/product producers where they can send packaging to the sorting facility to do sorting tests. The brand owners/product producers need to pay for this.

Finance flows

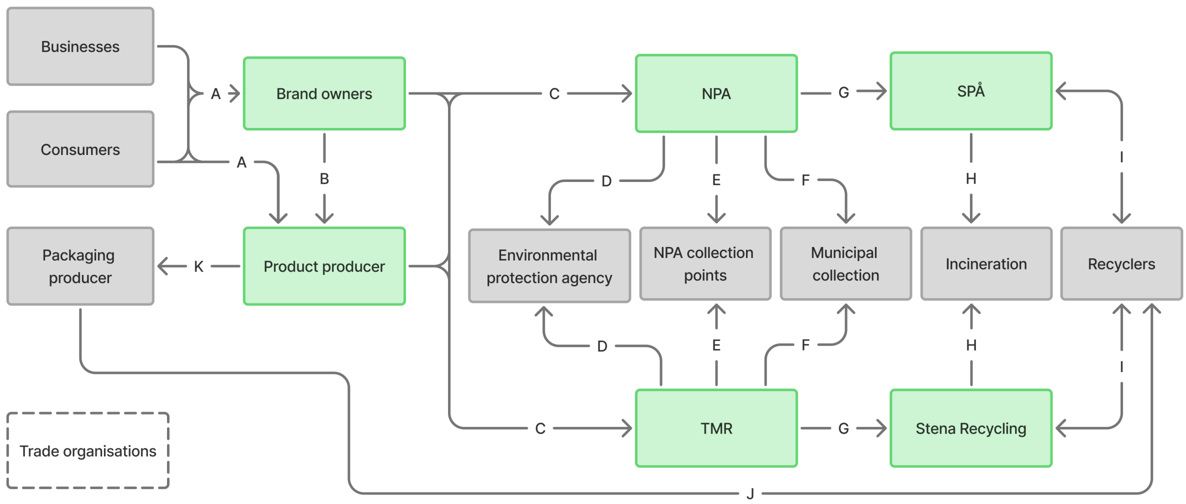


Figure 8: Finance flow between actors in the plastic packaging value chain. Green have been interviewed within this project. Dashed are not a part of this flow.

Financial flows are shown in Figure 8 which is based on the combined results from the interviews. The flows are explained below:

A: Consumers and businesses buy products via retailers.

B: Brand owners pay product producers for white-label products.

C: Companies that put plastic packaging on the market pay a packaging fee to whichever of the two PROs they decide to be connected to. Both PROs in Sweden base the packaging fee on the recyclability, divided into three categories. Currently, brand owners pay the packaging fee for imported white-label products and product producers pay the packaging fee for white-label products paid in Sweden, but this will soon change so brand owners pay the packaging fee for all white-label products.

D: The PROs pay a combined administrative fee of 2.5 million SEK per year to the Environmental Protection Agency, divided according to market share.

E: NPA, the largest PRO, operate collection points for commercial packaging waste which is financed by both PROs according to market share.

F: The PRO pay municipalities for the cost of collecting consumer/household plastic packaging waste.

G: The PRO pay sorting facilities to manage the plastic packaging waste.

H: The sorting facilities need to pay incineration plants to handle waste that could not be sorted into a fraction or if there are no recyclers that want a certain fraction. Parts of the waste that is incinerated is for example toys and shoes, (which is wrongly sorted as packaging by consumers) and parts is unsortable due to a lack of DfR.

I: For some fractions, sorters gets payed by recyclers and for some fractions the sorters needs to pay the recyclers, depending on the value of the material.

J: Packaging producers pay the recyclers for recycled plastic material.

3.2.2 Producer responsibility organisations in Sweden

In Sweden, all Extended Producer Responsibility (EPR) schemes, except those for pharmaceuticals, are managed through Producer Responsibility Organisations (PROs). This collaborative approach streamlines the process for individual producers, helping them meet national EPR targets, including those related to plastic packaging (Naturvårdsverket, 2020).

The two approved PROs in Sweden are NPA (86.8% of the market for plastic packaging in 2024) and TMR (13.2% of the market for plastic packaging in 2024)(Swedish Environmental Protection Agency, n.d.).

Both organisation supports producers in their legal obligation to be connected to a PRO as well as report packaging placed on the Swedish market to the Swedish Environmental Protection Agency. Additionally, they provide advisory services to producers, focusing on improving and verifying packaging recyclability as well as ensuring legislative fulfilment [Interview, TMR]. The PROs have differentiated packaging fees for different levels of recyclability, with less recyclability giving higher fees. Producers are responsible for financing the collection and recycling of their packaging, and the PROs ensure that they comply with the statutory reporting requirements. It is mainly self-reporting and a question about trust, which can result in a free-riding problem [Interview, NPA].

NPA

NPA are providing guidance on packaging to producers [2] by direct contact with companies, where NPA's customer managers and materials specialists assist in explaining what measures can be taken to optimise the recyclability of packaging and through plastic packaging guides (referred to as DfR guidelines in this report)[interview, NPA]. The guidelines are based on RecyClass and adjusted in dialogue with SPÅ to determine the differentiated packaging fee.

TMR

TMR provides advisory services to producers, focusing on improving and verifying packaging recyclability as well as ensuring legislative fulfilment [Interview, TMR]. Unlike NPA, TMR's guidelines are not aligned with RecyClass standards or specific sorting facility requirements, resulting in a less comprehensive approach. This is partly due to the absence of collaboration with major recyclers like Stena Recycling and Fortum, reflecting TMR's broader, less site-specific guidance. Additionally, the positioning of the two main sorting facilities is carefully calculated, and recycling compared to reuse systems is generally more viable in densely populated areas of Europe, where supporting infrastructure is more developed, a condition less common in northern Sweden.

[2] As defined in the Swedish law 'Förordning (2022:1274) om producentansvar för förpackningar'.

3.2.3 Sorting facilities in Sweden

This section will present the plastic packaging sorting facilities Swedish Plastic Recycling, Motala and Stena Recycling, Lanna.

Swedish Plastic Recycling, Motala.

In Motala, late 2022, the world's largest and most efficient plastic recycling facility for household packaging was finished. A site also called Site Zero. It is covering 60,000 square meters, 60 NIR sensors, and cutting-edge real-time optimised technology that analyses the material and efficiently sorts it, the new facility can sort 200,000 tons of plastic waste per year (Swedish Plastics Recycling, 2024). Compared to other sorting facilities, the number of NIR sensors is one thing that stands out. These sensors pick out/remove either what is desired (positive sorting) or what is not desired (negative sorting) in different steps. In Site Zero, positive sorting is initially conducted, generally followed by a negative sorting step aimed at removing incorrectly sorted materials to enhance quality. For a few specific streams, the second sorting step also consists of positive sorting, similar to the initial step [Interview, Swedish Plastic Recycling].

The plant also uses lasers, GAIN (a deep learning camera system) and electromagnetic sensors (Edo et al., 2024). Moreover, it is equipped with screening drums, ballistic separators, exhaust air technology, compaction systems, an intelligent bunker management system, fully automatic baling presses and digital process monitoring. All this combined creates a complex sorting system that ensures both high recovery rates of targeted plastics and quality of the sorted fractions.

Step by step of the sorting process in the facility described as follows: (Plaståtervinning, 2025) bale gets opened, and a shredder grinds down the plastic packaging so it gets sortable. Following a bag opener before a magnets/metal separator, remove roughly 30 tons of metals a week to metal recycling. The material then passes through a drum screen, followed by an Eco Star disc screen and sieve, which sort materials by size and shape. The following step is a Balistic separator & windshifter separates flexible and non-flexible plastics before 19 NIR sensors sort everything by plastic type and colour. An optical that handles 20 tons of plastic/hour, and SPÅ has decided to add two loops on this stage for maximum efficiency.

The sorted fractions go to big bunkers (see table 4) and into bales before send to recyclers.

The recycling rate in 2023, if defined as how much that was put on the market compared to how much became secondary plastic material, for commercial plastic packaging waste was at 50.3% and for households plastic packaging waste it was 23.7%, which combined becomes 36.3% (Swedish Plastics Recycling, 2024). The recycling rate is not well defined, and in discussion with both Stena Recycling and SPÅ everything depends on what and when you set it as recycled. However, you want to go from tray to tray for high-quality recycling and not down-cycle packaging to other applications. Agriculture plastics, for example, can use recycled material from plastic packaging waste, but the massive flow from packaging waste needs to loop back to packaging to reach circularity [Interview, Swedish Plastics Recycling].

After the sorting, 12 fractions come as output from the sorting process in Motala. Rigid PP, rigid HDPE, flexible LDPE, flexible PP, transparent PET trays, transparent PET bottles, coloured PET bottles, EPS, PS, PVC, and lastly, two grades of mixed polyolefin laminate. Metal and non-plastic rejects and gets energy recovered in Sweden (Swedish Plastics Recycling, 2024). SPÅ does not sort PLA for recycling, even though it would technically be possible, but there is no market for it, while PVC is sorted into a separate fraction but not recycled [Interview, Swedish

Plastics Recycling]. The variety of items that ends up in this PVC fraction, of which much is not packaging, means that it would need further sorting to be recycled. It is also damaging to incineration plants so parts of the plastic is landfilled [Interview, Swedish Plastic Recycling]. PS and transparent PET can be recycled to new food-grade packaging as long as it is collected separately from the household waste from the consumer [Interview, Swedish Plastics Recycling].

Stena Recycling, Lanna.

TMR sends its waste to Stena Recycling in Sweden and Fortum in Finland, and only Stena Recycling was included in this study due to its relevance to the Swedish context. According to TMR, the sorting processes at Fortum and Stena Recycling are similar in this context [Interview, TMR], and since the Fortum sorting facility is outside of Sweden, they were not included in this study.

TMR and Stena Recycling do not have an ownership or any other form of long-term relationship and connection to each other as NPA and Motala. TMR is a customer of Stena Recycling using some free capacity they have. Stena Recycling, with their sorting facility in Lanna (Sweden), handle both commercial and household plastic packaging waste. Around 2/3 of the 36,000 tons/year they handle is household plastic packaging waste.

The customer, which is TMR in this case, chooses the recycling rate and that determines the price. *"When someone says that 70% is being recycled, it means 70% of the collected plastic is being recycled"* [Interview, Stena Recycling]. For example, TMR requires their waste to get 60% recycled, and a 50% recycling rate would be cheaper to sort. About the technical maximum rate, it lies between 70% and 75% but chemical recycling in a lab environment could probably increase it further.

What constitutes down-cycling is somewhat of a grey area in recycling [Interview, Stena Recycling]. For example, making railroad sleepers from old plastic is turning it into something useful that they include in their recycling rate, but it is not new packaging.

The process in Lanna can be summarised as (Stena Recycling, n.d.): Firstly, bale or loose waste into the sorting flow to get the size reduced, then a magnet to remove iron, screening, followed by remove other metals and foil before friction washing. After the friction washing sink and float separation for flexible and non flexible plastics, drying, granulating and lastly polymer gets sorted by NIR sensor into big bags.

Comparison of fractions at sorting facilities in Sweden

Table 4 show a comparison of the fractions sorted at Swedish Plasitc Recycling and Stena Recycling. In the interview with Swedish Plastic Recycling, it was mentioned that PVC can not be used for energy recovery due to damaging effects on incineration plants, is currently sent to landfill. Most of it is not plastic packaging but for example shoes and toys that are sorted as packaging by mistake by households. Swedish Plastic Recycling recycle two fractions into new food-grade packaging, which is PS and PET. PET is not highlighted as food-grade in Table 4 as no conclusive answer of what PET fraction this is was found.

3.2.4 Disturbing factors for sorters in Sweden

At Swedish Plastic Recycling, soft plastics is a major challenge. The soft plastics with a lot of printing on them, makes it impossible to guarantee the purity of them but the situation looks a bit better for hard plastics, as the labels are often different and somewhat easier to handle

Table 4: Comparison of the sorted fractions at Swedish Plastic Recycling and Stena Recycling. If no explanation is given, no conclusive answer about what happens to this fraction was found.

	Swedish Plastic Recycling, Motala	**Stena Recycling, Lanna**
PE rigid	High-quality recycling (not black)	Recycler then sort it as coloured/uncoloured
PE flexible	High quality recycling (not black)	
PP rigid	High-quality recycling (not black)	Recycler then sort it as coloured/uncoloured
PP flexible	High quality recycling (not black)	
PET bottle transparent	High-quality recycling (also to food-grade applications)	
PET bottle coloured	Down-cycling to for example textile fibers	
PET tray transparent	High-quality recycling (also to food-grade applications)	
PET mix		x
Mixed foil		x
EPS	Low-quality recycling	Energy recovery
PS	High-quality recycling (food grade possible)	
PVC	Partly landfill	
PO-mix 50	Down-cycling to for example pallets and railway sleepers	
PO-mix 75	Down-cycling to for example pallets and railway sleepers	
Rejected	Energy recovery	Energy recovery

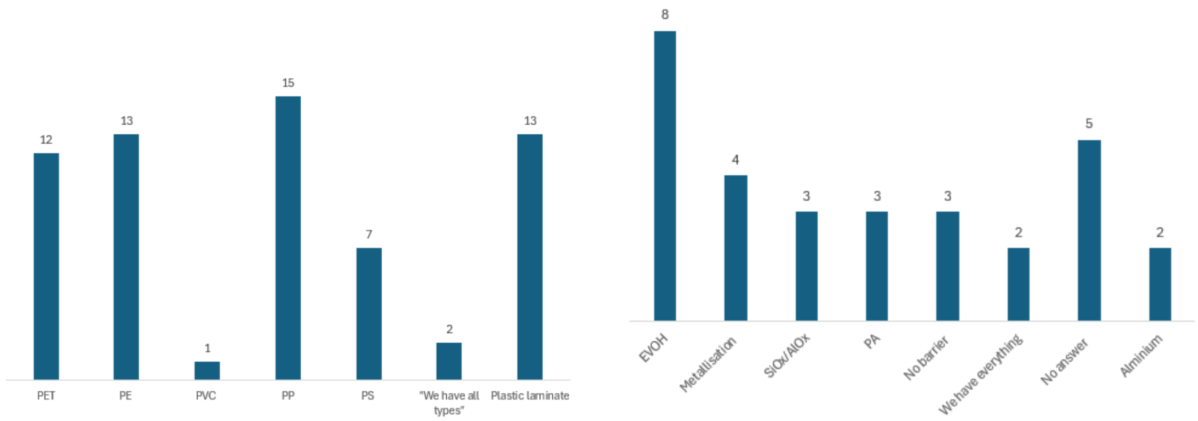
[Interview, Swedish Plastics Recycling]. In a later interview with PreZero they agreed that printing inks are challenging and something that is not supposed to be recycled and can create toxic substances.

As an answer to the question of the most disruptive factor in the sorting process that affects both price and output, both SPÅ and Stena Recycling identify batteries as the biggest issue as these regularly cause fires [Interview, Swedish Plastics Recycling][Interview, Stena Recycling]. The problem is that batteries regularly cause fires, leading to production losses, increased fire protection costs, and posing a safety risk to the employees [Interview, Swedish Plastics Recycling].

3.2.5 Packaging design: Overview of the process

Before diving into the packaging design, an overview of what plastic packaging types, labels and barriers was collected to see that several different types are covered. Answers to Q1 and

Q2, as presented in Figure 9, show that there is a wide variety of packaging options covered by the product producer interviews. Several companies stated that they actively avoided PLA and PVC, and one company mentioned that it currently has PVC but is looking to replace it. Aluminium as a barrier is also getting phased out, and EVOH levels shrink to meet the maximum of 5%. Several of the companies that use PS mentioned that they want to find alternatives.



(a) Q1. Which plastic packaging materials and polymer types (e.g. PP, PET, HDPE) do you currently use?

(b) Q2. What type of barriers and labels do you currently use in your packaging? Labels are not included as only limited answers were provided.

Figure 9: Answers to Q1 and Q2 of the product producer interviews. (Company answers were coded to more than one label.)

Further was questions about packaging design were intended to provide an overview of the packaging development process across the companies to understand what drives the process of new design, what part does DfR have, and what trends can be seen in the choice of material.

When and where changes occur in design vary with the design and/or marketing department appearing as the main starting point, see more in Figure 10a. Many interviewees highlighted several people or departments are involved, and that there are often trade-offs between things such as design, marketing, materials and what production machines they have access to. *"You want to come up with products that drive sales and stand out on the shelf. Usually, you start by working with an agency to get a rough idea of the packaging cost, then you bring in suppliers to figure out what's technically possible and what the final price will be"* [company 7].

In the discussion about the material and barrier choice, mono-material has increased, but the less recyclable multi-laminate is still a big part of the market, with 15 companies of 19 interviewed using it. One application for multi-laminates that is hard to replace is cheese packaging even though producers stated that they have been able to convert bags with grated cheese to mono-materials. The mono-laminates are more fragile causing problems when blocks of triangular cheeses with sharp edges are packaged.

Barriers in general serve an important purpose of protecting the food to last longer and increase the so-called shelf life. Fewer barriers can increase the food waste, which makes it complex, and several interviews discussed whether more DFR-adjusted packaging can lead to more food waste (read more in the discussion). (9)

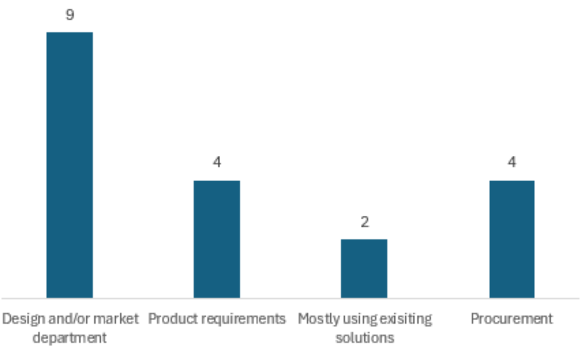
Several companies also highlighted that they have some percentage of recycled plastic in several of their non-food packaging items, but in food-packing items, there are examples of recycled plastic mainly from PET. When looking at the reason behind the low use of recycled plastics, the companies interviewed brought up price and food safety concerns. That separate flows of packaging are needed to increase the amount of food-safe recycled plastic in food packaging.

The costs assosicated with packaging is becoming more important. One company stated that *"In the procurement process, packaging is secondary, but with new costs it becomes more expensive and important"* [Company 8]. A few companies “took the hit” short term with more recycled plastic, although it is nothing customers accept to pay more for,for building partnerships and securing the supply chain for food-safe plastics long term with higher fees and requirements in the future.

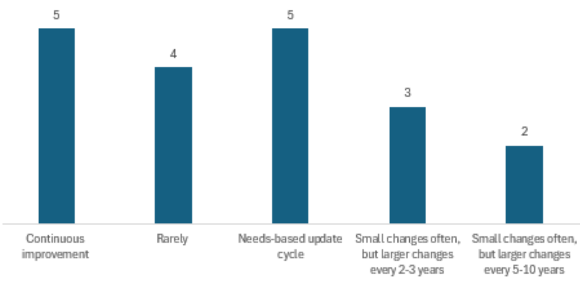
Companies in the study knows material changes will happen but there are differences in how they act with high uncertainties around PPWR from building supply chain to minor changes until 2028.

"for many years there were not that big material changes, but in the coming years we will likely need to make large material changes every year, not just due to laws but also consumer demands"[company 2].

When to make changes in design, the most common approaches were continuous improvement and a need-based update cycle, with many companies having big portfolios of products. The most interesting finding from this part is in the "rarely" category. They gave quite short answers like "we rarely do updates, besides maybe printing", but most of these companies state that they have recyclable packaging. A conclusion that can be made from that is, design decisions that are made have an impact for many years. How often companies make changes is presented in Figure 10b.



(a) Answers to Q3. What is the starting point in your packaging development process?



(b) Answers to Q4. How often do you make changes in the design?

Figure 10: Answers to Q3 and Q4 of the product producer interviews.

3.2.6 DfR in Practice: How Companies Find and Use Guidelines

In this section, answers corresponding to support, tools and guidelines companies use to navigate within DfR of their packaging.

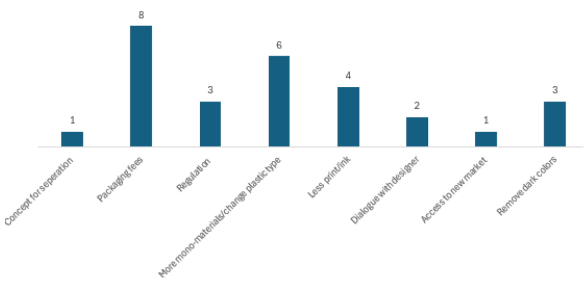
DfR as a concept could be interpreted in various ways, and there are similar concepts as DfE (design for Environment),DfC (design for Circularity), DfS (design for sustainability) and the answers to this question varied, which is the reason for the mixed categories of the answers presented in Figure 11a. When an answer was coded as "regulation", the interviewee responded either with focusing on requirements in the current or upcoming legislation.

Tools in this process of DfR also vary and few companies have their own software, and the question mostly got understood as the NPA guidelines for grading the package and the connected fee for putting it on the market. The answers to Q6 are presented in Figure 11b. The category "PRO guidelines across markets" includes the NPA guidelines in Sweden, but these companies also look at design guidelines for other markets where they are active. 18 of the 19 companies in the study are connected to NPA, and all of them used or had good knowledge about the guidelines. The approach to achieving sustainable packaging varies among companies. It requires significant effort to report each product, and the NPA guidelines exceed 90 pages. Some companies systematically work with the requirements and initiate internal projects to improve their packaging step by step, while some larger corporations de-prioritise these efforts due to the high administrative costs connected to reporting the packaging fees. In contrast, all smaller companies that were interviewed actively work on improving their packaging solutions.

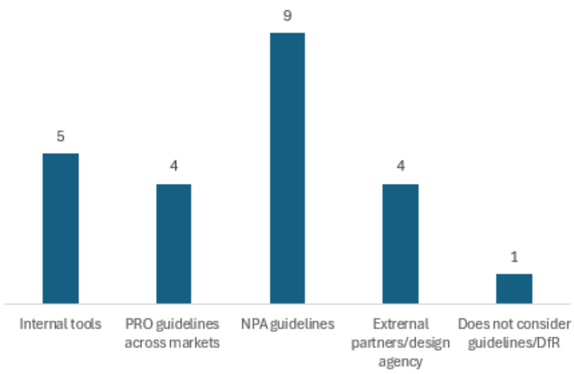
Further did most companies in the study know about RecyClass and all companies that know about RecyClass talk positively about harmonised guidelines. CEFLEX was mention by a few companies but they also mention that it is only relevant for flexible plastic packaging.

Q7 about which of these tools currently consider, or could consider, DfR principle gave no conclusive answers and most correspondents had already touched upon this in Q6.

A general conclusion from the product producer interviews is that differentiated packaging fees, based on design for recycling principles, established by the PROs do impact design and decisions among product producers to improve the recyclability of plastic packaging. Several companies state that they actively work in projects to move a package to a lower packaging fee or consider packaging fees in design choices, which means adapting the packaging to make it recyclable.



(a) Q5. In what way does Design for Recycling (DfR) influence your choice of materials and design strategies in packaging development?



(b) Q6. What tools/software do you use during the design phase?

Figure 11: Answers to Q5 and Q6 of the product producer interviews. (Company answers were coded to more than one label.)

3.2.7 Harmonisation: A Long-Desired and Welcome Step Forward

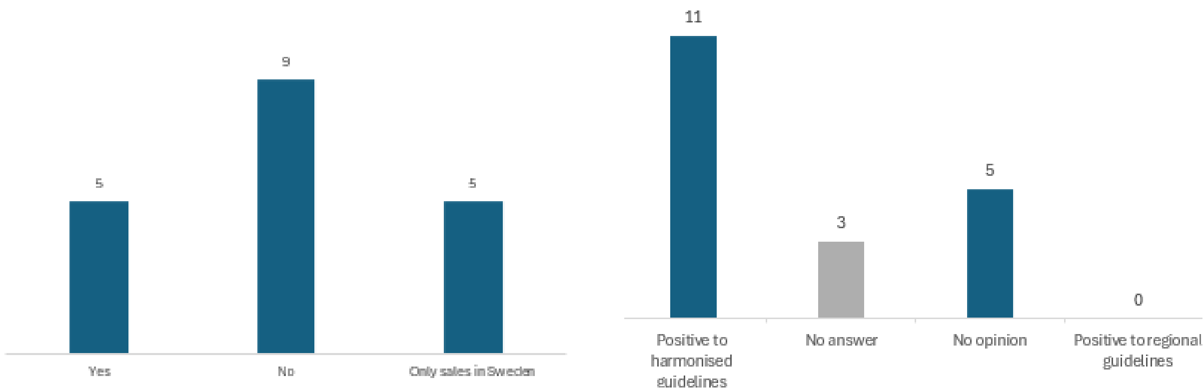
Around 2020 and earlier PROs developed its own guidelines adapted to local infrastructure [Interview, Swedish Plastic Recycling]. There were no European harmonised industry standards for DfR and a big challenge with many producers located in several markets and packaging manufacturers have requested harmonised guidelines for a long time and with the introduction of the Packaging and Packaging Waste Regulation (PPWR), efforts to harmonise guidelines across European markets have gained momentum[Interview, Swedish Plastic Recycling].

All 19 companies interviewed for the product producer interviews were either supportive of harmonisation, had no opinion, or reported no significant impact from this process. Companies operating in multiple markets currently rely on tools like RecyClass and CEFLEX for DfR support, aiming to benefit from economies of scale through standardised products. Although minor regional variations, such as language-specific packaging, may still be necessary, most companies aim to reduce the effort required to align with diverse recyclability guidelines. An example of a regional design adjustment is a company introducing packaging with a certain percentage of bioplastic to reduce local plastic bag taxes (see Figure 12).

The cost of plastic packaging has also risen substantially in recent years, driven by regulatory fees, littering penalties, and fossil-based plastics levies. These rising costs have transformed previously minor expenses into significant financial considerations, making it more challenging to maintain the scalability benefits of regional markets.

Harmonisation is clearly a priority, as evidenced by the fact that 74% of the interviewees mentioned PPWR without any specific prompt, highlighting its importance for the industry.

In addition to standardising guidelines, some companies also hope for harmonised reporting systems. As one respondent noted, "Reporting systems also look very different for different countries. Even in the Nordic region, the way internal accounting systems need to be set up is completely different. Norway is currently the most complicated for these products" [Company 3].



(a) Q8. Do you design packaging differently for various markets (e.g., different countries or regions)?

(b) Q9. What is your view on design guidelines based on regional recycling infrastructure compared to general EU-wide guidelines?

Figure 12: Answers to Q8 and Q9 of the product producer interviews.

3.2.8 Data Exchange and Traceability: Insights from industry

The last three questions of the product producer interviews touch upon data exchange and traceability. This includes who has information, what information is valuable and how is the knowledge about traceability solutions and data exchange.

Most companies had a mix of how they gathered information. It can be both upstream, like asking the suppliers of the packaging they use and downstream by contacting the PROs and using their guidelines. It can be concluded that together with technical specifications from the suppliers, with the guidelines from NPA or in some cases RecyClass and CEFLEX product producers, lays the puzzle to the best of their ability.

"We have quite a few people monitoring this and working on it internally. We use technical subscription services and databases. We're also involved in organisations and forums. The suppliers of plastic raw material are also keen to know what's going on" [company 3].

Three larger companies state that they have product lifecycle management systems where they store information about their products, including information from the packaging suppliers about all the packaging components.

"Plastic suppliers very often respond with what the law says and that they comply with it, they usually only have an eye on the legal requirements. With new legal requirements, it becomes easier to make demands on suppliers"[company 4].

Two companies, on the other hand, state that they have had packaging suppliers come to them with proposals for better packaging alternatives. Continuing, what information they do not have from the EoL phase that could be valuable for their packaging. There was interest in traceability solutions for food-grade material, but many had difficulty seeing a clear use of EoL data today for more than marketing purposes. This low interest in the use of EoL data may be due to the lack of value for the companies, but when asked about traceability solutions, such as digital watermarks or digital product passports, the awareness was low among the product producers, and it is hard to see the use of anything you do not understand. See more in Figure 15 where mention anything = low, mention solutions briefly = medium and had a discussion about traceability = high.

Combining with an overall low-medium traceability awareness in general, can this be concluded as either governmental bodies and other actors will be the only ones needing it, or the knowledge about how to interpret data is not there yet. One company had high awareness and had been heavily involved, said that *"HolyGrail 2.0 will be dead before it is even born, because AI will take over that before HolyGrail 2.0 has been deployed"*[company 5]. Another was more optimistic *"I wondered why the HolyGrail 2.0 project had not been a success yet"*[company 1]. Tracer-based sorting, on the other hand, has not been established among producers in Sweden or any other actor we interviewed, and so far only in the literature.

An organisation that was note planned to interviewed and came up in the interviews was GS1 Sweden which is owned by DLF and SVDH who are working with traceability and digital services, was a part of the discussion as well.

GS1 Sweden is the Swedish part of international non-profit organisation GS1 that provides unique article numbers and related services, including what could be considered (DPP) when connected to what they call master data which is a database that can contain a wide variety of product attributes such as size and colour, to companies [Interview, GS1 Sweden] which could be used as a base when developing traceability solutions for plastic packaging.

The requirement for recycling at scale in the PPWR involves data-exchange across the value chain. A conclusion from the value chain interviews of this study is that no such process is currently established in Sweden.

From the interview with Stena Recycling and Edo et al. (2024), both summarise that AI and digital technologies will transform waste sorting by enabling better separation of more materials, improving quality, and increasing efficiency [Interview, Stena Recycling]. AI will enhance operations by processing the large volumes of data generated through integrated sensor systems, leading to faster, more cost-effective sorting.

Several interviewees in the product producer interviews stated that it is challenging to obtain recycled material of food grade quality, even though some have managed to secure contracts for this, something that requires more traceability.

"Traceability solutions need to be found to ensure that packaging can be in contact with food. Better pre-sorting so that plastic from different industries is not mixed. Today, it is not possible to safely meet the requirement in PPWR for recycled material" [Company 1].

Another actor that arose under the process related to traceability was the Swedish institution for Standards(SIS). To get the whole supply-chain organised and standardised solution, standards are an important part. SIS is the organisation that represents Sweden in European and global standardisation. SIS main responsibilities are to manage standards and develop new standards through technical expert groups called technical committees. Standards are an important tool to bring together the many steps of the value chain, as this can be difficult through other means, such as industry organisations (Interview, SIS). Standards are generally voluntary but there is a category of standards called harmonised standards that are referred to by law, meaning that companies needs to follow the standard unless they are able to prove that they fulfil the requirements in the law by other means (interview, SIS).

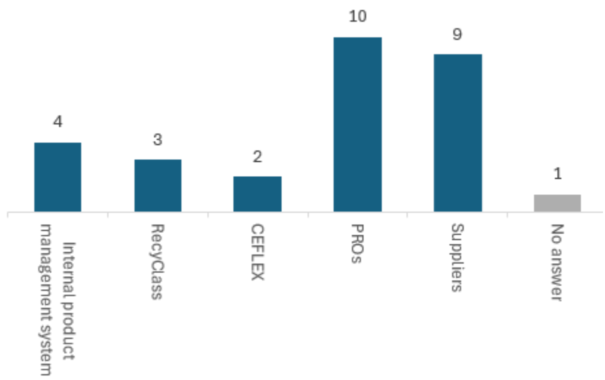


Figure 13: Q10. Retrieving information about recyclability of packaging. (Company answers were coded to more than one label.)

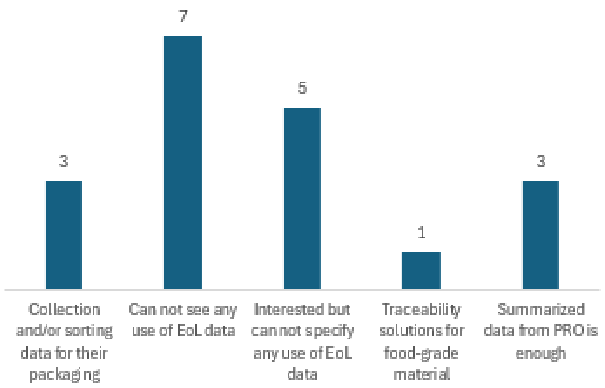


Figure 14: Q11. Which data from the end-of-life phase would help you in the design process? (Company answers were coded to more than one label.)

3.2.9 Recyclable packaging: The biggest challenges for product producers

As a last question of the product producer interviews, a more broad question was asked to see what will be challenge looking forward and the companies could list multiple challenges.

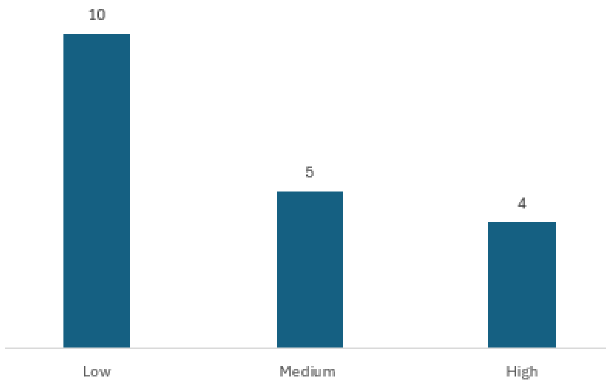


Figure 15: Q12. Traceability awareness of the companies

The two biggest challenges that emerged was to protect food and transition away from multi-laminates. These are, to an extent, connected because the multiple layers often serve one purpose each for protecting fresh food and extend the shelf life. Though some compaines was talking about laminate in general product specific products such as butter, meat and cheese was mentioned.

It is important to change to mono material to get recycling at scale and a circular economy, but if it is done wrong, increased food waste can erase the progress. *"It is important to remember that only one slice of cheese into the waste have bigger environmental impact then the whole package around it"*.

With this in mind 6 of the 15 companies interview from the plastic initiative 2025 have successfully reach 100% recyclable packing and shown that is possible.

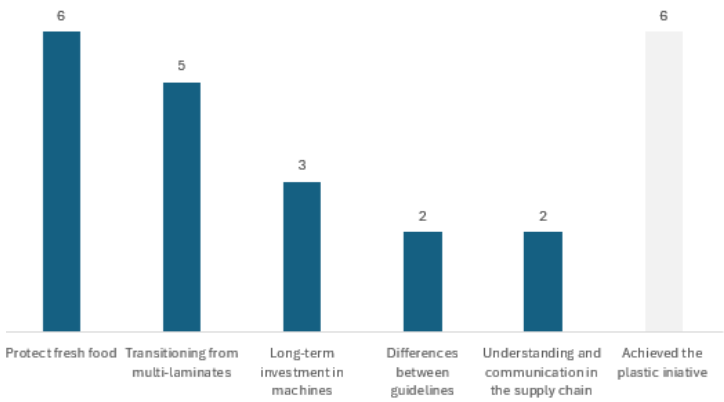


Figure 16: Q13. Biggest challenge to reach complete recyclability of packaging. (Company answers were coded to more than one label.)

3.3 DfR guidelines comparison

The product producer interviews showed that the established method for transferring data/-knowledge from the EoL of plastic packaging to the BoL today is through what is called Design for Recycling guidelines. These are documents that in one way or another compile knowledge from the sorting and recycling steps of the value chain into criteria that product producers and brand owners can use to assess the recyclability of their packaging.

At least 17 design for recycling guidelines exist focusing on either country, EU or the global level (Pierri et al., 2024). These will be standardised through the PPWR legislation by CEN (European Parliament and European Council Regulation 2025/40, 2025). Comparing existing DfR guidelines allows for a qualitative comparison of the differences and to see how harmonised the current landscape is.

Two of the large European DfR guidelines are RecyClass and CEFLEX, as presented by Pierri et al. (2024) and through the interviews. The two PROs in Sweden, NPA and TMR, provide criteria for producers that determine the packaging fee (green is the lowest fee, red is the highest) while NPA also provides more comprehensive DfR guidelines. NPA bases its guidelines on RecyClass [Interview, NPA]. To compare the results of these DfR guidelines and criteria, product specifications were provided for a variety of products by a large company. This data can not be shared due to the sensitive nature of the data. The products were selected to cover a wide range of plastic types and applications. All were food items as this was the data that was available. Recyclability was evaluated for each product by going through the guidelines for each product, resulting in each DfR guideline producing a recyclability classification for each product. The results were compared to see where the DfR guidelines converge and diverge.

Several assumptions were made, particularly when evaluating the packaging in RecyClass. It was assumed that no additives or adhesives were used or that they had no impact on sorting or recycling. For multilayer packaging, it was assumed that water-based acrylis was used. The packaging was assumed to have no liners, seals or valves. Inks were assumed to follow EUPIA guidelines. It was assumed that mechanisms such as tamper evidence wraps are removed by the consumer and sorted separately, or that it had no impact on recycling. As no product tests were possible within the time frame and resources of this project, it was assumed that only low amounts of product residue were left in the packaging during sorting and recycling.

The assessments were made based only on what the guidelines actually say, and a single design aspect can have a huge impact on the classification when looking at the NPA design for recycling guidelines[Interview, NPA]. For example, a paper label on a specific plastic fraction makes the recyclability equal to red. NPA packaging fee criteria have a broader view and look at the whole plastic packaging. Material specifications for labels is tricky to obtain from suppliers today, so it is not taken into consideration in the packaging fee criteria for NPA as of now, but PPWR will probably take labels into consideration [Interview, NPA]. During the product producer interviews, it was pointed out that packages are sometimes given a "better" classification after a dialogue with the material specialists at NPA, and the recyclability of the packaging can be proven.

The results of the comparison can be found in Table 5. TMR, NPA and CEFLEX have similar system for displaying the recyclability using the three levels Green (compatible with high-quality recycling), Yellow (low-quality recycling) or Red (energy recovery or the packaging is at risk of contaminating the recycled material). RecyClass uses a slightly more advanced ranking system from A to F. A and B allow for high-quality recycling or closed-loop recycling, while C is the equivalent of Yellow for the others. E and F are the equivalent of Red. For RecyClass, the difference between E and F and "Not recyclable" is that RecyClass first does a check to know if it is even reasonable to check the recyclability and the label "not recyclable" is given if it is not. CEFLEX does not have a result for all packaging as it only covers flexible plastics.

From Table 5, it becomes evident that there are considerable differences between the DfR guidelines and the requirements they have. When assessing the packaging, a striking difference was that even though they might have given the same classification to a package, the reason it was downgraded from a higher level was often different.

Table 5: Comparison of how different DfR guidelines and packaging fee criteria classify the recyclability of some example packaging.

	TMR packaging fee criteria	RecyClass	NPA design for recycling guidelines	NPA packaging fee criteria	CEFLEX
1. Cooking oil bottle	Green	C	Red	Green	Not covered
2. Shampoo bottle 1	Yellow	F	Yellow	Yellow	Not covered
3. Shampoo bottle 2	Green	B	Red	Green	Not covered
4. Potato fries (frozen)	Green	B	Yellow	Yellow	Yellow
5. Toothpaste tube	Yellow	C	Red	Red	Red
6. Coffee bag type 1	Red	Not recyclable	Red	Red	Red
7. Coffee bag type 2	Yellow	Not recyclable	Red	Red	Red
8. Sour cream type 1	Green	A	Yellow	Yellow	Not covered
9. Sour cream type 2	Green	B	Yellow	Yellow	Not covered
10. Meat tray type 1	Green	C	Red	Green	Not covered
11. Meat tray type 2	Green	C	Red	Green	Not covered
12. Chocolate	Green	A	Red	Yellow	Yellow
13. Crisps	Yellow	B	Yellow	Green	Yellow
14. Cheese	Red	Not recyclable	Red	Red	Red

Further, there is considerable differences in Europe's waste management. In Figure 17, 18, and 19is collection, sorting and recycling of flexible PE is shown (The maps, used with RecyClass approval, is indicative and may change over time. For further questions about the maps contact RecyClass).

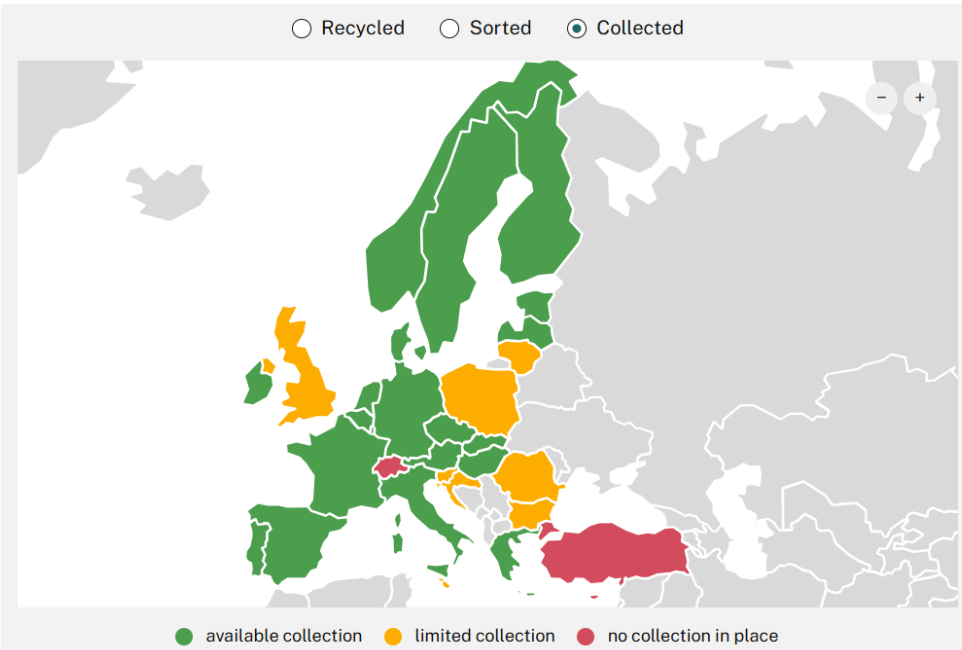


Figure 17: Collected PE flexible in Europe(RecyClass, 2025a)

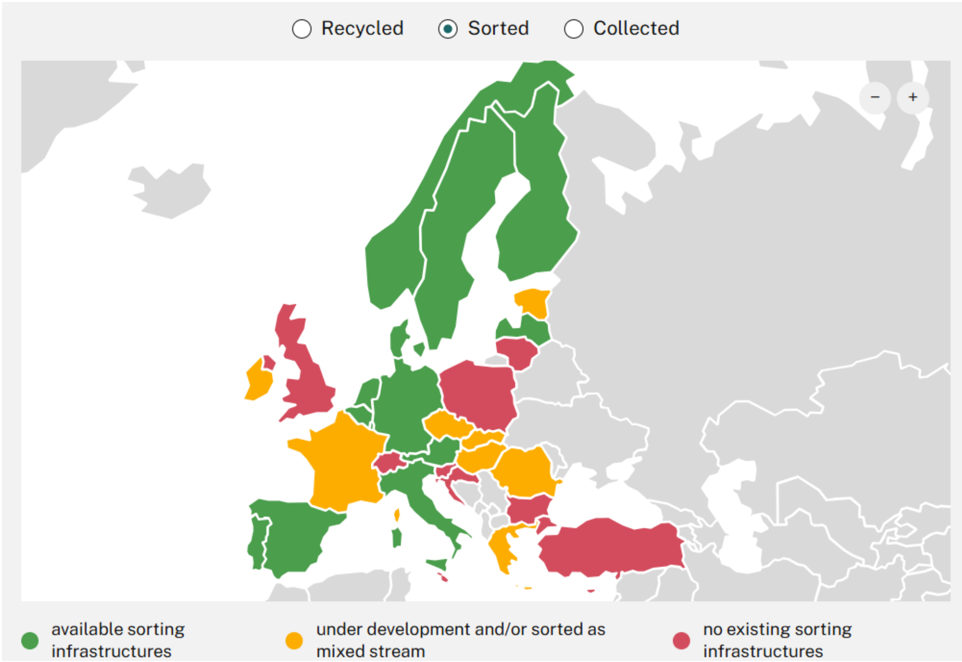


Figure 18: Sorting infrastructure of PE flexible in Europe (RecyClass, 2025c)

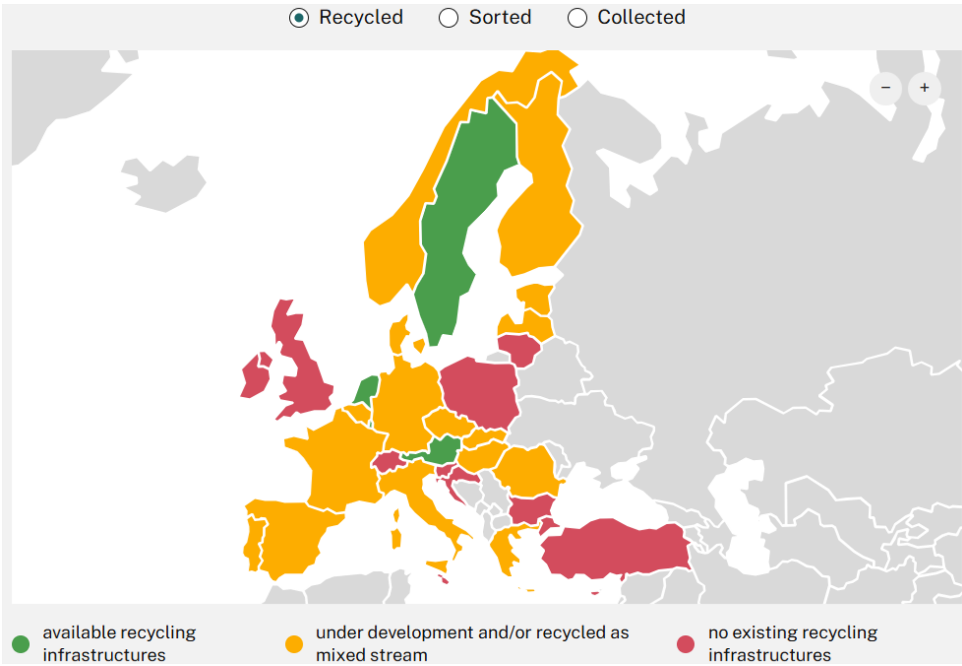


Figure 19: Recycled capacity of PE Flexible in Europe(RecyClass, 2025b)

3.4 Business models

In this section, CRAB Traceability Systems and Business Model Canvas from this thesis are presented.

3.4.1 CRAB Traceability Systems

The Circular Resource Analysis Bridge (CRAB) is a start-up with the mission of revealing the often hidden processes involved in the end-of-life treatment of packaging. This will be achieved by using advanced AI-driven camera systems to monitor and analyse resource streams, providing valuable insights into the complex paths that packaging materials follow as they move through sorting and recycling systems (CRAB Traceability Systems S.à r.l.-S, 2025).

3.4.2 Business Model Canvas from this thesis

To address the third research question and identify market gaps based on this master thesis, the Business Model Canvas (BMC) framework was used. This model captures the key elements of how organisations create, deliver, and capture value. For a more comprehensive analysis, the Triple Layer Business Model Canvas was also applied, integrating social, environmental, and economic dimensions to provide a holistic perspective on business strategy.

The business model canvas should be understood as a way of framing the ideas from the master thesis within a business context, rather than presenting them as fully developed business models. The ideas are what the authors have deemed the most important gaps in the value chain to increase circularity.

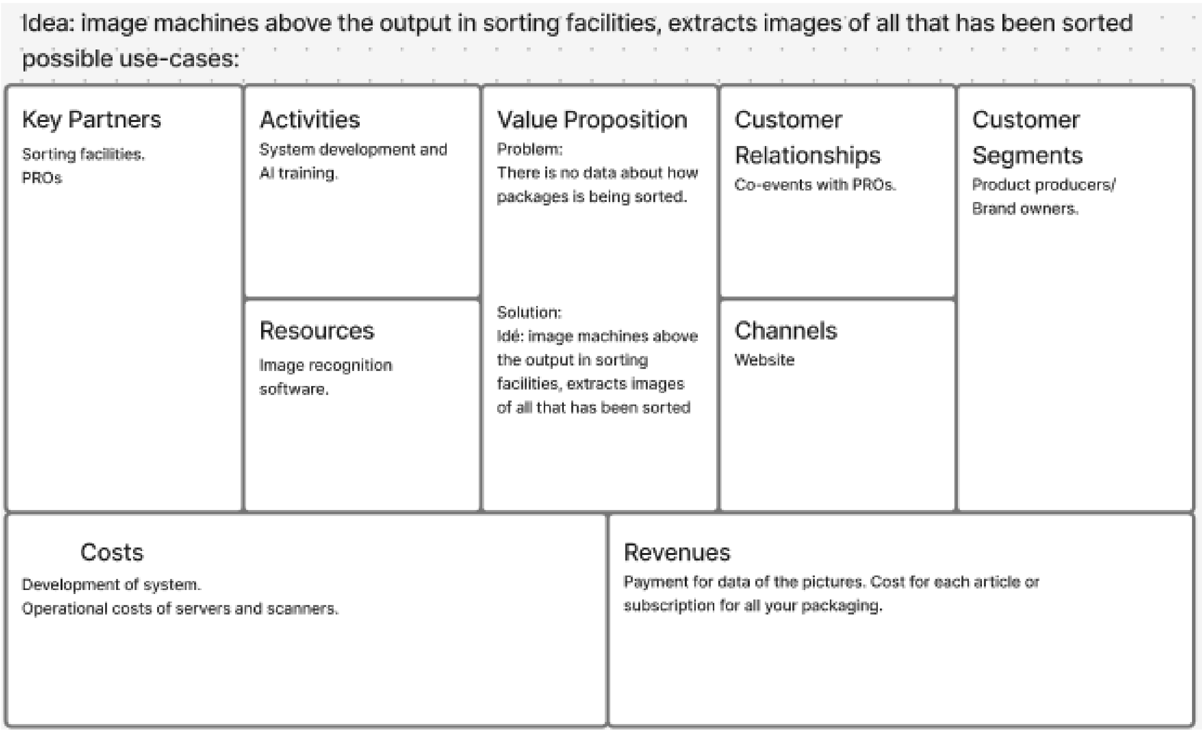


Figure 20: Economic layer of Business Model Canvas for idea one.

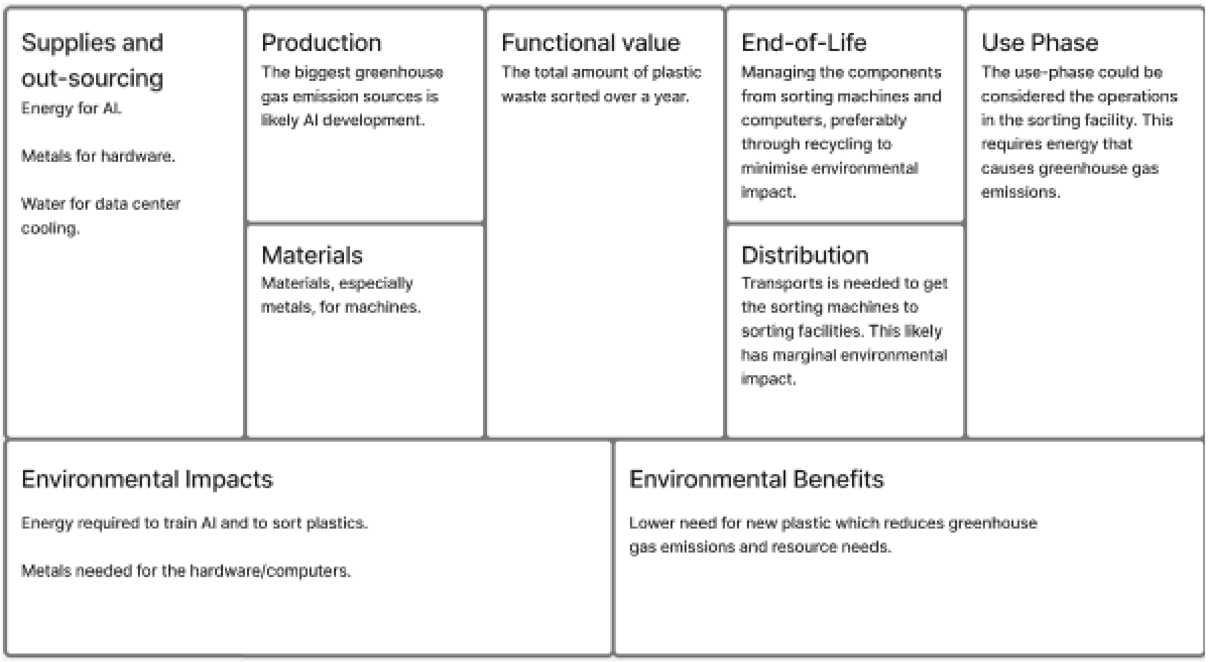


Figure 21: Environmental layer of Business Model Canvas for idea one.

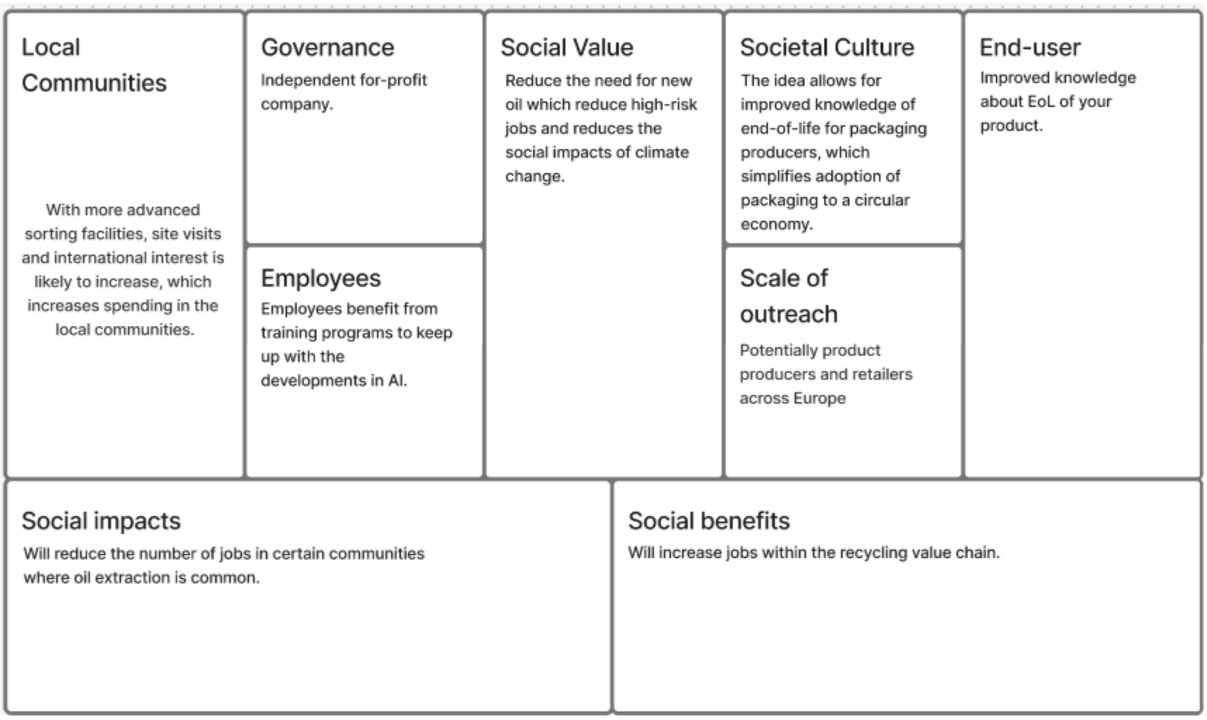


Figure 22: Social layer of Business Model Canvas for idea one.

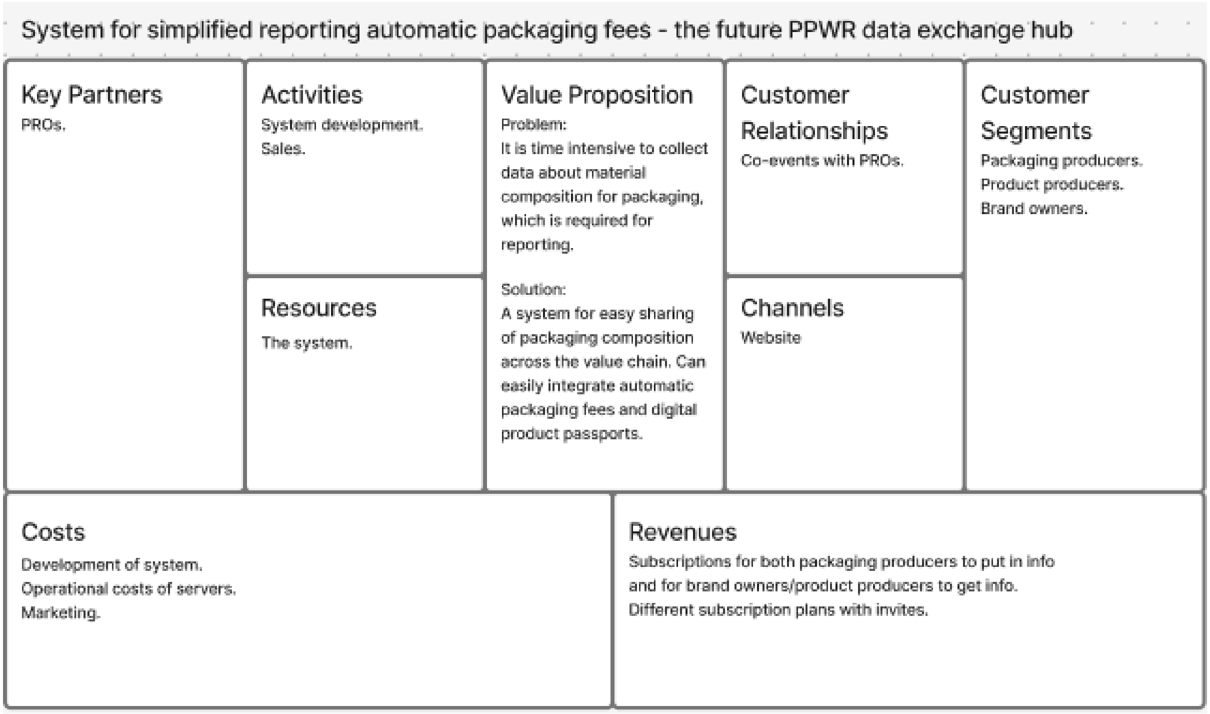


Figure 23: Economic layer of Business Model Canvas for idea two.

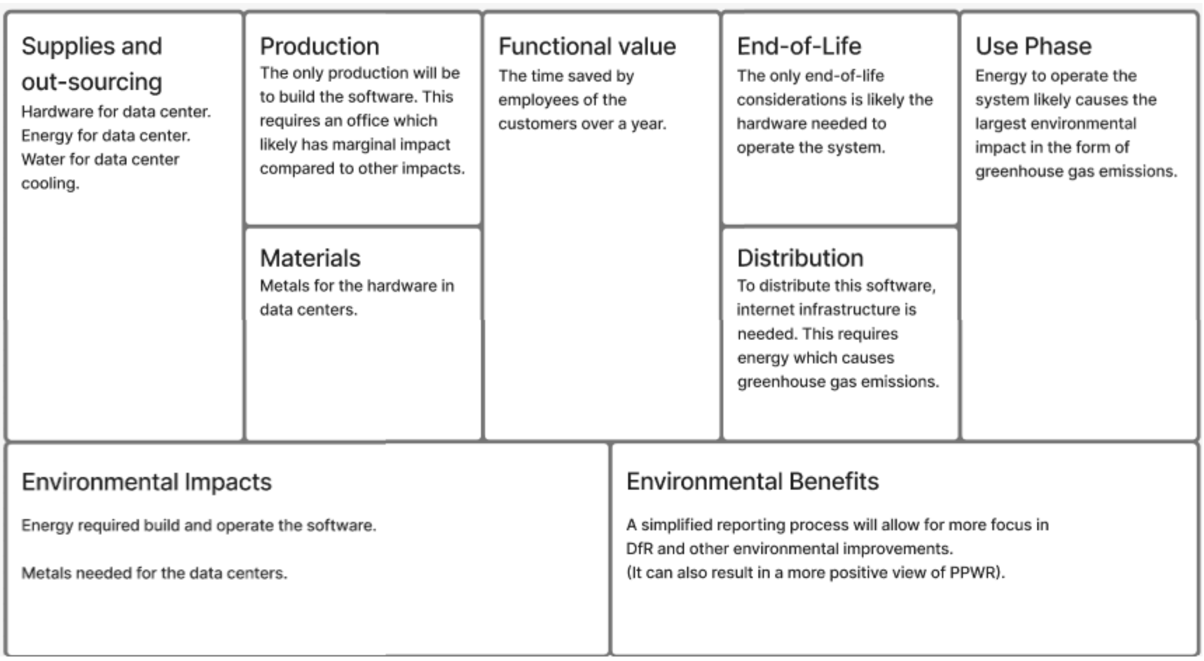


Figure 24: Environmental layer of Business Model Canvas for idea two.

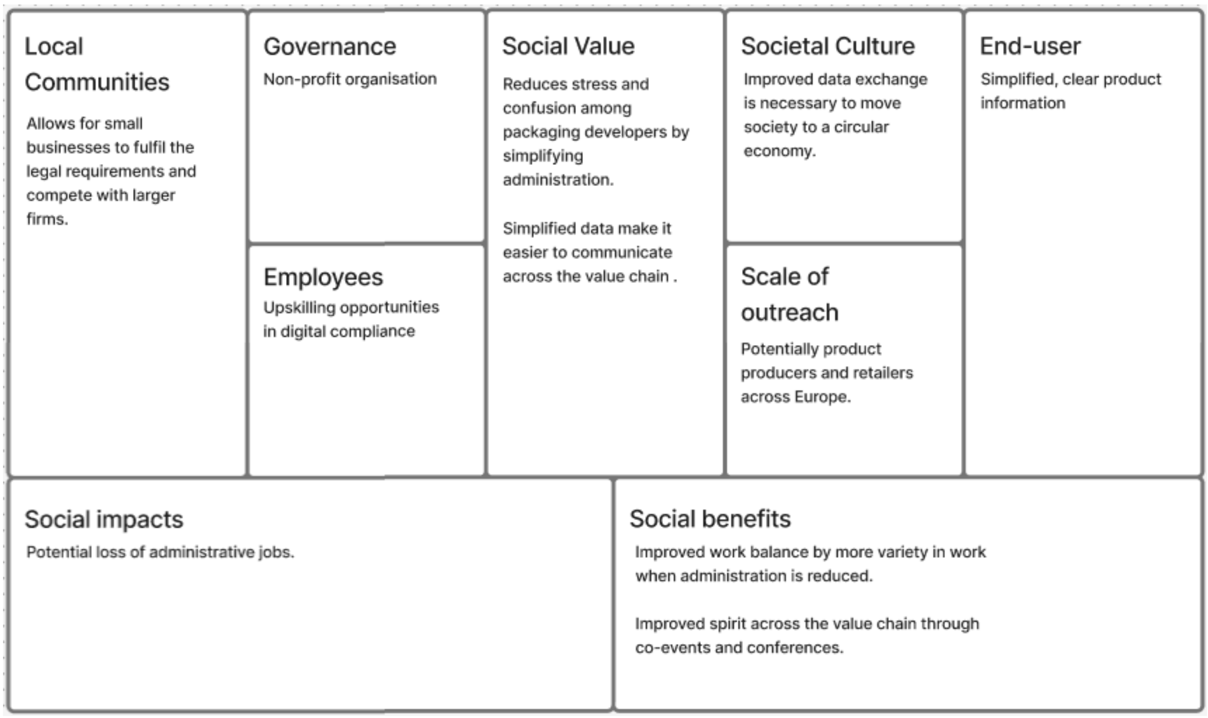


Figure 25: Social layer of Business Model Canvas for idea two.

4 Discussion

4.1 Guidelines - the information flow of today

This project set out to explore data exchange between the beginning and end of the plastic packaging value chain. One such data exchange emerged as the mainstream method for data exchange today, which was through DfR guidelines. This is a way of abstracting data from several sources, such as lab tests in the case of RecyClass and knowledge from specific sorting facilities in the case of NPA/Swedish Plastic Recycling. Packaging design (and recyclability) can only be influenced by the beginning-of-life but product companies do not feel the consequences. Recyclers are impacted by poor packaging design from a DfR perspective (as they can not sort the waste or sell it as a high-quality material) but can not do anything about it. A key benefit to the DfR guidelines approach, confirmed through the interviews, is that a core part is differentiated packaging fees, which effectively incentivise product producers and brand owners to improve packaging design. However, several problems remain, such as that DfR guidelines can yield divergent results as shown by the DfR guideline comparison, and that there is a lack of harmonisation across Europe's Extended Producer Responsibility (EPR) schemes, as noted by studies like Pruess (2023). This inconsistency is frustrating for producers, and the producers are very positive to harmonised guidelines across the EU as seen by the interviews. Nevertheless, the findings and interviews affirm that differentiated fees do have a real impact. The varying price levels significantly influence company behavior and support better packaging practices, as also concluded in studies such as Lorang et al. (2022), which show that differentiated packaging fees can incentivise eco-design.

It is not established that DfR guidelines is the best method for data exchange. There is actually several disadvantages with the approach. As established, there is a divergence between the different DfR guidelines which creates uncertainty. The assessments made using the DfR guidelines is quite subjective and requires a lot of packaging knowledge and material composition data, and it is not even certain that it is actually recycled. Solutions such as AI/image recognition or traceability mechanisms therefore pose interesting possibilities of looking at how a packaging actually performs in the real world sorting and recycling facilities, as illustrated by the presented business models.

4.2 Problems for high-quality recycling

The first research question aimed to identify the state of the art in plastic packaging design, collection, sorting, and recycling in Sweden. This was explained both through the interviews, literature review and through the identified flows. However, a critical follow-up question remains: how effectively is this system functioning? Is it achieving its intended goals?

Theoretically, it is working. PROs having the responsibility, product producers work with DfR, fees are differentiated to motivate, labels on packaging for consumers, and collection points seem to be closer to consumers, with municipalities taking control of collection and Kerbside collection. There is a modern sorting facility in Motala and recyclers, even though no recyclers exist in Sweden today. With an end-of-life value chain spread across Europe, it is paramount that sorters such as Swedish Plastic Recycling and Stena Recycling make sure that certificates are available for the recyclers they choose to use. It is a developed system, but is it built for high-quality recycling?

Ekvall et al. (2025) wrote that it does not distinguish between down-cycling and high-quality recycling. Which we got confirmed by making railroad sleepers are classified as a material that gets recycled. We need railroad sleepers as well, and good if they are not virgin plastic, but with the massive amount of packaging produced every year, no other material than itself can meet this demand.

Some of the problems with down-cycling are easier than others. For example have companies have decreased their use of ink, and dark colours, particularly carbon black, as Jakobs and Kroell (2024) notes in the literature review, and sorting experts in the interviews. Multilayer films are a more tricky one. Koinig et al. (2022) idea of advanced detection and ejection technologies is to abstract at the moment. Seier et al. (2023) wrote that it is currently hindered by insufficient purification methods, but neither PreZero, Stena Recycling, nor SPÅ mention it in the interviews. Maybe it is a cost question, and purification methods will be better, or chemical recycling will be implemented. Today, it is only mechanical recycling connected to the big PROs, and Ding and Zhu (2023) says that both chemical and mechanical will be needed. So, preferably, more mono materials to get recycling at scale and a circular economy.

4.3 Recycling at scale

The PPWR requires that all packaging put on the market should be recyclable and that producers should use more recycled content in the packaging, but there is not that much recycled food-grade plastic today for the plastic producer to use. The fact that it (the standards developed to support PPWR) will be just considered and not adopted as harmonised standards directly is a new way of working and can be seen as a dissatisfaction from the EU commission towards the industry [Interview, SIS]. There are several solutions to increase the amount of food-grade recycled plastics, with one of the ideas that emerged though the project being a thin layer of virgin plastic layer closest to the product to protect it properly and then the rest of the packaging could be recycled plastic with less requirements of safety and purity. This is an idea that Stena Recycling also brought up in the interview when discussing AI and PPWR impact [Interview, Stena Recycling]. Other experts depreciates the idea instead because of the risk; contaminants can still be mitigated through the layer and get contaminated [Interview, Swedish Plastic Recycling]. Instead, they believed in better sorting by more separate flows. The fractions HDPE, PET and PS have good potential for food-grade applications and expanding the collection portfolio, like **Roosen<empty citation>** suggested, can be one way. Though collection is already hard with wrong and low volumes ending up in plastic packaging waste, and maybe it is more a mindset problem, as Scriosteanu and Criveanu (2024) wrote, than the number of fractions possible to sort in the bin at home. Interestingly, the separate flow in the deposit system of Sweden has a recycling rate around 90%, something that is way higher than the studied flow(Pantamera, 2023).

In the 29 interviews, on how to achieve recyclability has been discussed back and forth, and in the search for how to sort, fix the multilaminate, and ensure traceability, you can lose the bigger picture. Why do we want to change the plastic packaging? To use the resources on Earth more carefully and release less carbon to the atmosphere. More recyclability leads to a smaller carbon footprint, but the packaging often has a lower impact than the meat or cheese it protects. Increased food waste for better DfR packaging will not make it better, and potentially worse. It is therefore important that barriers fulfil their purpose and have food waste in mind, but it is not a reason to slow down or lower the ambition for high-quality recycling.

4.4 Traceability/Chain of custody - a neccessity looking forward

Traceability is becoming more and more relevant for actors in the plastic packaging value chain, especially with the newly introduced PPWR EU legislation introducing a "chain of custody" mechanisms that producers should use to ensure that their packaging fulfils the upcoming requirement of recycling at scale. Both the literature and the interviews indicate that data from the end-of-life currently have limited impact on packaging development and the beginning-of-life overall, even in the few cases where it is available. The fact that most product producers see none or limited use for end-of-life data is telling regarding the current state of data use in the industry, although a reason for this could be the low availability of EoL data. There will likely be a lot of changes in how the product producers work over the coming years, with an increased focus on data both to and from the end-of-life. Several methods exist, such as the standards and services provided by GS1 Sweden, but to use these to the full extent, more cooperation across the value chain is necessary. Information and data, not DfR, is likely the big question for the industry in the coming years, as confirmed by one of the companies in the interviews.

4.5 The flows of today (material, information and finance)

One main result from this thesis is the flow in Sweden today. At the material flow, the vast majority goes out in Europe after sorting, making communication and harmonisation in Europe important. It will not be enough that it can be sorted at Stena Recycling and Swedish Plastic Recycling to be circular. The kerbside collection extension will be interesting and see how it further impacts the recycling rate in Sweden, and probably collection will increase, but it also needs to be clean streams as well. The finance flows are impacted by the EPR scheme, and differentiated fees have a good impact. How moving the responsibility of reporting white label products produced in Sweden from the product producer to the brand owners will impact is not obvious because it is included in the price of the product when brand owners buy a product. The incentive is a way of moving away from production but also closer to the "big players". It is not decided how it will be at the time of writing this thesis, but with PPWR it probably will not matter. PPWR will provide enough incentives.

About the information flow, there was an exception in finding more data exchange, but it was more of gathering general DfR knowledge from suppliers and PROs. It can also be initiatives like the plastic initiative 2025 with trade organisations, associations/groups and events. SPÅ is pretty new, but the evaluation of your packing at their facility is a great step in data exchange, but it is still manual and on a small scale. The difference in information flow between NPA and SPÅ, compared to TMR and Stena Recycling, was a finding that shows how different the PRO in Sweden work at the moment.

These flows demonstrate that Sweden's material flow is closely tied to European collaboration, the financial flow is significantly shaped by Extended Producer Responsibility (EPR) mechanisms and differentiated fee structures, and the information flow remains fragmented and underdeveloped, with varying practices among Producer Responsibility Organisations (PROs).

4.6 Similar research

Hsu et al. (2022) have conducted a similar study of conducting interviews from October 2019 to November 2020 with interviewees across the plastics value chain in Germany, the Netherlands and the UK, but not specifically focused on plastic packaging. Conclusions from that study include that there is a lack of focus on design for recycling for plastic. This thesis project concludes that there is a considerable focus on DfR on plastic packaging among the frontrunners of product producers. There are likely several reasons for this with the main one likely being the large increase in focus on the area over the last five years as seen by the large increase in published articles in Section 3.1.1. Another reason could be the difference of what countries the interviewees are active in as a few interviewees in the product producer and complementary interviews have indicated that Sweden is a frontrunner on the topic. Hsu et al. (2022) have used a snowballing approach to find interviewees while the product producer interviews was sampled from an industry initiative that could be considered "state-of-the-art" which could also create the difference.

4.7 Business model canvas

Two of the biggest gaps/problems in the market identified were the lack of data on how packaging is sorted and the intensive work of collecting all data today and for the upcoming requirements.

The first idea of image recognition can potentially store a lot of data in the form of images, and data analysis, such as image search or image recognition, can determine which fractions certain packaging items have been sorted into. A problem is that the design of packaging changes over time, and the approach is sensitive to this, potentially leading to recognition challenges. The data is likely very valuable, especially if it can be used to ensure packaging fulfils the PPWR recycling at scale requirement.

Compared to CRAB traceability systems, this is more to match image with image solution that requires constant updates from companies using the image database and is not integrated across the entire lifecycle of a product solution. The customer is also more focused on the product producer paying a subscription fee depending on how many pictures or products they want, and sorting facilities are more of a key partner, along with the PROs. Instead of guessing with guidelines, this gives actual data to exchange, where it ends up and can motivate when reporting as well.

The second idea counters the administrative and data exchange problem across the value chain, with a focus on beginning-of-life, with possible extensions to the end-of-life at a later stage. The system replaces the current approach of product producers and brand owners asking for material specifications and filling them into their system manually or doing manual calculations. A challenge is data ownership and security, as the data is sensitive, so this needs to be managed responsibly to get trust from the industry. Another challenge is that such a system only works if large parts of the industry are connected. There are examples of actors, such as GS1 Sweden or NPA, that could take the role of running the system, which would likely make implementation easier. Examples of initiatives for similar systems already exist in some countries, such as Packaging Cockpit from Circular Analytics [Interview, Packaging Cockpit/Circular Analytics].

4.8 The million-dollar question

Lastly, data exchange is one of the fundamental pillars of a circular economy but it is lacking for plastic packaging. Both Ding and Zhu (2023) and Hahladakis and Iacovidou (2018) have concluded it, and loads of technologies and start-ups are trying to solve this million-dollar question. Holygrail 2.0 has its digital watermarks, there is Tracer-Based Sorting (TBS), RecyClass has guidelines, GAIN - TOMRA's Deep Learning technology and CRAB Traceability Systems.

Looking at the literature collected, most of it has been a massive increase last 3-5 years, and the quantity and interest in every interview show it is a highly relevant topic. The ideas and interest are there, but who is driving? In one way, PPWR sets the playground and rules, but will PRO have no power when it gets implemented, then? Looking at brand owners and retailers, they have a big share of the market, resources and will get the responsibility of reporting the packing grade to NPA and TMR. How will this impact them and the market?

By 2028, the PPWR is expected to adopt its acts for recyclability. Until then, the most effective approach is to proactively enhance DfR practices and strengthen communication across the value chain, ensuring a smoother transition when these regulations come into force in 2030.

4.9 Societal, ecological and ethical considerations

The project likely has a positive impact on society. As mentioned in the business model canvases, the business ideas as well as this thesis project and the broader transition to more recycled material will likely result in certain shifts in society. Jobs will likely be lost in industries such as oil extraction and virgin plastic production but there is no reason that this would not be compensated by an increase in jobs in the part of the value chain related to sorting and recycling. Such transitions do, however, always have a large impact for the people involved and it is not certain that jobs would be created in the same regions as they are lost in. It is therefore important that society takes responsibility in ensuring that it is as smooth as possible.

The increase in data exchange will increase transparency and in turn likely increase trust in the recycling system among consumers as customers today can not trust that the plastic they sort for recycling will be recycled. Producers in the interviews stated that they do not distinguish between their basic and premium brands when it comes to design for recycling, and with PPWR more sustainable packaging will be a "must have" rather than a "nice to have", it is therefore not likely that environmentally better packaging would be a question of demographics which paves the way for a broader impact. With the new PPWR legislation, the product producers are obligated to take responsibility for their packaging that could be considered their ethical responsibility according to a polluter pays principle.

4.10 Limitations and Future research

While these interviews have provided a wide-ranging view of the value chain, there are still areas that require deeper investigation, presenting opportunities for future research.

Firstly, the product producer companies in the interview study have made public commitments to make their packaging recyclable. The results of the interviews can therefore not be used to draw general conclusions about product producers, and results can only represent the current "state-of-the-art" for the industry in Sweden. The EPR schemes and the value chains still look very different across Europe and have different levels of commitment. Further research in other EPR schemes across Europe's countries can give more knowledge to understand the different markets.

Secondly, the interviews did not cover the first step plastic producers or the final step (recyclers) of the value chain, even though including these actors could have provided a more complete understanding. Plastic producers (the companies that sell packaging to product producers) emerged as important to provide material specifications and data to product producers, so interviewing these actors would be a natural next step if further interviews were to be conducted.

The number of actors interviewed in the complementary value chain was also limited, which introduces a risk of bias, as the perspectives of a few individuals may have a disproportionate impact on the results. This approach focused more on the PRO and its immediate upstream and downstream actors, reflecting their financial influence. However, recyclers were not included, partly due to the lack of available actors in Sweden. For instance, Omni Polymers, a recycler and potential interviewee collaborating with TMR, went bankrupt in the summer of 2024. Future studies should consider including these stages to capture a more comprehensive view of the value chain, providing insights into both the origins and end-of-life processes of materials. In particular, understanding the role of recyclers is critical, as they play a key part in closing the loop and determining the quality and possibility of recycled materials.

Thirdly, the literature review was carried out through three searches, but the results were analysed together. The keywords that were used might have been too narrow to cover all the relevant literature, and future research could benefit from more established keywords and a more systematic approach to selecting keywords. Three keywords that could be used are, for example "tracer", "sorting" and "chain of custody".

5 Conclusion

With this project, the aim was to increase circularity of the plastic packaging industry through analysing the current state-of-the-art and data exchange to find gaps in the value chain.

The newly introduced Packaging and Packaging Waste Regulation has already drawn a lot of focus among the product producers in Sweden. Even though many uncertainties still exist, which makes DfR improvements for packaging tricky at the moment, the general attitude towards the regulation and harmonised DfR guidelines is positive. The PPWR has brought the necessary focus to the recyclability of plastic packaging and high-quality recycling.

The current plastic packaging value chain is far from circular, but to increase circularity, a lot more collaboration and integration is needed throughout the industry. Data exchange is one of the corner-stones of a circular economy compared to a linear economy which is why this requires more focus. A conclusion that can be made is that the state-of-the-art companies putting plastic packaging on the market have a focus on DfR, but the main tool for them is DfR guidelines, which only present generalised data. An understanding of how a particular package performs in the sorting and recycling stages would allow for a better understanding of both how to design recyclable packaging and improve sorting facilities. It is therefore important that the industry works together to both collect more data in the end-of-life stages and make the data available to packaging developers efficiently and cost-effectively. When the plastic packaging industry takes these steps towards an increased data focus, it is important to remember to integrate cost incentives, such as the current differentiated packaging fees, as these have a significant impact.

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A Appendix - Interview protocol for semi-structured interviews

Interview Protocol	
Section	**Questions**
Warm-up Question	Q0. What made you participate in the Plastics Initiative 2025?
Plastic packaging and plastic types	Q1. Which plastic packaging materials and polymer types (e.g., PP, PET, HDPE) do you currently use? Q2. What types of barriers and labelling do you use for your packaging?
Your design and packaging development process	Q3. Can you outline the key steps in your packaging development process? Q4. How frequently do you modify or update your packaging designs? Q5. In what way does Design for Recycling (DfR) influence your choice of materials and design strategies in packaging development? Q6. What tools/software do you use during the design phase? Q7. Which of these tools currently consider, or could consider, DfR principles? Q8. Do you design packaging differently for various markets (e.g., different countries or regions)? Q9. What is your view on design guidelines based on regional recycling infrastructure compared to general EU-wide guidelines?
Data exchange, traceability and future packaging	Q10. Where do you get or can get information about the recyclability of your packaging? Q11. What input/data from end-of-life (sorting, recycling) would help you in the design process? Q12. Are you familiar with solutions for traceability such as digital watermarks and digital product passport? What potential and obstacles do you see? Q13. What is your biggest challenge in achieving 100% recyclable plastic packaging for you?
	Q14. Do you have any additional comments or insights you would like to share?

Table 6: Interview Protocol for the semi-structured interviews.

B Appendix - Interview questions for Complementary Value Chain Interviews

The complementary value chain interviews were held in both English and Swedish, and beyond the question, a short introduction about the project was provided. Questions are presented in their original language, and spontaneous follow-up questions are not included in the Appendix. For interviews in Swedish, an English translation is provided.

B.1 Interview with DLF

1. Vad är din roll?
   What is your role?

2. Vad är bakgrunden till plastinitiativet? Vad har skapat intresset för projektet?
   What is the background to the plastics initiative? What created the interest for the project?

3. Har ni någon uppfattning av vilka företag som är med? Vad har fått dem att skriva på?
   What is your perception of which companies have chosen to participate? What have made them sign the initiative?

4. Har ni någon uppfattning av vilka företag som inte valt att vara med?
   What is your perception of which companies have chosen not to participate?

5. Kan ni utveckla var behovet av detta krav kommer ifrån? Är det era medlemsföretag som drivit på för det här?
   Can you elaborate on what the requirement comes from? Is it your member companies that have pushed for this?

6. Kan ni utveckla vad ni menar med spårbarhet i hela värdekedjan? (Nämns på er hemsida)
   Can you elaborate on what you mean with traceability throughout the value chain? (Mentioned on your website)

7. Har du några övriga kommentarer eller tillägg?
   Do you have any other comments or additions?

B.2 Interview with GS1

1. Vi vill gärna ha en introduktion till GS1 och spårbarhet så vi vet att vår egen tolkning är rätt. Vilka alternativ för spårbarhet finns både hos er och i allmänhet?
   We would like an introduction to GS1 and to traceability so that we know that our own understanding is correct. What alterantives for traceability is available from you and in general?

2. Hur ser ni på digitala vattenmärken och digitala produktpass? Är era tjänster att betrakta som digitala produktpass? Tittar ni något på att börja använda digitala vattenmärken?
   What is your opinion on digital watermarks and digital product passports? Is your service offerings to be considered a digital product passport? Are you considering starting to use digital watermarks?

3. Två andra tekniker vi läst om är blockchain och certifications. Vad för potential ser ni i det?
   Two other technologies we have read about is blockchain and certifications. What potential do you see in them?

4. Vad innebär PPWR när det kommer till spårbarhet? Vad ser ni för potential och utmaningar? Hur kan ni hjälpa förpacknings och återvinningsbranschen relaterat till detta?
   What will PPWR mean when it comes to traceability? What potential and challenges do you see with it? How can you help the packaging and recycling industry related to this?

5. I PPWR finns bland annat ett krav om att det ska finnas spårbarhetsmekanism för att avgöra så att förpackningar återvinns i stor skala som europeiska kommissionen ska besluta om senast 2030, har ni några tankar kring hur detta kommer fungera?

In PPWR there are requirements that there should be a chain of custody-mechanism to ensure that packaging is recycled at scale that the European Commission will decide on at the latest 2030, do you have any thoughts about how this would work?

6. Vi har förstått att företag rapporterar in data till er om de är kopplade till era standarder. Vilken data relaterat till förpackning och återvinning handlar det om idag? Hur används denna data?
   We have understood that companies report data to you if they are connected to your standards. Which data related to packaging and recycling is included in that today? How is it used?

7. Tittar ni något på datautbyte på andra hållet dvs från sorterare/återvinnare eller butik tillbaka till producenten?
   Do you look at data exchange in the other direction, namely from sorter/recycler or store back to the producer?

B.3 Interview with NPA

1. Hur ni arbetar med rådgivning till företagen idag (vilken data får dem)?
   How do you work with guidance to businesses today (which data do they get)?

2. Skiljer det sig för företag som är på flera marknader?
   Is there any differences regarding this if companies are active at several markets?

3. Vad är det vanligaste frågorna och funderingarna från företagen?
   What is the most common questions from companies today?

4. Hur ser ert samarbete gällande information ut med SPÅ? Vad får ni från SPÅ?
   How is your collaboration regarding information with SPÅ? What do you get from them?

5. Hur arbetar ni när ni tar fram avgiftsnivåerna för plastförpackningar samt era guidelines?
   How do you work when you develop the the different packaging fees for plastic packaging and your guidelines?

6. Hur ofta gör ni/tänker ni göra uppdateringar i riktlinjerna?
   How often do you/do you plan to make updates to your guidelines?

7. Kontakt/utbyte med Expra? Hur arbetar ni för återvinning i hela EU?
   Contact/exchange with Expra? How do you work for recycling in the rest of Europe?

8. Vad ser ni för potential i digitala verktyg och simuleringar för DfR i framtiden?
   What potential do you see in digital tools and simulations for DfR in the future?

9. Vilken end-of-life data ser ni skulle kunna hjälpa företagen?
   What end-of-life data do you see could help the companies?

10. Vi såg att ni har ett Strategiskt Partnerskap med Bower. Hur ser det partnerskapet ut? Vilken datautbyten finns mellan er?
    We was that you have a strategic partnership with Bower. What does this partnership look like? What data exchange exists between you?

11. Tittar ni något på tekniker som digital watermarks eller digital product passports idag?
    Do you look anything at technologies such as digital watermarks or digital product passports today?

12. Ser ni någon potential i dessa tekniker?
    Do you see any potential in these technologies?

13. Har du några övriga kommentarer eller tillägg?
    Do you have any other comments or additions?

B.4 Interview wth Circular Analytics/Packaging Cockpit

1. What is your background?
2. What is your role today?
3. How good knowledge do you have about the recycling process in Sweden? What are the pros and cons of the way Sweden is doing it?
4. Can you give us an introduction to Packaging Cockpit?
5. How do you know it is recyclable?
6. What data/information is used to determine the technical recyclability?
7. What do you mean by "it can be used across the value chain on the website"?
8. What is the difference between Packaging Cockpit PACO and RecyClass?
9. What are the big "guideline" or "tools" overall in the industry?
10. How will PPWR impact the industry?
11. What is your take on traceability for plastic packaging?

B.5 Interview with PreZero Polymers

1. What is your background and role today?
2. What are the most disruptive factors in the recycling of plastic, specifically focusing on the packaging itself?
3. Does PreZero currently offer PCR polymers that are food-grade? Are there specific plastic types that are easier for food-grade? We have heard that PET and PS are easier.
4. Any idea about how close to RecyClass PPWR guidelines will be?
5. The PPWR will require every company to ensure that their packaging is recyclable at scale. Do you have any ideas about how this can be achieved? Is PreZero looking at this in any way?
6. What do you think about HolyGrail, digital product passports and other traceability solutions?
7. What type of collaboration is there within the Swartz group regarding plastic packaging?
8. What is the future of sorting? Image recognition/AI?

B.6 Interview with SIS (Swedish Institute for Standards

1. Kan du berätta om din roll som projektledare och erfarenhet inom plastförpackningar och återvinning?
   Can you talk about your role as project leader and your experience in plastic packaging and recycling?

2. Vad är SIS roll i att guida plastförpacknings utvecklingen för att göra flödet mer circulärt?
   What is the role of SIS in guiding the plastic packaging devveloper to make the flow more circular?

3. Vilka standarder är på gång gällande design for recycling? Vi har förstått att minst en prEN 18120.
   What standards is comming regarding design for recycling? We have understood that it is at least prEN 18120.

4. Går det att få tillgång till en standard som är Under Approval?
   Is it possible to get access to a standard that is Under Approval?

5. Hur fungerar ett Standardisation Request från EU? Hur implementeras det till PPWR senare och är det stor risk att det blir skillnader?
   How does a Standardisation Request from EU work? How is that implemented in PPWR later and how big is the risk that there are differences?

6. Vad har du för spaningar om framtiden för plastförpackningar?
   What is your ideas about the future for plastic packaging?

7. Har du några övriga kommentarer eller tillägg?
   Do you have any other comments or additions?

B.7 Interview with Swedish Plastics Recycling

1. Var säljer ni era fraktioner? (länder och företag)
   What fractions are you selling? (countries and companies)

2. Skickas allt insamlat plastförpackningsavfall från Sverige hit?
   Is all the collected plastic packaging from Sweden sent to you?

3. Skickas plast också från andra länder till Site Zero (volymer)?
   Is plastic from other countries also sent to Site Zero (volumes)?

4. Har ni databyte och samarbete med liknande anläggningar inom EU?
   Do you have data exchange and collaborations with similar facilities in EU?

5. Vad vet ni om avfallsströmmarna som kommer in till er anläggning?
   What do you know about the waste streams that come in to your facility?

6. DfR nämns flera gånger i er hållbarhetsredovisning och ni skriver att det är en av de två viktigaste parametrarna för återvinningsgraden. Det vore därför intressant att höra er utveckla på ämnet.
   DfR is mentioned several times in your sustainability report and you write that it is one of the two most important parameters for the recycling rate. It would therefore be interesting to hear you elaborate on the subject.

7. Hur mycket påverkar ni hur förpackningen är designad?
   How much are you impacted by the packaging design?

8. Vad är det mest disruptiva faktorn i sorteringsprocessen som påverkar priser och kan åtgärdas genom ändrad design? (kemikalier, färg, plasttyp)?
   What is the most disruptive factor in the sorting process that impact price and can be fixed through changing the packaging design (chemicals, colour, plastic type)?

9. Vilka åtgärder ser ni för detta?
   What measures do you see for this?

10. Er webbplats anger upp till 95 procent av den mottagna plasten kan sorteras ut och återvinnas i nästa steg, och att kapaciteten är 200 000 ton. NPA bilden säger att 77% går till återvinning (high och low quality). Hur mycket av plasten sorteras idag som återvinningsbar? I vilka steg sorteras denna plast ut, och vad gör den icke-återvinningsbar? Föroreningar, tillsatser, plasttyp etc.?
    Your website states that up to 95 percent of the plastic you recieve can be sorted and recycled in the next step, and that the capacity is 200 000 tons per year. A chart from NPA shows that 77% goes to recycling (high and low quality). How much of the plastic today is sorted as recyclable? In what steps is this plastic sorted out and what makes it non-recyclable? Contaminants, additives, plastic type etc?

11. Ser ni energiåtervinning som återvinning, eller inkluderar era siffror enbart materialåtervinning?
    Do you view energy recovery as recycling, or is only material recycling included in your numbers?

12. Många producenter har uttryckt att det är problematiskt och att det är svårt att få tag på återvunnen plast som är livsmedelsgodkänd. Hur ser ni på detta? Funkar någon av era fraktioner idag för detta?
    Many producers have expressed that it is problematic and that it is difficult to obtain recycled plastic that is allowed to be used in food-grade applications. How do you view this? Can any of your fractions be used for food-grade applications today?

13. Vad hade behövts för att göra den återvunna plasten livsmedelsgodkänd?
    What would be necessary to make recycled plastic approved for food-grade applications?

14. För att få förpackningar som kan vara i kontakt med mat – är det genom att tvätta mer eller nya strömmar? Är det för kontaminerat vid insamling? Spårbarhet?
    To get packaging that can be used in contact with food - is the best solution to do more washing of the material or introduce new waste streams? Is it too contaminated at collection? Traceability?

15. Plockprovet (visar bild) är det vad som är tekniskt möjligt eller på faktiskt data på de 12 strömmarna? Hur hade det sett ut?
    The picking test at Site Zero from the NPA packaging manual, does it show what is technically possible or from actual data on the 12 streams? Would there be a difference?

16. På studiebesöket fick vi dessa siffror (visar siffror). Kan ni förklara dem igen?
    At the site visit you showed us these numbers (show the numbers). Can you explain them again?

17. Processkarta möjlig att få för att testbygga i CRAB? Är det okej?
    Process map to build the facility in CRAB? Is that ok?

18. Många vill ju veta exakt vad som händer med deras förpackning efter att den källsorterats. Kan ni utveckla vad som menas (visar paragraf från rapport om datadelning till producenter)?
Many wants to know what happens to their packaging after it is collected. Can you elaborate on what you mean with data sharing with producers?

19. Digital Product Passports, ser ni någon potential i det?
Digital Product Passports, do you see any potential in that?

20. Hur i övrigt ser ni på PPWR och hur det kommer påverka återvinningsbranschen?
What, in general, is your view of PPWR and how will it impact the industry?

B.8 Interview with Stena Recycling

1. Hur mycket av plasten i anläggningen är förpackningsplast? Vilken kapacitet har anläggningen?
How much of the plastic in the facility is packaging plastic? What capacity to you have?

2. SPÅ pratar mycket om återvinningsgraden och att det är en av de stora KPI:erna – vill ni utveckla lite kring återvinningsgraden hos er?
SPÅ talks a lit about recycling rate and that is one main KPI, do you want to elaborate a bit about the recycling rate at your facility?

3. Vilka är huvudstegen i återvinningen, hur ser processen ut?
What är the main steps in the recycling, how does the process look?

4. Hur mycket går till nya plastförpackningar vs lågkvalitativ användning?
How much goes to new plastic packaging vs low-quality recycling?

5. I återvinningsgraden inkluderas både hög- och lågkvalitativ. Dvs även järnvägssleepers?
In the recycling-rate is both high and low quality recycling included. That is, also railway sleepers?

6. Kan ni beskriva de utgående fraktionerna? Finns det kanske något plockprov?
Can you describe the outgoing fractions?, is there any sample test?

7. Jobbar ni med RecyClass eller CEFlEX och harmoniserar detta ihop med TMR?
Do you work with RecyClass or CEFLEX and harmonise these with TMR?

8. Hur mycket kan ni påverka producenter i hur en förpackning ska designas?
How much can you impact the producer in how the packing gets designed?

9. Vad är den mest disruptiva faktorn i sorteringsprocessen som påverkar pris och utfall – t.ex. kemikalier, färg, plasttyp?
What is the most disruptive factor in the sorting process effect price and outcome? For example chemicals, colours or any plastic fractions?

10. Har ni idag några fraktioner som fungerar för livsmedelskontakt idag? Räcker mer tvättning för att kunna godkänna fraktioner?
Do you have fractions that works for food today? Is more washing necessary for getting it approved?

11. Skulle AI kunna hjälpa till att särskilja plast med/utan livsmedelskontakt för att möjliggöra dubbla fraktioner eller på annat sätt stötta branschen?
Could AI help out in sorting plastic with food contact and plastic without food contact to enable double fractions or in anyway supprt the industry?

12. Många producenter vill veta vad som händer med deras förpackning efter källsortering – hur mycket kan ni spåra?
Many producers what to know what is happening with their packaging after it gets collected, how much can you trace it today?

13. Ser ni potential i digitala produktpass (Digital Product Passports) eller digitala vattenmärken (HolyGrail)?
Do you see potential in digital product passport or digital watermarks like Holygrail?

14. Hur ser ni på PPWR:s påverkan på återvinningsbranschen?
How do you see PPWR will impact the recycling industry?

15. Det finns lite/inga offentliga statistikpriser på återvunnen plast – delar ni bilden att listpriser inte alltid speglar verkligheten och är det enda som finns?
There is little/none official statistics on the price of recycled plastic. Do you share that picture that list price do not reflect the reality but is the only existing way of guidance?

16. En möjlighet vi ser är att en AI skulle kunna tränas till att särskilja plast med och utan tidigare livsmedelskontakt. Vad tror du om en AI-kamera för att plocka ut dessa plastförpackningar som är livsmedelsgodkända?
One possiblity we see is that AI can be trained to sort with and without earlier food contact, What do you think about a AI camera to pick out plastic packaging that is food contact approved?

17. Vi är också nyfikna på din syn på PPWR och hur du tror att det kommer påverka återvinningsbranschen framåt. Vad är viktigt att tänka på för att säkerställa att regleringen leder till förbättring – och inte oönskade konsekvenser?
We are curious about your view at PPWR and how you believe it will impact the recycling industry in the future. What is important to consider, especially to secure a regulation that leads to an improvement and no unwanted backlash?

B.9 Interview with SVDH

1. Hur arbetar ni med SPÅ och NPA?
How do you work with SPÅ and NPA?

2. Håller ni i utbildningar eller rådgivning kring DfR för era medlemmar?
Do you have any courses or guidance around DfR for your members?

3. I färdplanen mot fossilfri konkurrenskraft skriver ni att plastförpackningar ska vara återvinningsbara 2025, vill du utveckla kring detta?
In the roadmap to fossil free competitiveness you write that all plastic packaging should be recyclable 2025, can you elaborate on this?

4. Hur ser ni på regionala designriktlinjer baserade på regionens återvinningsinfrastruktur jämfört med generella EU-riktlinjer?
What is your view in regional guidelines based on the regional recycling infrastructure compared to general EU-guidelines?

5. Vi är intresserade av att förstå EMV bättre. Hur är er syn på EMV? Hur tas de varorna fram? Hur påverkar det DfR?
We are interested in understanding EMV (a term for white-label products) better. What is your view on EMV? How are these products developed? How is it impacted by DfR?

6. Vilka standarder finns eller skulle kunna skapas för återvinning?
   What standards exists or could be created for recycling?

7. Hur arbetar era medlemmar med DfR idag?
   How do your members work with DfR today?

8. Var får ni eller kan ni få information om era medlemmars förpackningars återvinningsbarhet?
   Where do you get or where could you get information about your members packaging recyclability?

9. Vilken end-of-life-data (sortering, återvinning) skulle hjälpa er medlemmar i designprocessen?
   What end-of-life data (sorting, recycling) could help your members in the design process?

10. Delägarskapet i GS1 Sweden möjliggör att säkerställa och utveckla effektiva varu- och informationsflöden genom standarder. Vill ni utveckla detta? Vilket informationsflöde finns idag kring återvinning?
    Your co-ownership of GS1 Sweden enables the development of effective product and material flows through standards. Can you elaborate on this? What information flows exits today regarding recycling?

11. Vilken kännedom har ni om spårbarhetslösningar som digitala vattenmärken eller digitala produktpass?
    What knowledge do you have about traceability solutions like digital watermarks and digital product passports?

12. Vad är största utmaningen med att uppnå 100% materialåtervinningsbara förpackningar för era medlemmar?
    What is the biggest challenges to reach 100% recyclability for packaging for your members?

13. Har du några övriga kommentarer eller tillägg?
    Do you have any other comments or additions?

B.10 Interview with TMR

1. Hur hanterar ni era plastförpackningar idag? Vi har förstått att de skickas till Stena Recycling i Lanna.
   How do you handle your plastic packaging today? We have understood that it is sorted by Stena Recycling in Lanna.

2. Arbetet med Stena och Fortum (som de nämnde i förra frågan), vilket datautbyte har ni mellan varandra?
   Regarding Stena and Fortum (that they mentioned in the previous question), what data exchange do you have?

3. Vilken data rapporterar företagen till er?
   What data do the companies report to you?

4. Arbetar ni med rådgivning till företagen idag (vilket datautbyte har ni mellan varandra)?
   Do you work with guidance to companies (what data exchange do you have)?

5. Skiljer det sig för företag som är på flera marknader?
   Is there any difference for companies that act on several different markets?

6. Vad baseras rådgivningen på?
What is this guidance based on?

7. Vad är det vanligaste frågorna och funderingarna från företagen?
What is the most common questions and concerns from companies?

8. Hur arbetar ni när ni tar fram avgiftsnivåerna (A,B,C) för plastförpackningar samt design guidelines?
How do you work to compile the packaging fee levels for plastic packaging, as well as design guidelines?

9. Hur ofta gör ni/tänker ni göra uppdateringar i riktlinjerna?
How often do you do updates to these guidelines?

10. Kontakt/utbyte med Expra? Hur arbetar ni för återvinning i hela EU?
Contact/exchange with Expra? How do you work with recycling in the rest of EU?

11. Vad ser ni för potential i digitala verktyg och simuleringar för DfR i framtiden?
What potential do you see in digital tools and simulations for DfR in the future?

12. Vilken end-of-life data ser ni skulle kunna hjälpa företagen?
What end-of-life data do you see could help companies?

13. Tittar ni något på tekniker som digital watermarks eller digital product passports idag?
Do you look anything at technologies such as digital watermarks or digital product passports today?

14. Ser ni någon potential i dessa tekniker?
Do you see any potential in these technologies today?

15. Har du några övriga kommentarer eller tillägg?
Do you have any other comments or additions?

C Appendix - 2-page summary of master thesis

This summary was send out to all the interview participants at the end of the project to summarise the findings.

Cirkulär Ekonomi: Design för återvinning och datautbyte för plastförpackningar

Oscar Ivarsson, Olliver Persson[1]
Master Thesis Summary, 28 maj 2025
Industrial Ecology, Chalmers University of Technology

Cirkulär ekonomi har blivit ett viktigt koncept till att implementera konkreta lösningar för användningen av begränsade resurser och minska miljöpåverkan. För plastförpackningar finns två stora problem. Dels är insamlingsgraden lägre än för andra förpackningsmaterial, då 54% av plastförpackningarna samlades in för återvinning 2023. Dels så är inte alla de förpackningar som samlas in återvinningsbara. Den nya EU-förordningen Packaging and Packaging Waste Regulation (PPWR) är tänkt att åtgärda detta, skapa gemensamma EU-regler för att minska handelsbarriärer mellan länder och få hela EUs förpackningsanvändning mer cirkulär.

I detta masterarbete har en litteraturstudie och en intervjustudie genomförts med 19 företag som sätter plastförpackningar på den svenska marknaden. Därtill har intervjuer genomförts med ytterligare tio kunniga aktörer från värdekedjan. Sammanställningen nedan visar de viktigaste insikterna från dessa diskussioner.

Rapporten i sin helhet kommer att skickas till intervjudeltagarna men finns också på Chalmers Open Digital Repository från slutet av juni.

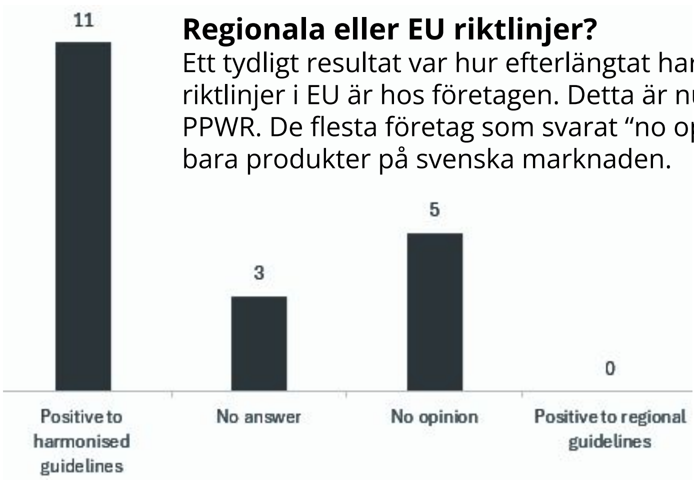
Tre viktiga från PPWR

Design för återvinning (DfR)
Senast 2030 ska alla förpackningar vara återvinningsbara till högkvalitativ plaståvara enligt designriktlinjer som EU publicera 2028 efter att ha beaktat kommande återvinningsstandarder från CEN[2].

Återvunnet material
Alla förpackningar ska innehålla en viss mängd återvunnet material senast 2030, exempelvis är kravet 10% för kontaktkänsliga produkter.

Återvinning i stor skala
EU kommer presentera en "chain of custody"-mechanism som ska användas av producenter för att säkerställa att deras förpackningar återvinns i stor skala.

Urval av intervjusvar



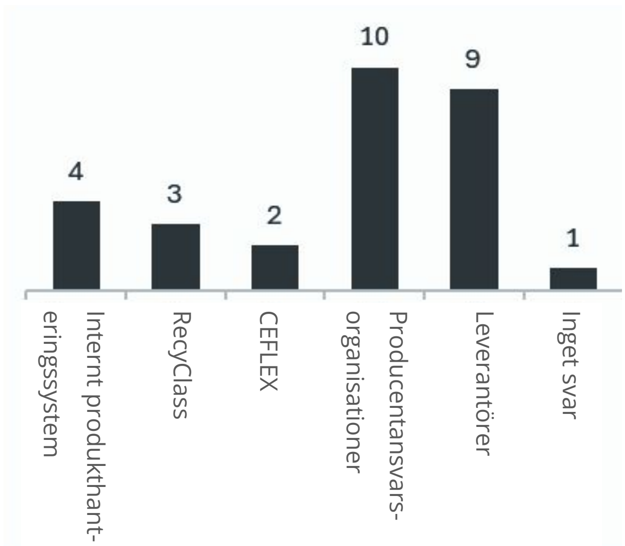
Regionala eller EU riktlinjer?

Ett tydligt resultat var hur efterlängtat harmoniserade riktlinjer i EU är hos företagen. Detta är nu påväg med PPWR. De flesta företag som svarat "no opinion" har bara produkter på svenska marknaden.

Var får företagen information om återvinningsbarhet?

Som svar på denna frågan sa de flesta att de vänder sig till sin producentansvarsorganisation (NPA/TMR) för att få information/hjälp om återvinningsbarhet om deras förpackningar men även europeiska riktlinjer som RecyClass och CEFLEX förekommer, mest hos de företag som finns på flera marknader. Att vända sig till sina leverantörer är också vanligt, främst för information om vad förpackningarna består av.

Företag med egna märkesvaror är idag bara ansvariga för förpackningsavgiften för importerade varor men tar snart över rapporteringsansvaret även för svenska varor. Detta kommer kräva mer datautbyte mellan producent och varumärkesägare.



[1] Kontaktuppgifter författare: Oscar Ivarsson (oscarjohanivarsson@gmail.com), Olliver Persson (olliver.persson@gmail.com)
[2] CEN är en organisation som tar fram EU-standarder.

Två stora utmaningar inom design för återvinning

1. Multilaminat

En tydlig utmaning som lyfts i våra intervjuer är övergången från multilaminat till monomaterial, monolaminat eller andra återvinningsbara alternativ. Multilaminat filmer består av flera plasttyper med olika smältpunkter, vilket underlättar produktionen men försvårar återvinningen. Monolaminat kräver högre precision vilket i sin tur är viktigt att beakta vid investeringar i nya maskinparker.

2. Matsvinn

I flera av intervjuerna nämns det att återvinningsbara förpackningar kan få negativ effekt om det ger mer matsvinn eftersom produkten har större klimatpåverkan än förpackningen. Detta bekräftas i en artikel av Pauer et al.[3] som beräknar att utsläppen från bacon är 54 gånger högre än för baconförpackningen.

	TMR packaging fee criteria	RecyClass	NPA design for recycling guidelines	NPA packaging fee criteria	CEFLEX
1. Cooking oil bottle	Green	C	Red	Green	Not covered
2. Shampoo bottle 1	Yellow	F	Yellow	Yellow	Not covered
3. Shampoo bottle 2	Green	B	Red	Green	Not covered
4. Potato fries (frozen)	Green	B	Yellow	Yellow	Yellow
5. Toothpaste tube	Yellow	C	Red	Red	Red
6. Coffee bag type 1	Red	Not recyclable	Red	Red	Red
7. Coffee bag type 2	Yellow	Not recyclable	Red	Red	Red
8. Sour cream type 1	Green	A	Yellow	Yellow	Not covered
9. Sour cream type 2	Green	B	Yellow	Yellow	Not covered
10. Meat tray type 1	Green	C	Red	Green	Not covered
11. Meat tray type 2	Green	C	Red	Green	Not covered
12. Chocolate	Green	A	Red	Yellow	Yellow
13. Crisps	Yellow	B	Yellow	Green	Yellow
14. Cheese	Red	Not recyclable	Red	Red	Red

Designriktlinjer

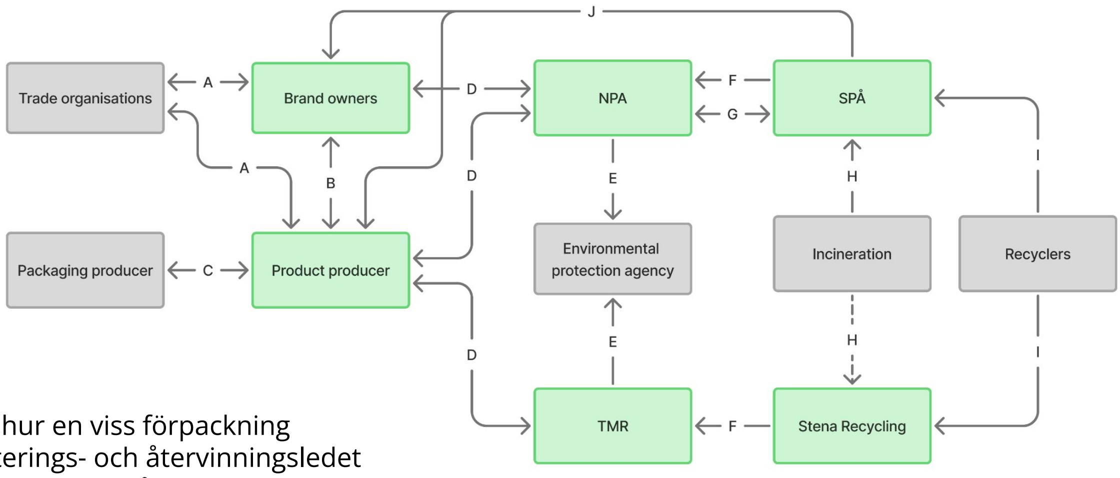
Flera organisationer tillhandahåller designriktlinjer för återvinning. De flesta producenter använder NPAs riktlinjer. Att riktlinjerna är kopplade till förpackningsavgiften är ett viktigt incitament för att fler förpackningar ska bli återvinningsbara.

Studien granskade två europeiska riktlinjer samt NPA och TMR genom att utvärdera 14 artiklar. En slutsats är att det är relativt stora skillnader mellan olika riktlinjer. Tolkningarna är författarnas egna. Faktorer som plasttyp, etikettmaterial och tryck hade stor påverkan.

Informationsflödet i branschen

Informationsflöde

Nedan är en karta över informationsflödet i branschen, varav gröna rutor symboliserar intervjuade aktörer. Flöde A visar det informella utbytet kring design för återvinning som idag är mer allmänbildande än konkret datautbyte mellan aktörer. Flöde G representerar kommunikationen om riktlinjer mellan NPA (Näringslivets Producentansvar) och SPÅ (Svensk Plaståtervinning). TMR är kund till Stena Recycling men samarbetar inte lika nära. Flöde J är de återvinningstester som producenter kan göra hos SPÅ.



Spårbarhet

Förståelse för hur en viss förpackning fungerar i sorterings- och återvinningsledet skulle ge bättre insikter både för att kunna designa mer återvinningsbara förpackningar och för att förbättra sorteringsanläggningarna. Det är därför viktigt att branschen samarbetar kring data från slutfasen av livscykeln och göra denna information tillgänglig för förpackningsutvecklare på ett effektivt och lönsamt sätt. När steget mot ett ökat datafokus sker är det också viktigt att integrera ekonomiska incitament såsom de differentierade förpacknings avgifterna.

[3] Pauer, E., Tacker, M., Gabriel, V., & Krauter, V. (2020). Sustainability of flexible multilayer packaging: Environmental impacts and recyclability of packaging for bacon in block. *Cleaner Environmental Systems*, *1*, 100001.

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