Improving packaging recyclability from a waste treatment perspective

The development of an interactive tool on design for recycling

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attero
energiek met milieu

“If there won’t be collaboration across the chain, circularity will not be reached”

(Expert 5)

Preface

Attero

Attero was pleased to have Margot as intern working on her thesis. Attero finds it very important that plastic packaging designers are better informed on the recyclability of their packaging. We frequently get requests from designers across Europe to visit our sorting and recycling plants to get a better idea of this recyclability. Margot has bridged this knowledge gap by developing a very comprehensive tool that takes designers on a virtual tour through our plants to provide the understanding they need. The fact that KIDV has embraced this tool to include into their e-learning underpins the value of the tool. We want to thank Margot for her good work and being a great and pleasant person to work with.

KIDV

For the past six months, Karen van de Stadt (packaging expert) and Petra Veen (Advisor Education and Research), both working for the Netherlands Institute for Sustainable Packaging (KIDV), have been working closely with Margot. Since the beginning of June, we have been in contact with Margot and have seen how she has gone from question to final design of a tool. She has consulted the KIDV several times in the process. The final tool that Margot has developed is very much in line with the KIDV’s tools and advice form. The Recycle Check Flexible Plastic Packaging was used as a guideline while designing the tool. In addition, the working form, the visual representation of the different process steps, fits very well with the already existing e-learning modules of the KIDV. For these reasons, the KIDV chose to adopt the tool and use it to advise the packaging industry.

Contents

Summary

The growing impacts of climate change are urging us to take action and move towards a more sustainable packaging system. The packaging industry is responsible for 44% of plastic demand globally (Plastics Europe, 2022), and has a large environmental impact. The necessity for plastic packaging and their relatively short life cycle demand fitting implementation of end-of-life strategies, including recycling. The complexity (both to implement and to understand) of a recyclable packaging, which is based on multiple factors, acts as a barrier to sustainability implementation. The packaging and waste industry are the start and end points in a linear waste chain but will become connected in a circular system, which demands more collaboration. Efforts are made to move the processing method of this stream from incineration to recycling, demanding strong collaboration across the chain and specifically between the waste treatment and the packaging industry. This research is executed in collaboration with Attero, a Dutch waste treatment company that sorts and recycles plastic waste. Attero experiences an increasing demand in requests and questions from the packaging industry related to packaging recyclability and is looking for a way to contribute to more recyclable packaging by sharing their knowledge and point of view. This research provides an exploration of the role of the waste treatment industry in improving packaging recyclability.

Part I of this research aimed at understanding the potential of the waste treatment perspective in improving design for recycling implementation. The transition towards a circular economy is necessary to create more sustainable packaging solutions, but this transition is troubled by different perspectives on sustainability and recyclability, which causes confusion as to what is a well-recyclable packaging. A circular economy demands, among others, an effective recycling system, which in its turn, demands alignment between the packaging and waste industry. Recycling goes beyond reprocessing a material into a new application, it includes the collection, sorting, and reprocessing of materials, where the quality of the recycled product directly influences the quality of the recyclate. Analysis of the two industries gave insight into the future of plastic packaging recycling and what role both industries have in realising this. Where the packaging industry must reduce its material use and create well-recyclable packaging, the waste industry must keep improving the recycling technologies. To help align the packaging and waste industry, design guidelines exist. Current guidelines on design for recycling inform the packaging industry about what packaging is recyclable, but these guidelines fall short in explaining why certain packaging is recyclable, creating an information gap. The sorting and recycling processes lay at the root of the guidelines and could help the packaging industry understand the importance of D4R. The hypothesis from the information gap was further confirmed by performing a user study with the intended target group. This confirmed the lack of knowledge on the waste treatment perspective and the potential added benefit of visually educating the packaging industry on the waste treatment processes. The result of the first part was the incentive to develop a tool that educates the packaging industry about the link between the sorting and recycling processes and packaging design.

Where the first part of this research indicated the challenges around design for recycling in the packaging industry and pinpointed an information gap within the current design for recycling methods, the second part proposes a solution for the identified problem by translating the requirements into a tool. An interactive, educational tool was created that visually explains the sorting and recycling processes for plastic packaging and links these to the corresponding design for recycling guidelines. This tool was made with the implementation of the design for recycling guidelines of the KIDV Recycle Checks.

By means of a user test the tool was tested on its educational effect, usability, and applicability, the results showed that the tool satisfied the intended goal and succeeds in educating the user on the waste treatment processes. An improved understanding of the connection between sorting and recycling processes and packaging design was created. Furthermore, the quality of information was approved by experts in the overlapping field of packaging and waste, they indicated that the tool was a novel and useful addition to the field. After comparing the final result to the requirements, the tool was declared feasible and was implanted on the website of Attero. It is recommended that Attero actively uses the tool in their contact with clients. For the KIDV it is recommended to further explore the added value of the visual elements and research how the Recycle Checks could benefit from more visual elements on the sorting and recycling processes.

This research has shown that communicating the waste treatment perspective is an important factor in improving the recyclability of packaging. An absolute answer on what is the most sustainable packaging does not exist but an improved understanding of the underlying reasons for the existing D4R rules can help the packaging industry to navigate their sustainability choices and ultimately increase the implementation of design for recycling methods, bringing us one step closer to a CE.

Glossary

D4R	Design for Recycling
KIDV	Kennis Instituut Duurzaam Verpakken – Netherlands Institute for Sustainable Packaging
AFV	Afvalfonds verpakkingen
NIR	Near-Infrared
GHG	Greenhouse gas
CE	Circular Economy
PMD	Plastic Metal and Drinking cartons. The PMD waste stream is separately collected in most of the provinces of the Netherlands.
EMF	Ellen MacArthur Foundation
LAP	Landelijk Afval Beheerplan, National waste management plan
PSP	Packaging Sorting Plant
PRP	Polymer Recycling Plant
IenW	Ministry of Infrastructure and Water Management Ministerie van Infrastructuur en Waterstaat
SME	Small to Medium sized enterprise

Introduction

The growing impacts of climate change are urging us to take action and move towards a more sustainable system. One framework to do so, that has gained interest along policy makers and industry, is circular economy. Along these industries is the packaging industry, a sector that is responsible for 44% of plastic demand globally (Plastics Europe, 2022). These immense volumes, combined with a generally extremely short life cycle, also makes plastic packaging one of the major components in waste composition. Large efforts are made to move the processing method of this stream from incineration to recycling, demanding strong collaboration across the chain and specifically between the waste treatment and the packaging industry.

This research will explore the role of the waste treatment industry in improving packaging recyclability. Now that the linear economic system is shifting towards a circular economic (CE) system, the relations between stakeholders are also shifting. Where before a product would be made without an end-of-life destination, nowadays more focus is put on the recycling of products and keeping them in the chain. This circular system connects the end and the beginning of the chain, where before, in a linear system these were the stakeholders furthest apart. This connection creates a shared interest in well recyclable products because the material quality of what gets thrown away will largely determine the quality of what comes out as the recycled product.

One industry in which this development is closely monitored is the packaging industry. Because of the large amounts of plastic used in this market and the fast nature of its consumption, improving packaging recyclability can have a great positive impact on our dependency on fossil fuels and our emissions. Although the packaging sector is growing more aware of the importance of sustainability and efforts are being made, there is still a long way to go.

The waste treatment plays a role in this. They hold a valuable position where they can monitor what packaging is or isn't recyclable and how this is related to the packaging characteristics. Taking recyclability into account in the design process of a product is called design for recycling, within packaging design this design mindset has been developing in the past years and design guidelines for packaging recyclability exist. Despite the availability of these guidelines, only 27% of packaging on the Dutch market is well-recyclable, while it was found that 29% of packaging could be made well-recyclable by changing the packaging design (Brouwer et al., 2021). Combining the perspective of the waste treatment with packaging design has potential to improve recyclability. This report aims at researching the contribution that the waste treatment perspective can bring to increase packaging recyclability focussing on design for recycling implementation.

Figure 1: *Research aim*

Attero case study

This research is executed in collaboration with Attero, a Dutch waste treatment company that sorts and recycles plastic waste. Attero experiences an increasing demand in requests and questions from the packaging industry related to packaging recyclability. This not only shows the growing drive for more sustainability, but also the challenges in finding what is most sustainable. Attero realises that a large part of a product's recyclability is determined earlier on in the product's cycle, outside of the influence of the waste treatment, and is therefore happy to see the growing interest of the packaging industry to learn more about the waste treatment. From experience of the guided tours they give in their facilities, they know that seeing what happens in the waste treatment hugely impacts people's perception of waste treatment and influences their design choices. Attero would like to continue spreading their perspective but cannot keep increasing the number of visitors. In order to broaden their reach, they would like to find another way to share their perspective with the packaging industry. With this research it is explored how and in what format Attero can contribute to more recyclable packaging by sharing their knowledge and point of view.

KIDV

During this research a collaboration with the Netherlands Institute for Sustainable Packaging (KIDV) arose. Given the position and activities of KIDV, they advise and inspire companies with practical information to make their packaging more sustainable, their knowledge aligned well with this research. The tool idea became bigger than Attero and gained societal importance, a logical step was to implement it on a national level. The collaboration includes the usage of their Design for Recycling guidelines (the Recycle Checks) in the tool for Attero and the adoption of the tool idea by KIDV. KIDV will develop an e-learning module, based on the Attero tool, that they will use in their training program about sustainable packaging.

Scope

Even though this research takes place in a CE context which encompasses all the stakeholders in the chain, it specifically focusses on the connection between waste treatment and the packaging industry. While the whole waste chain will be investigated to gain sufficient knowledge of the complete system, influences of other stakeholders except the waste treatment and packaging industry will not be taken into account, because the goal is to improve packaging recyclability at the source.

Attero is a waste treatment company that processes waste from multiple material streams, for this thesis the scope was narrowed to packaging waste. Specifically plastic packaging, since this is a large section of the waste composition and because Attero recycles plastic packaging foils in their polymer recycling plant. Packaging waste is found in residual waste, biowaste and PMD waste streams. Because packaging waste in

biowaste is not allowed according to the Dutch government, except the biodegradable plastic bags, it is currently seen as pollution within the stream. (IenW et al., 2020) Besides this, the governmental focus on recycling as the main strategy to circularity and the fact that the biodegradable plastic industry is still in its infancy and therefore lacks stability have led to exclusion of plastics in biowaste from the scope of this research.

Although reaching a circular economy is a goal that goes beyond country borders, this research focusses on the Dutch waste infrastructure only. The Dutch waste system is one of the most advances waste systems (NTCP & HTP, 2022), this combined with strict monitoring of packaging and recycling developments generates valuable data which can be used for this research. Limiting the scope to Dutch packaging waste in residual waste and PMD waste creates a clear framework and ensures the availability of sufficient and up-to-date data given the current focus from the government and research on improving packaging sustainability.

Research questions

The research aim is translated into two research questions:

1. How can the waste treatment perspective contribute to supporting design for recycling implementation in the packaging industry?

2. How can the perspective of the waste chain be translated into a tool for Attero to use to support D4R implementation?

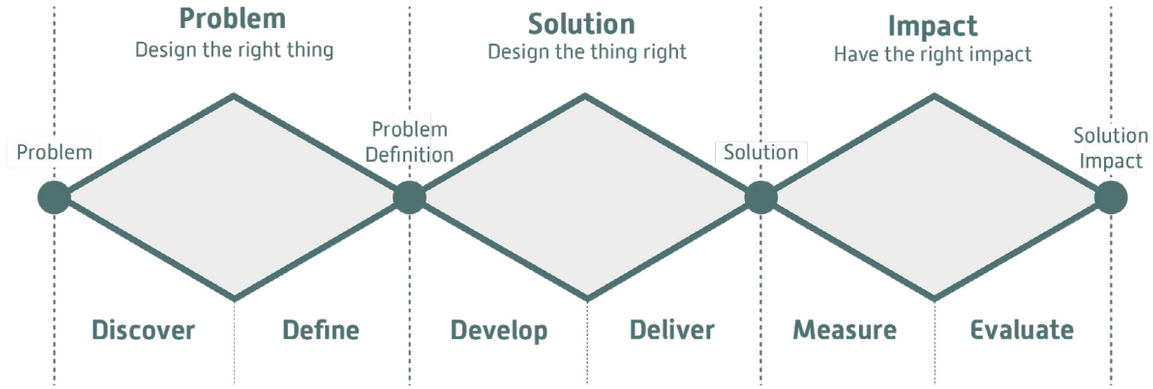


Figure 2: Triple diamond methodology

Methodology

In order to answer the research questions a design methodology was used, specifically an adaptation of the well-known double diamond, which visualizes the diverging and converging aspects of a design process (Kochanowska & Gagliardi, 2022). A third diamond has been added where the proposed solution that results from the second diamond is implemented and where the impact of the solution is measured (Chen, 2020; Lima, 2023). A visualisation based on the methodology of Lima can be seen in Figure 2. The three diamonds each correspond with a part of the report. The report structure is visualised in Figure 3.

First, a broader understanding of the context was needed. This was achieved by collecting qualitative data from literature research, speaking with employees from Attero, attending conferences in the field of packaging, circularity, and plastics, and interviewing relevant experts. All this information is combined in part I of the report and forms the theoretical framework from which the first research question can be answered. The theoretical framework explores the definition of sustainability and CE, followed by the role of plastics packaging and recycling in reaching sustainability. After analysing the separate elements of a circular plastic chain, the complete waste chain and its challenges is described. From here an information gap is formulated which presents the first concept of a tool for packaging design. To further investigate this option, more research was done in the form of 13 semi-structured interviews with the players from the industry (indicated as Companies), which consists of suppliers, buyers, and designers of packaging, but also with players that operate on a more chain wide level (indicated as Experts). Not only did these interviews provide data on the needs of the target group, but they also provided additional insights from an industry perspective that strengthened the theoretical framework. Therefore, the results from the interviews are presented in two ways. Relevant background information was added throughout the theoretical framework, when this is done the corresponding interviewee is referenced, and concrete input on the tool was presented separately in chapter 6. Together, the theoretical framework and the interview results made it possible to answer the first research

Introduction

question and to form a design brief which is taken as a starting point to answer the second research question in Part II.

In Part II of the report the requirements are translated into a tool for packaging design. It builds upon the findings of part I of the report and explores how these can best be implemented into a tool, answering the second research question by doing so. The technical processes of waste treatment and packaging design were translated into an understandable storyline in consultation with Attero and KIDV. This information was then visualised and presented in a clear and interesting way for the user.

Lastly, the tool is validated in Part III of the report, because the tool will become openly available on the website of Attero it was important to validate its contents and added value. Validation was done in two parts, a user test on the functionality, educational effect and applicability of the tool and a test with experts in the overlapping field of waste treatment and packaging. The feedback of the user test was incorporated into the final version of the tool and the results from both tests were used to assess if the tool meets the requirements. Finally, implementation advice is given for both Attero and KIDV.

The report concludes with a discussion and conclusion of the results. Lastly, recommendations for further research are given

The combination of multiple data sources in the methodology not only provided a theoretical base but also an accurate depiction of reality in the industry, together forming a complete understanding of the context. The collection of data from packaging industry players in addition to literature research was found extremely valuable given that the outcome was designed to be implemented in their sector. Since the field of packaging is rapidly changing and working towards a more sustainable

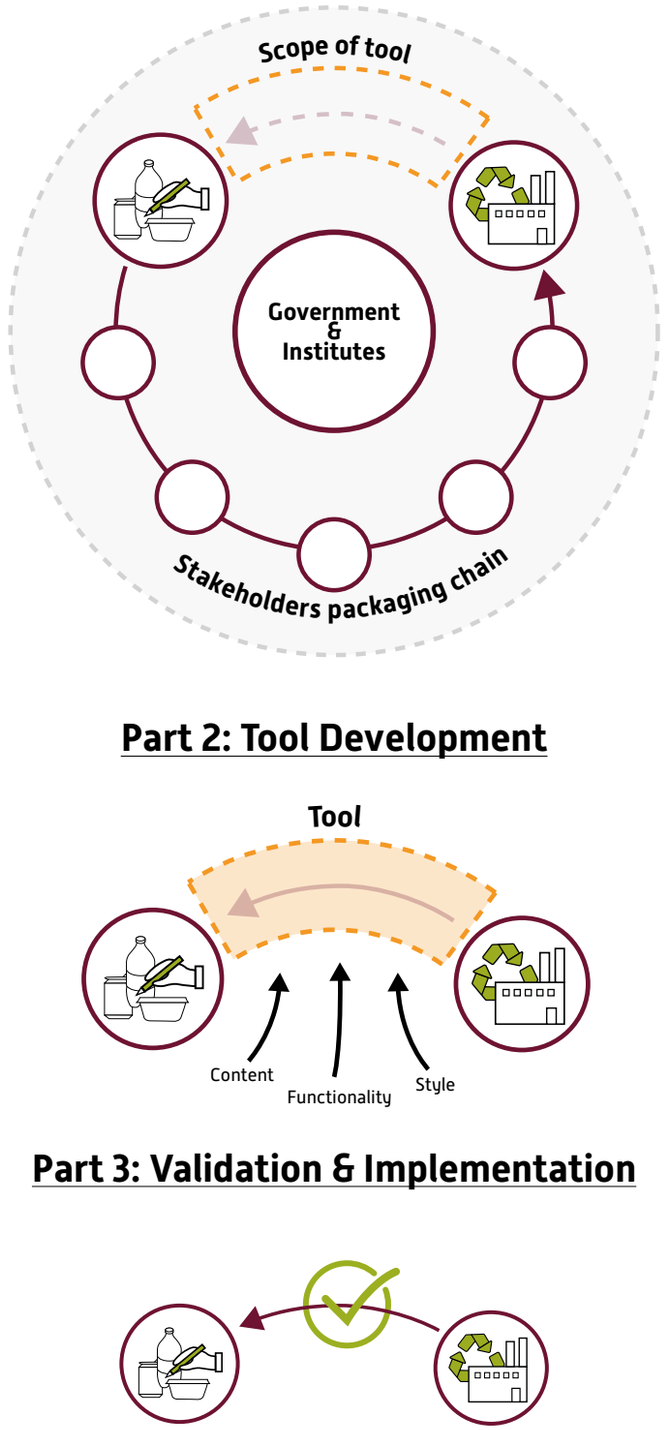
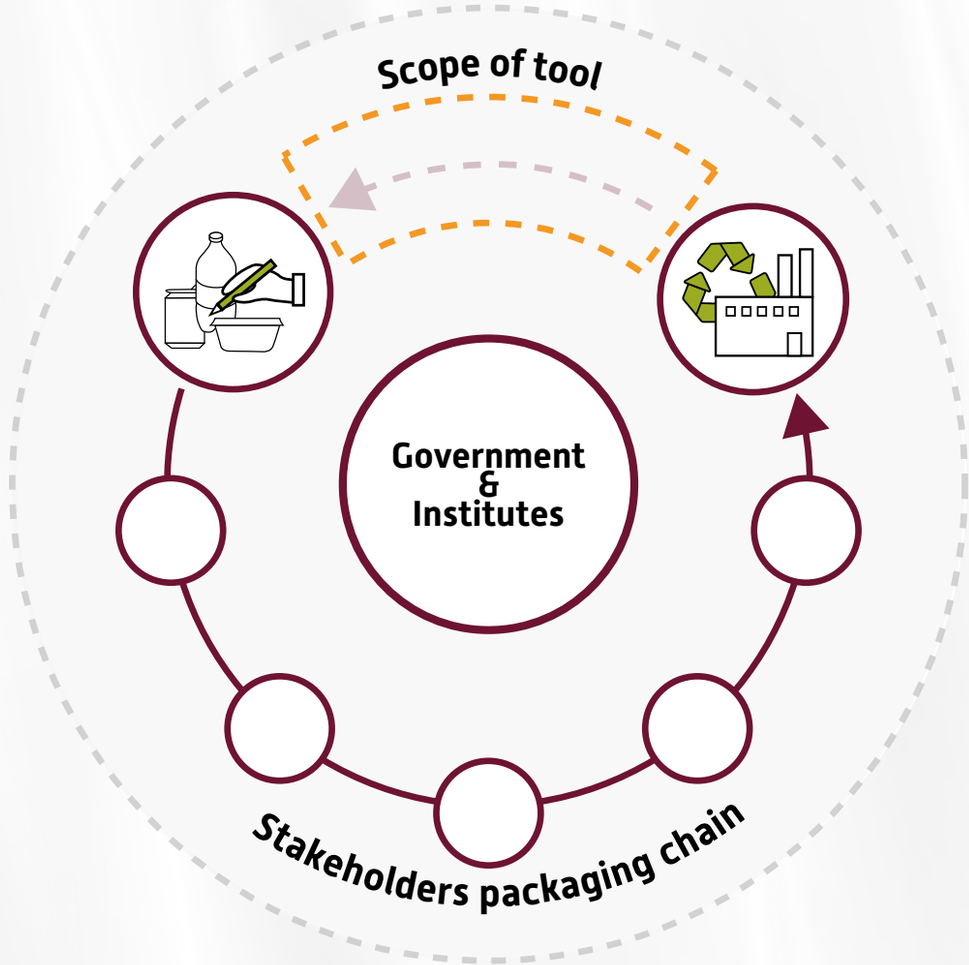


Figure 3: Report structure

Part I

Finding Context

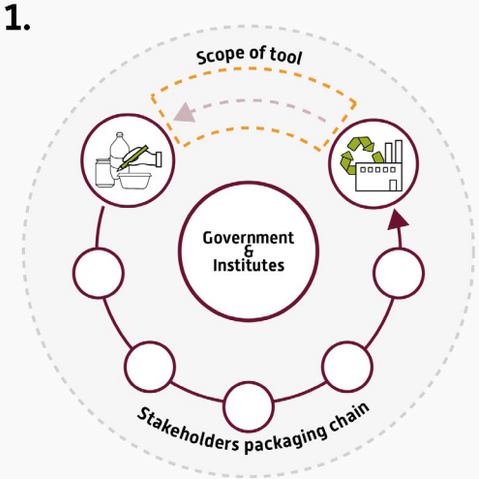
1. Introducing sustainability
2. Plastic packaging
3. Waste treatment and recycling
4. The waste chain
5. Information gap
6. Industry perspective



1 Introducing sustainability

By focussing on improving recyclability in the packaging industry this research is linked to sustainable development. The increasing use of this concept over the past decades and the complex challenges that it is used for have clouded its definition. Before being able to use the concept of sustainability it needs to be defined. This chapter defines the word, introduces the concept within the context of packaging development and waste treatment, and lastly introduces the concept of a Circular Economy.

1.



1.1 The definition of sustainability

Many definitions of sustainability exist, and the meaning of the term has evolved over time (Morelli, 2011). Where it originally encompassed the ability to be maintained in existence without interruption or diminution it has now grown into a synonym for “good” or “green”, anything that is positive. Leading to the corporate use of the term also known as greenwashing. (Engelman, 2013). Especially now, when the effects of the climate crisis are becoming more severe, it is important to use the term sustainability in a correct way, as Ramsey (2015) mentions, “a good definition will allow us to recognize an activity as real or as “faux” sustainability.

A commonly adopted definition in literature can be found in the Brundtland report, where sustainable development is defined as: “Development that meets the needs of current generations without compromising the ability of future generations to meet their own needs” (Bruntland, 1987). Despite its popularity it has also received critique (Károly, 2011), Károly argues that the definition is flawed by not defining the needs of the current generation. Above a certain societal level, needs are influenced by social status. The needs of developed countries differ from those of less developed countries, and in comparison, the needs of the rich are luxuries for the poor. Furthermore, sustainable development has been linked to economic growth, as seen in the triple bottom line construct, where the economy is one of the three pillars of sustainability, next to society and ecology (Elkington & Rowlands, 1999; Ruggerio, 2021). This connection implies that sustainable development needs growth, and thus the needs of future generations will continue to grow. This raises the question whether sustainability can be reached when our needs are ever-growing?

This paper does not propose a new definition for sustainability, but it does encourage the reader to be critical about the terms sustainability and sustainable development. The Brundtland definition is adopted, with the sidenote that one should always define their needs and consider if they are sustaining a need or a luxury.

1.2 Sustainability in context

Despite having defined sustainable development, its meaning tends to vary depending on the context of application. Every context might ask for different needs to be sustained, and once more it is of importance to define these needs (Vos, 2007). Especially when these needs cover multiple perspectives, as with packaging. In this research the sustainability of packaging is evaluated, this evaluation covers two industries that both have a different perspective on packaging, resulting in different needs.

Packaging is a product that fulfils multiple roles, spread out over different stages in its life cycle, with the main goal being to ensure that the packaged product can be used. To reach this goal a packaging should fulfil the following functions (Lutters & ten Klooster, 2008; Ten Klooster, 2002):

- Protect or preserve the packaged product
- Enable distribution of the packaged product
- Inform stakeholders in the entire packaging chain about the packaged product.

These functions do not take sustainability into account. A challenge in defining the needs for sustainable packaging is the fact that its functions change while the packaging is going through the chain (Ten Klooster, 2002). When considering packaging development and waste treatment, a fundamental difference in their perception of sustainable packaging is that the packaging no longer holds a product once it reaches the waste treatment. For the waste treatment the scope of a sustainable packaging has been reduced to the ability of the packaging to be processed into new resources and its environmental impact during this process. For the packaging industry the scope includes both the impact of the packaging itself and the impact of the packaged product. Therefore the environmental impact, and thus the sustainability of a packaging cannot be seen separately from the packaged product (De Koeijer et al., 2017). It is important to be aware of the different measures with which the packaging and waste industry approach sustainability.

1.3 Circular Economy

The current gap between the waste treatment and packaging industry originates from a linear model of consumption, where new materials are extracted for a take-make-dispose system. The limits of this system are becoming more prominent, emphasizing the need for more efficient use of our earth’s resources and energy. The conclusion that the resources of the earth are finite, and that unlimited growth will cause depletion and cause environmental disaster has already been made decades ago by the Club of Rome in their report “The limits to growth” (IPPC et al., 2022; Meadows et al., 1972). Despite this warning, the world population and global economy are growing, fuelled by a growing material supply. Global material extraction has tripled since 1970, and almost doubled since 2000, settling at a 100 billion tonnes presently. The use of virgin materials is not expected to slow down anytime soon, further pushing the limits of our earth (Fraser et al., 2023; Oberle et al., 2019).

In order to fight this rising consumption a new system mindset is needed, Circular Economy (CE). The concept of a circular economy has found its way into national and international policymaking as it is seen as a framework to implement sustainable development (Kirchherr et al., 2017). A circular economy is based on a closed-loop system, where materials stay in

1 Introducing sustainability

the cycle, meaning that an item does not get disposed of but returns. The Ellen MacArthur Foundation (EMF) has a renowned position in striving for a circular economy, their definition of a CE is one of the most used (Geissdoerfer et al., 2017).

"The circular economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design." (MacArthur, 2013)

What makes CE an interesting framework for this research is one of its key aspects; to design out waste. This principle lays the bridge between the packaging industry and the waste treatment. Where the packaging industry has the power to design a product with a circular mindset and where the waste treatment is no longer treating waste, but resources. In a fully circular system waste does not exist, all systems regenerate themselves and material circulates forever, this is depicted in the butterfly diagram of the EMF, Figure 4. This diagram shows how materials cycle through the economic system, both on a biological and a technical level, where the recycling of waste is part of the technological cycle (MacArthur, 2013). The level of circularity of a system is often indicated using R-strategies. Where the first R-strategy contained only Reduce, Reuse, and Recycle, more elaborate versions have been developed (Kirchherr et al., 2017). A literature review showed that a 3R strategy is most common, while 5R dominates literature from a waste management and environmental sector. More elaborate R strategies are from recent years but are growing (Reike et al., 2018). The

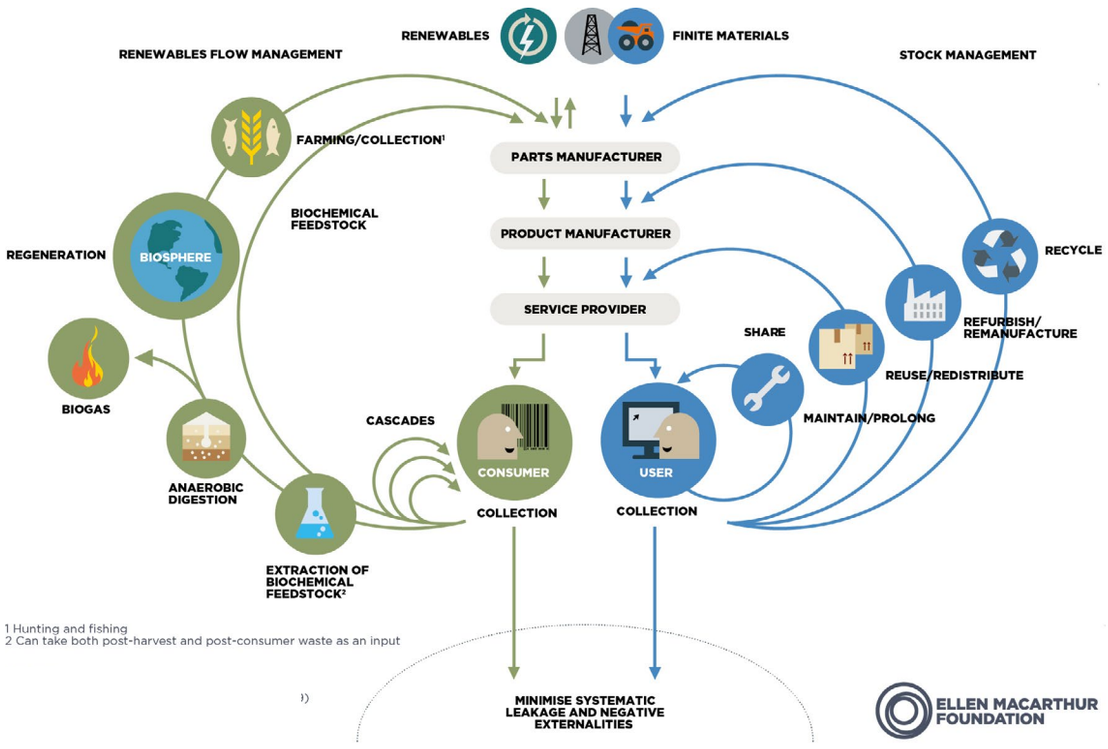


Figure 4: *EMF Butterfly Diagram (Ellen Macarthur Foundation, 2015)*

R-framework of the Netherlands Environmental Assessment Agency consists of 9 R's and can be seen in Figure 5 (PBL et al., 2017).

Within every R-strategy there is a waste hierarchy built in where the shortest R loops are highest in the hierarchy. The circularity of a system is highest when the first R is to be achieved, refuse. One should again define their needs for a certain product and first of all, decide whether it has a reason to exist before thinking about reuse or recycling.

Refuse>Recycle

The waste treatment is located at the bottom of the list, it is important to realise that recycling is part of a circular economy, but only when all the previous R-strategies are not an option anymore. Kirchherr found that definitions of CE that put a strong emphasis on the first R-strategies, refuse, rethink and reduce, were less favourable. Using a subverted definition of CE without waste hierarchies allows businesses to make minimal changes and still claim circularity (Kirchherr et al., 2017). Although recycling is part of the circular economy, it should not be used as a quick and easy solution for more consumption (Koniecka, 2022). The recycling of a product that has no need, is not sustainable.

Sustainability is not easily definable, and its complexity is spread out over multiple industries. Within the packaging industry, sustainable development demands different measures than in the waste industry. In this research, a circular economy framework is used to help transition the linear approach, which lies at the root of these differences, towards a circular system where sustainability is an integrated value and where industries align to preserve our planet for future generations.

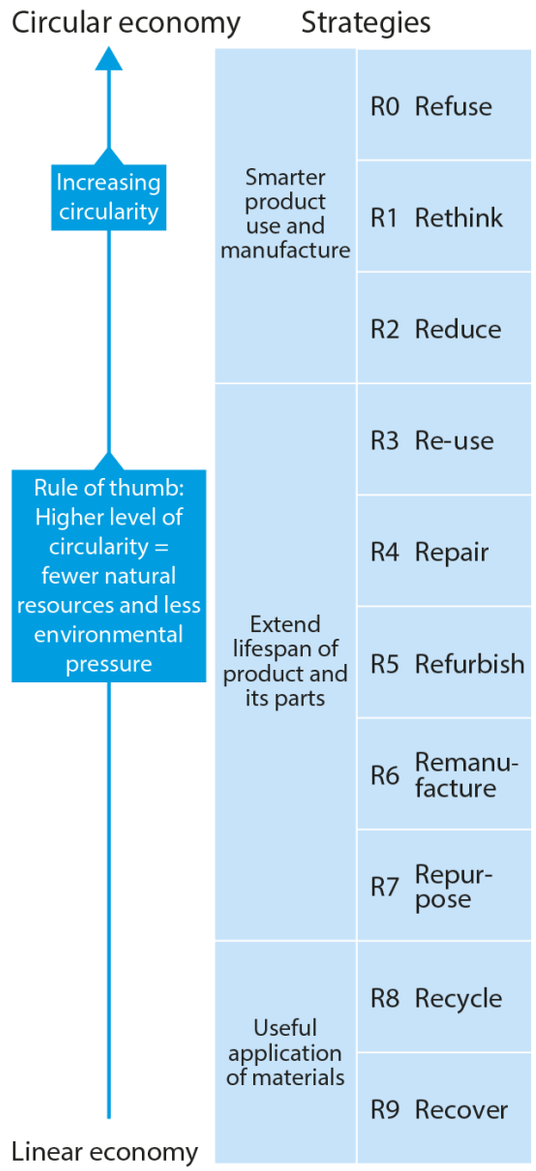
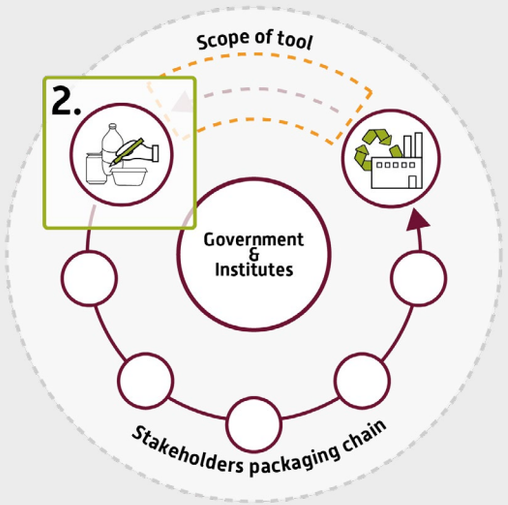


Figure 5: *R-strategy of PBL (PBL et al., 2017)*

2 Plastic Packaging

Plastics have taken over the world and a life without them is unthinkable nowadays, this comes with a price since they have also been polluting the planet. Packaging makes up a major part of plastic production and the impact it has on the environment has not gone unnoticed. This chapter explores the contradictory need for and risks of plastic packaging, focussing on the future of packaging and how this can be made more sustainable by design for recycling.



2.1 The rise of plastics

The global production of plastics has increased from almost 2 million tonnes is 1950 to 381 million tonnes in 2015. (Geyer et al., 2017) This is a growth rate that no other manufactured material has ever reached. Reasons for this growth are the societal benefits of plastics in human health, energy savings, and conservating materials, thanks to their resistance to chemical, biological, and physical degradation, but also their many extraordinary properties (Andrady & Neal, 2009; Halden, 2010). They are, lightweight, durable, flexible, can be moulded into any shape, are easily mass produced and the raw materials are readily available and cheap. Unfortunately, their functionalities and low price points have steered this durable material into single use products, even though plastics take hundreds of years to break down (Geyer et al., 2017). A large part of plastic production can be attributed to packaging applications, which accounted for 44% of global plastic usage in 2021 (Plastics Europe, 2022). More information on what plastics are and an overview of the most used plastics can be seen in Box: 1 and Box: 2.

2.2 The risks of plastic (packaging)

With this immense growth of plastic packaging production and usage, the awareness of the environmental impact and health risks of plastic packaging have also gained increased attention. The risks of plastic packaging cover a broad range of topics. Plastics production was responsible for 4,5% of global GHG emissions in 2015 and took up 22% of European industrial fossil gas consumption in 2020, three times more than gas consumption by the European steel industry (Cabernard et al., 2022; CIEL et al., 2022). The gross amounts of plastic, their widespread applications, and a 'throw away mindset' have led to a world full of plastic waste, especially packaging waste. When plastic packaging ends up as litter in the environment, chemical or physical deterioration results in microplastics that pollute not only oceans, rivers, and soils but also reach human foods and thus human digestive systems and bloodstreams (Kadac-Czapska et al., 2023; Wijngaard et al., 2020). Consumption of microplastics negatively affects digestive, respiratory, and circulatory systems (Jadhav et al., 2021). Research from TNO showed that the packaging industry is one of the main sources of microplastics (Urbanus, 2022). Furthermore, an abundance of plastic waste is exported to developing countries, where unsafe techniques are used to process the plastic waste resulting in health hazards for the environment and the local population. The Netherlands was the largest exporter of plastic waste to developing countries within the EU in 2021 (Plastic Soup Foundation, 2022).

2.3 The future of packaging

Although the downsides and risks of plastic packaging are known, a world without packaging is not possible. Plastics have taken over a crucial role in the food industry, preventing food waste by keeping the produce fresh (Kakadellis et al., 2021). Now that more people are living in cities worldwide, the supply chains are becoming more intricate, and rely more on packaged products (Kakadellis & Harris, 2020). Because of this essential role of plastics in modern society, it is all the more important to create a circular plastic economy.

Multiple alternatives for plastic packaging are in development, ranging from packaging free grocery stores, reusable containers, bulk delivery services, and alternative packaging materials (Asgher et al., 2020; Beitzen-Heineke et al., 2017; Coelho et al., 2020). These alternatives might all find a place in the system and will contribute to some extent to the plastic problem, but they will not eliminate plastic packaging completely and it is not given that they will result in a lower environmental impact (Evans et al., 2020). To minimize the environmental impact of the plastic packaging that will remain necessary, packaging should be made circular by integrating end-of-life thinking along the whole chain. Plastics must be made to be reused, repaired, and eventually recycled to close the loop. Focussing on recycled plastic will not only keep the material in the loop but also lower the dependency on fossil fuels since the recycled plastics can be used again. In 2030, a mandatory percentage of recycled content has to be used in packaging, this will push the packaging industry to make recyclable packaging (European Union, 2022; Thoden van Velzen et al., 2023).

2.4 Design for Recycling

One approach to reach an efficient recycling system is Design for Recycling (D4R), a product development strategy that includes recycling as the end-of-life during the design process. When designing a product, not only its functionalities

What are plastics?

Plastic is a term used to both indicate a material group and to describe the physical properties and behaviour of a material. The name plastic is derived from the Greek plastikos, meaning "capable of being shaped or molded'. Plastics are a sub-category of a larger class of materials named polymers (Kershaw, 2015). Polymers are long repeating chains of molecule groups, which can be abundantly found in nature, for example in DNA, hair, and cell walls. However, they can also be created out of crude oil, by rearranging crude oil components into synthetic polymers. By finetuning the molecular chains the structural and functional properties of the polymer can be influenced and the use of additives can improve the stability of the polymer or give them additional properties like flame retardants (Wijngaard et al., 2020).

Box: 1: *What are plastics*

2 Plastic Packaging

Types of plastic (Plastics Europe, 2022)

PE – polyethylene
PE is the most used plastic in the world (both LDPE and HDPE) as it accounted for more than 1/3 of the plastic production in Europe, the US, China, and India in the period between 2002 and 2014. (Geyer et al., 2017) Polyethylene can either be low-density (LDPE) or high-density (HDPE). Normally PE is thermoplastic, however it can become thermosetting in cross-linked polyethylene. It has a low melting point compared to other thermoplastics.
PE has many different uses but is mostly used for packaging. For example, in milk-jugs, butter cups, containers, agricultural films, bubble wrap, saran wrap, plastic bags, etc.

PP – polypropylene
PP is a thermoplastic polymer, similar to PE but slightly harder and more heat resistant. PP is the second most popular plastic, after PE. (Geyer et al., 2017) PP has a low density and is commonly used in engineering plastics because of its tough but flexible properties, it has good fatigue resistance. Therefore it is used for more rigid applications like plates, cups and cutlery, but also bottles, and pots. It can also be used for film, PP film is very strong and resistant against tears. Furthermore, PP is commonly used in furniture and consumer products.

PVC – polyvinyl chloride
PVC is the 3rd most produced plastic in the world, after PE and PP. Rigid PVC is a thermoplastic polymer. It is a hard material with good mechanical properties, therefore it is mostly used in the construction industry as window frames, floors, cables, pipes, etc. PVC is also used as a packaging material, with its main application in rigid films, and flexible films.

PET – polyethylene terephthalate
PET is the 4th most common polymer and is known for its use in textile fibres (polyester) and bottles. PET is a thermoplastic polymer that is very fit for recycling, mainly because of the almost exclusive use of PET in beverage bottles which creates a relatively pure material stream.

PS – polystyrene
PS is a thermoplastic polymer that can either be solid or foamed. PS has a poor barrier to oxygen and water vapour which makes it unfit for food packaging, however it is used for protective packaging. Furthermore, it is used for CDs and DVD cases, containers, lids, bottles, and more.

PUR – polyurethane
PU or PUR is a thermosetting polymer, although it can also be made as a thermoplastic polymer. It can be made from a wide range of starting materials and thus also has many different physical properties and applications. The most common application is foams, used for cleaning, cushioning, insulation, and more.

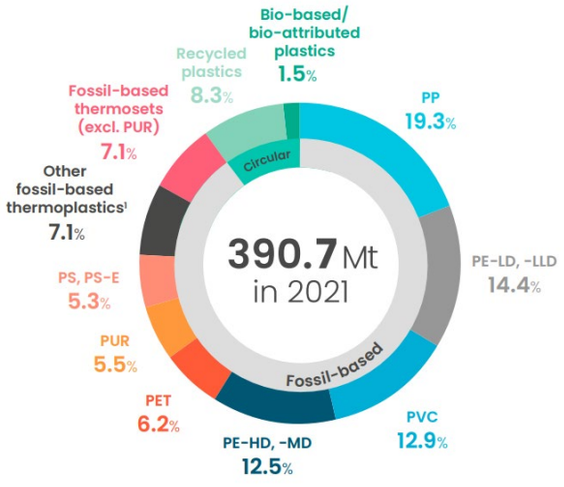


Figure 6: Global plastic production 2021 (Plastics Europe, 2022)

Box: 2: Types of plastic

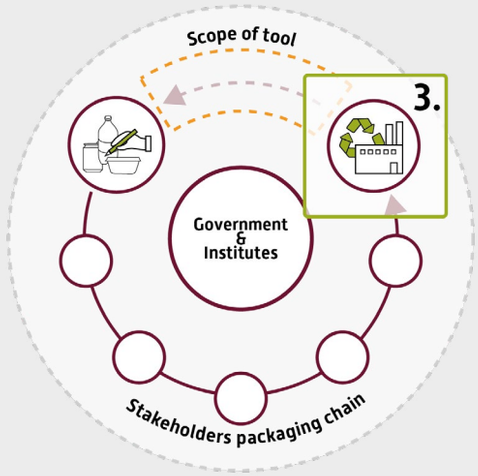
during use are considered but also the recovery of its resources is taken into account for when the product reaches its end-of-life. This includes thinking about material choices, use of inks and colourants, disassembly techniques, collection methods, and more. Correct usage of D4R guidelines will ensure compatibility with the waste management system (Löw et al., 2021). D4R is also promoted in the Ecodesign Directive of the European Union to implement more sustainable design methods (European Union, 2009; Ragaert et al., 2017).

The goal of Design for Recycling is to create a product that is fit for recycling. Guidelines exist that inform designers about for example, material choices, visual design choices, and dimensions that affect the recyclability of a packaging (Ceflex, 2023; KIDV, 2023; RecyClass, 2023). Even though there is already much information available about the practical aspects of Design for Recycling, there is still a lot of room for improvement when we look at the implementation of Design for Recycling methods. According to Brouwer et al., 29% of the potential for improvement in packaging recyclability can be assigned to adjustments in packaging design (Brouwer et al., 2021). Improving the use of Design for Recycling guidelines can greatly improve the recycling rates in the Netherlands.

Plastics play an essential role in modern society and although they are extremely polluting, we cannot live without them. Their immense quantities demand fitting end-of-life treatment to lower their impact on the environment. Design for Recycling is a necessary tool to close the plastic packaging loop.

3 The Waste Treatment and Recycling

The necessity of recycling plastic has become clear in the previous chapter, this chapter further elaborates on what recycling is and how this works within the Dutch waste system. At first sight recycling is a clear concept, making sure a product or material re-enters a new cycle of usage, but when applying recycling on a large and complex scale it can be interpreted in multiple ways. The recyclability of packaging is defined in more detail, the current state of plastic recycling is explored and the challenges of the waste treatment in reaching a fully recyclable system are described.



Note: from this chapter onwards interview results from the user study are included in the text which represent the industry perspective and strenghten the theoretical backround. More information on the interview procedure and the interviewees (companies and experts) can be found in chapter six.

3.1 Defining recycling

Recycling, just like sustainability, has multiple definitions. The definition from the European waste directive defines recycling as (European Union, 2008):

"Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations"

In short: the material of the original product is re-used for new applications, where the new application is not specified. Brouwer et al. argue that this definition is dependent on the goal and means. These goals and means will vary between countries and change over time and thus affect the demands of recyclable packaging, creating confusion for the packaging industry (Brouwer et al., 2021). To provide more structure for the packaging industry a global definition of recyclable packaging was developed by the European and American plastic recyclers (Groh, 2018). This definition has also been adopted by the Ellen MacArthur foundation and the Netherlands Institute for Sustainable Packaging (KIDV, 2021).

For this report the definition of the KIDV is adopted, according to their definition a packaging must meet four conditions to have good recyclability:

1. Packaging must be made of materials that can be collected or picked up by approved waste collectors.
2. Packaging must be sorted and/or bundled into pre-defined streams for recycling processes.
3. During the recycling process, the material is processed on an industrial scale and is reclaimed into a raw material.
4. The reclaimed raw material has a clear composition and can be used to produce new packaging or products.

Because this definition contains four subpoints there will be different levels of how recyclable a packaging can be. If for example a packaging is made from an appropriate material, which is correctly collected and sorted, but the barrier-layers of the material, which are needed to preserve the contained product, negatively affect the final recyclate, is this packaging recyclable or not? To cater for this range, multiple categories for recyclability exist (Brouwer et al., 2021):

- Well-recyclable
- Reasonable recyclable
- Limited recyclable
- Not recyclable

Multiple types of recycling exist, the different types are described in Box: 3. In this research the focus lies on mechanical recycling since this is currently the most used method and because

Different types of recycling

Within a circular economy, the goal is to keep materials in the cycle, preferably at their highest value possible. Similar as with the waste hierarchy this creates a recycling hierarchy (Ellen MacArthur foundation et al., 2016; Hopewell et al., 2009). Three types of recycling are explained.

Closed-loop mechanical recycling (Primary)
Closed-loop recycling ensures that the recycled material can be reused for the same application, maintaining the original value of the polymer. Closed-loop recycling keeps materials on the same level and therefore also allows materials to cycle multiple times in the same loop without significant material losses. For example, PET beverage bottles.

Open-loop mechanical recycling (Secondary)
With open-loop recycling the polymers are also kept intact, but material losses prevent the application of the recycled materials in the original application. This is called a cascade, when a material keeps cascading, at some point the quality is too low to be used for another application and the material leaves the cycle.

Chemical recycling (Tertiary)
Chemical recycling breaks down the polymers into monomers and by doing so returns them to the building blocks of new polymers. This does not preserve the value of a material, and when the building blocks will be used to form new materials, this will require energy. Chemical recycling is not yet widespread, but it does offer possibilities in the system of recycling.

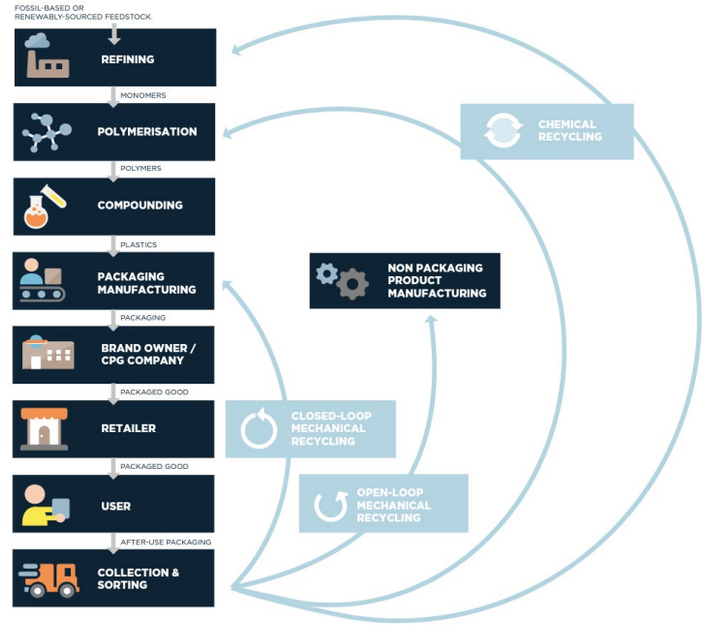


Figure 7: Types of recycling, (Ellen MacArthur foundation et al., 2016)

Box: 3: Types of recycling

3 The Waste Treatment and Recycling

Attero mechanically recycles its flexible plastics (Ragaert et al., 2017).

3.2 The Dutch waste system

The complete recycling process exists of three steps, collection, sorting, and recycling, Figure 8.

Collection

Collection of waste in the Netherlands is the responsibility of municipalities, as described in the national waste management plan (LAP 3) (Ministry of Infrastructure and Water Management, 2021). This includes the obligatory separate collection of residual waste, biowaste, paper and board, glass, and packaging metals and drinking cartons (PMD). The municipalities are free to decide how to collect this waste, leading to a fragmented system. One of the variations in waste collection is the difference between source separation and post-separation of the PMD waste. With source separation the PMD waste is collected separately from the residual waste, this should provide cleaner plastic waste. With post-separation no separate selection of PMD is done and these materials are disposed of in the residual waste, the plastics, metals, and drinking cartons are sorted out of the residual waste at the waste treatment (Thoden van Velzen et al., 2021).

Sorting

After collection the waste reaches the waste treatment and is sorted into the different valuable mono material streams. At Attero the plastic waste is sorted in the Packaging Sorting Plant (PSP), here 80.000 tonnes of source-separated PMD waste is sorted every year. With a series of sorting techniques, the waste is divided into valuable mono-streams, that can then be transported to their recyclers.

Before sorting the plastic waste by type, other materials have to be sorted out. Both to create a plastic stream that is as clean as possible by removing organic residue and to recover any other valuable materials like metals, drinking cartons, and aluminium. The remaining plastic packaging is sorted on material type with NIR technology. This optical sorting technology uses infrared rays to scan the material spectrum of each packaging item. In the end, six plastic streams are created, rigid PP, rigid, PET bottles, PET trays, flexible plastics (PE and PP), and mixed plastics, see Figure 9. These are then baled and transported to recycling facilities. To sort out a specific material it should be economically feasible, only significantly large and valuable streams are sorted out. Less common plastics, like biodegradable plastics, are currently not sorted out because they do not make up a large enough part of the waste.

Recycling

Recycling systems may differ for different types of plastics and between plastic recyclers. In this report the Polymer Recycling Plant (PRP) of Attero is taken as an example, here 25.000 tonnes of post-consumer plastic film are recycled every year. In general, the recycling process consists of grinding, washing, and compounding the plastics. More modern recycling plants contain extensive washing steps to remove any contaminants, labels, and adhesives. In all cases a coldwash is used, and in some cases a hotwash is used, which is more effective in removing persistent labels and adhesives. With the increasing demand for high-quality recyclate, it is expected that more recyclers are going to add the hotwash (NTCP & HTP, 2022). After washing, density separation techniques are used to remove unwanted multi-materials or labels. Once the plastic flakes are cleaned, they are dried and extruded into new plastic granulates.

A schematic overview of the sorting and recycling processes of Attero is depicted in Figure 9. Although the processes of Attero have been the source for this research, in general sorting and recycling facilities in the Netherlands are very similar. All waste treaters make use of the same techniques, any differences between them will be the brands and settings of the machines or the order in which the machines are set (NTCP & HTP, 2022).

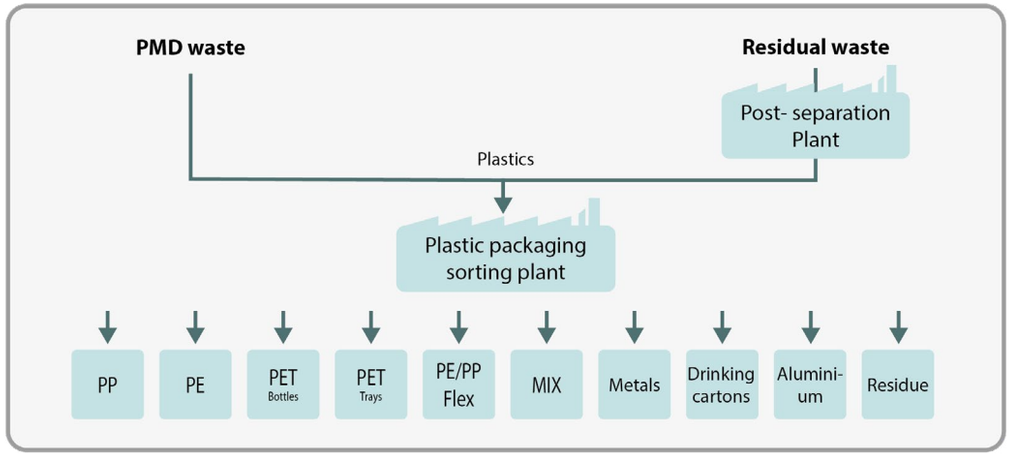


Figure 8: Dutch waste system

3.3 Current state of plastic packaging recycling

Plastic packaging is omnipresent in waste, it makes up 7,9% of residual waste and 61% of weight in PMD waste (Leenaars & Boer, 2017; Rijkswaterstaat, 2021). A Dutch citizen throws away 170kg of packaging waste each year, of which roughly 34kg is plastic packaging waste (eurostat, 2022). Of this packaging waste 49% is recycled, according to the Dutch Afvalfonds Verpakkingen (AFV), who is responsible for realising the national recycling targets (Afvalfonds Verpakkingen, 2021b). The Netherlands is one of the frontrunners in recycling with a percentage of 55% of plastic waste sent to recycling, compared to a European percentage of 35% (Plastics Europe, 2022).

Although this percentage has reached the intended goal of 40% recycling in 2021 (Afvalfonds Verpakkingen, 2021b), there is still a need for improvement to reach future recycling goals. In total 27% of the plastic packaging in the Netherlands is well-recyclable. Only 1% of packaging is not recyclable, other groups are either bad-recyclable or are not being sorted out for recycling, because there is no recycling infrastructure. More than a quarter of packaging, 29% can be made well-recyclable by adjusting the design, design for recycling is therefore seen as a powerful tool to reach packaging recyclability (Brouwer & van Velzen, 2017; Brouwer et al., 2021).

It should be noted that although there are plenty of percentages on recycling rates, there is no true number for the amount of recycled packaging (NTCP & HTP, 2022). There exists a data gap because of the different measures that are used in determining recycling rates. Differences exist in monitoring the recycling of plastics vs. plastic packaging, or the recycling of packaging from household waste only or also from industrial waste (NTCP & HTP, 2022) The scope and methods for acquired data are not always clearly mentioned, which makes it impossible to correctly compare the data. Furthermore, not all data gets shared. Interview

3 The Waste Treatment and Recycling

participant Expert 3 confirmed this problem. More information on the interview procedure and participants can be found in chapter six.

"There is a data problem, there is little data available for each step in the chain. We don't know how much packaging per type is on the market, we don't have numbers, little gets shared. We know very little." (Expert 3)

3.4 Being recyclable vs. being recycled

For optimum recycling rates packaging items and sorting and recycling processes should be fully aligned. This demands innovation from both the packaging industry and the waste industry. The need for more recyclable products is being felt and packaging companies are reacting to that. More and more companies are taking sustainability into account and focus on creating recyclable packaging, good examples are the packaging goals and commitments of supermarkets Albert Heijn and LIDL (AH, 2021; LIDL, 2023). However, not all packaging that is labelled recyclable is actually recycled. Because the definition of recyclable packaging contains multiple aspects, this causes confusion in claiming recyclability.

"Recyclable is a relative definition, so there are many differences between countries, regions, and companies." (Expert 1)

A lack of knowledge on what is recyclable is problematic in the packaging industry. A packaging can be made of recyclable material, but the use of disruptive adhesives can cause problems in the recycling process and prevent this recyclable material from actually being recycled. The line between being recyclable and being recycled is vague, communicating the experiences of the waste treatment could help with solving this. The knowledge level of the packaging industry on the waste treatment could be better. From the interviews, it came forward that most packaging/sustainability experts have a decent knowledge of the waste treatment, but that this knowledge does not spread across organisations. Educating the packaging industry about what happens in the waste industry will enhance the understanding of what being recyclable means. Interviewees that have visited a waste treatment facility found this very insightful.

"In general, the knowledge level is low, even I (recycling manager) still experience eyeopeners even though it is my daily task to understand the chain." (Company 2)

"It is complicated, every packaging has its benefits and downsides, does the optimal packaging even exist?" (Company 5)

Obviously, creating a closed recycling loop will demand efforts from both the packaging and waste industry. Without effective sorting and recycling systems, well-designed recyclable packaging still will not be recycled. From this chapter it became clear that the Netherlands has one of the more modern, effective, and elaborate recycling systems, which creates a large potential for D4R to make a difference.

Concluding, the recycling process is a complex process with many steps. Effective recycling needs a system of collection, sorting and recycling that is aligned with packaging design. With a definition that is interpreted differently across borders and organisations the term recyclable becomes fluid, which causes confusion amongst the packaging industry. Amongst this chaos, the Netherlands does have one of the more developed recycling systems in Europe, which creates the potential for improving recyclability through packaging design.

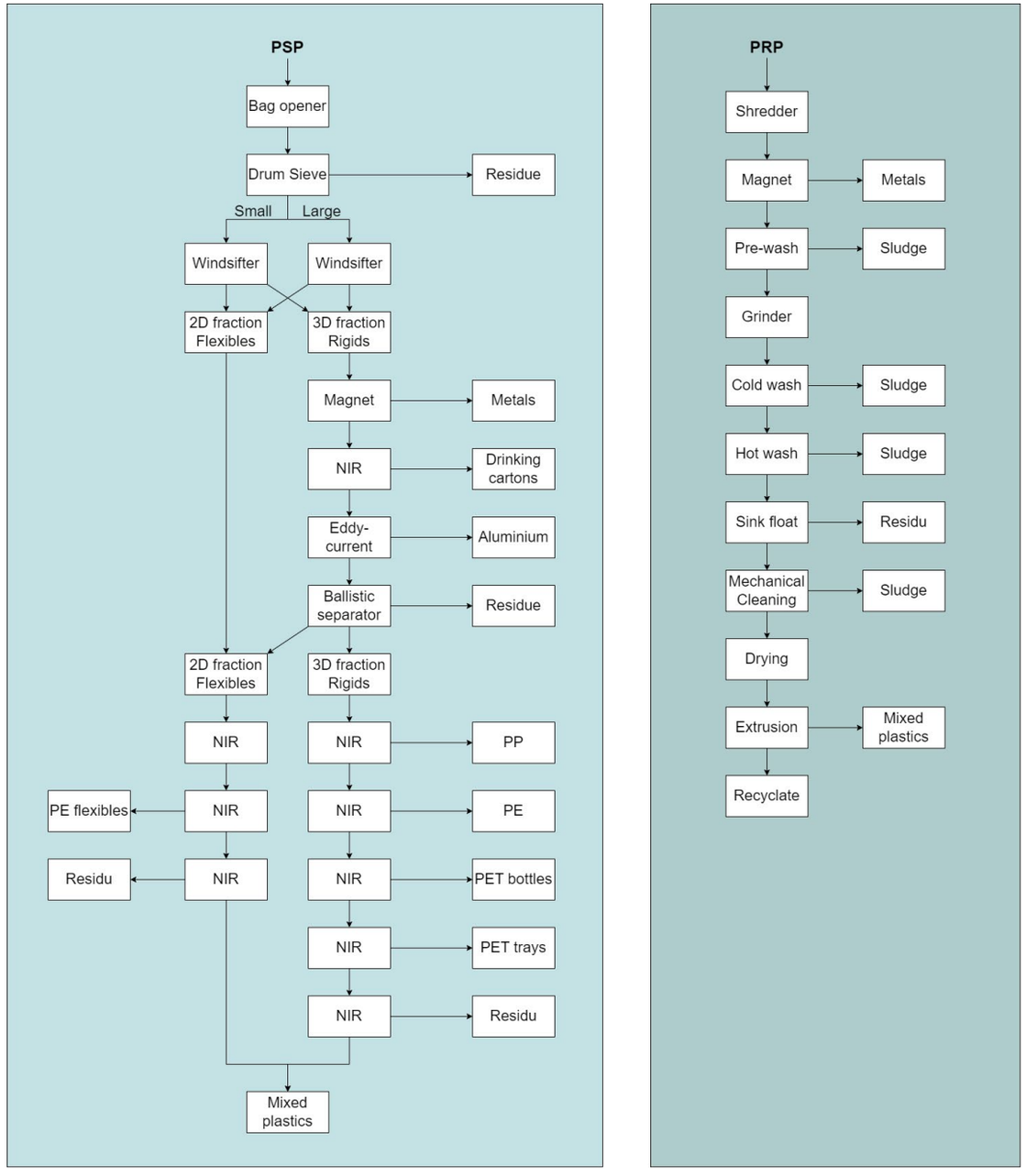
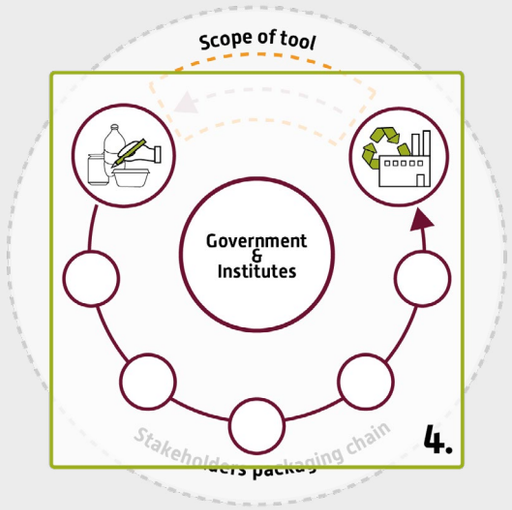


Figure 9: Sorting and recycling processes of Attero

4 The Waste Chain

Concluding from the previous chapters, reaching a circular plastics economy demands efforts and innovations from both the packaging and the waste sector. It has been addressed that both industries act in different contexts, with different needs for sustainability. In a circular economy, one should think in systems and reach outside their own box, focussing on their role as a link in the chain. In this chapter the waste chain and the interplay of actors are described. The importance of policy in facilitating and guiding a transition to a CE becomes clear and the existing policy instruments are analysed.



4.1 The waste chain and its stakeholders

Figure 10 shows the waste chain and its stakeholders. The purple cycle shows the stages of the life cycle of a packaging. Two types of stakeholders are identified, direct stakeholders, and indirect stakeholders. Direct stakeholders are the executive stakeholders, these stakeholders are located in the grey boxes and are responsible for one or more of the steps within the waste chain. Indirect stakeholders are not executing a step in the waste chain, but they do influence the infrastructure within the waste chain, they are located inside the green circle. Understanding the different stakeholders, their relation to each other, and their interests is essential to understand the challenges of reaching a CE and the role of the waste treatment herein. In this section, the relevant stakeholders, except the waste treatment, are introduced and their connection to and challenges in creating sustainable packaging are described using input from the interviews.

Suppliers
Suppliers provide the resources, either virgin or recycled, the available resources will subsequently influence the designers in their material choices. Suppliers therefore play an important role in the transition towards more sustainable packaging.

The designers
Designers make the decisions on the packaging characteristics, where functionality, costs, and quality often go before sustainability considerations.

"Functionality comes first of course; we want to put a high-quality product on the shelves. Next to that, new materials or ideas should fit into the existing production lines, it should be compatible." (Company 2)

When designers are willing to incorporate sustainability in the design, they often clash with the strong voice of marketing within companies. It sometimes prevents the sustainability teams from implementing more sustainable design choices, which they are willing to make despite higher costs or changes in brand image (De Koeijer et al., 2017).

"We are willing to remove a pretty shiny layer in order to make something recyclable." (Company 3)

"Even though it all is more expensive, this is a necessity." (Company 8)

Although convincing marketing and sales departments on sustainable design choices has proven to be difficult, a change in mindset is being felt and marketing is becoming more knowledgeable recently. Interviewee 8 explicitly mentioned that it is possible to convince marketing to choose more sustainable packaging options as long as they get informed on the topic and get engaged in the discussions.

The retailer
Retailers will eventually sell the packaging to the consumer, for packaging the retailers are predominantly supermarkets. The influence of supermarkets on what type of packaging enters the supermarkets is substantial, giving them a certain degree of power. Packaging is produced by thousands of companies, but most food packaging is sold in a few large retail organisations. Their demands on packaging characteristics influence all packaging designers.

"It all goes through only five retailers, so if they don't allow it anymore, there's nothing you can do about it." (Expert 1)

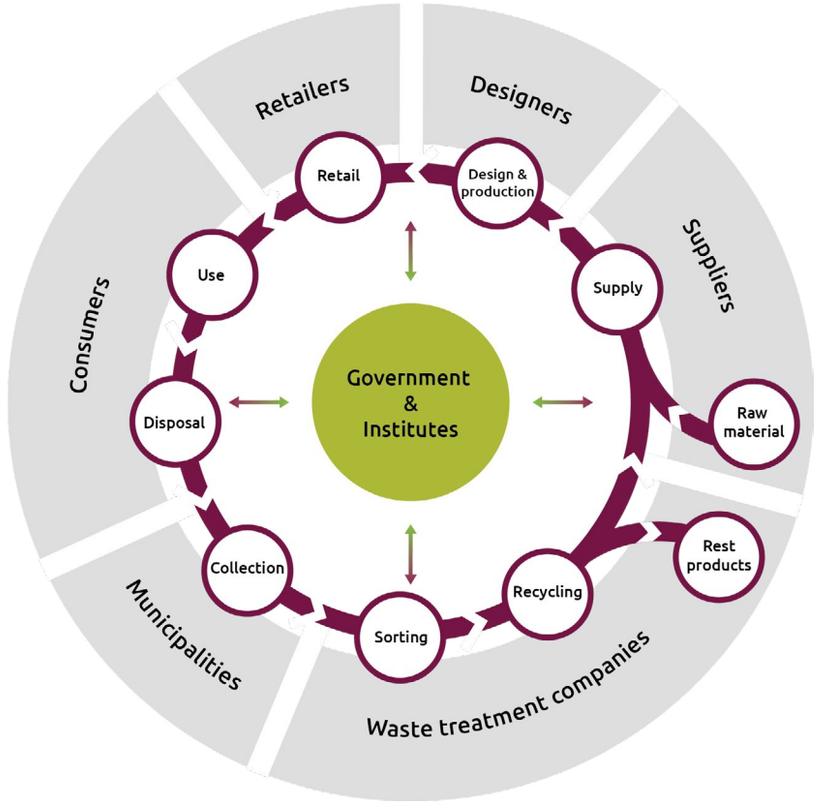


Figure 10: The waste chain

4 The Waste Chain

The consumer
The consumer is an important stakeholder in the chain that has a big influence on packaging developers. From the interviews it became clear that for many brand owners their brand image is an important motivation for packaging design choices, and that this is heavily influenced by their customers. Some examples were given in which an iconic design did not get changed to make it recyclable because of the brand image. In other cases, the brand image has led companies to choose a biodegradable packaging, which is not seen as a recyclable packaging, and these companies were aware of that. The consumer plays a big role in this, especially for companies that present themselves as more environmentally aware.

"We are operating in a market where the consumers are very alert" (Company 5)

Interestingly enough, these brands do not feel the freedom to use plastic packaging options, even though they know it is the more sustainable option according to KIDV. Their customer base expects an "environmentally friendly" packaging, which is often seen as a packaging without plastic. The interviewee in question did not test this hypothesis, so this remains an assumption of their customer wishes.

"We would prefer a plastic mono packaging, but this clashes with our brand image." (Company 6)

Municipalities
As mentioned in chapter three, the municipalities are part of the recycling system because they are responsible for the collection of waste. With this role they do not directly have an influence on sustainable packaging design, but the way the Dutch system is set up does affect sustainability implementation. The complexity of the system acts as a barrier for sustainable packaging design. One of the interviewees gave the non-harmonised waste collection system as an example. The difference between source-separated or residual waste collection can affect if a packaging will be recycled, but as a producer you cannot influence the location at which your packaging is disposed of or treated.

Governments and institutes
In contrast to the direct stakeholders these indirect stakeholders can take a chain-wide position. They play an important role in connecting the different players in the field and providing overview. The Dutch Ministry of Infrastructure and Water Management (IenW) is amongst others responsible for regulations concerning CE and waste. Organisations, either related to the government or not, play an important role in researching and monitoring the waste system. By sharing their knowledge they also provide guidance and overview to the other stakeholders.

4.2 The challenge of alignment

All stakeholders are to some extent influenced by each other. This influence is often larger from the stakeholders that are closest. Naturally, packaging designers will base their decisions mostly on the consumers and less on the waste treatment, as was described in the previous section. The purchase of the packaging by a consumer will financially aid them, while the end-of-life treatment of the packaging is less visible and does not have such a direct financial incentive. The decisions made by suppliers, designers, and retailers are however of great importance for the integration of sustainability in the waste chain because they will have influences throughout the whole waste chain (Oude Luttikhuis et al., 2014). Therefore, these stakeholders must be knowledgeable about the different stages in a packaging's life cycle, also the stages beyond consumer usage. The challenge is that this information about the rest of the life cycle stages is not always available at the beginning of the cycle. This is caused by a lack of communication, collaboration, and transparency between stakeholders (Oude Luttikhuis et al., 2014). Even though knowledge is available within each step of the chain, this knowledge currently does not spread, from the interviews it became clear that too little data is shared and that there is a lack of a system mindset.

"There is mainly a need for more knowledge in a broader sense, the experts are informed but there is a lot to improve on a broader organisational level, reaching the marketeers, finances, sales, etc." (Company 2)

Interdisciplinary communication between the actors of the packaging chain is necessary for sustainable development. The multifaced nature of packaging makes it a complex topic in which the terminology and technology differ between sectors (Lindh et al., 2016). Common terminology and understanding of the different sectors are essential to good communication, bridging the gaps between sectors and facilitating a circular mindset (Pascual et al., 2003).

As described in chapter one, the packaging industry, and the waste industry work with different perceptions of packaging and the sustainability of packaging. Reaching a circular economy demands innovation from both industries, however, innovations come with risks, can take multiple years, and can be costly. For example, the development of a new packaging material, the purchase of an improved extrusion machine or the redesign of a sorting facility. These types of decisions are not made overnight and require strong substantiation and a stable market. A challenge in the waste chain is that multiple scenarios for innovation are being worked on and there are constantly new techniques expected to arrive in the near future. As a company it is hard to decide whether to make the shift to something that is currently well-recyclable, or to wait for new technologies (Brouwer et al., 2021). Packaging producers would like to know what developments are taking place so that they can consider this while working on future packaging designs. Multiple interview participants indicated that in some cases a worse packaging alternative is now being accepted in the D4R guidelines whereas a better alternative, that already works, is not yet approved. This creates difficult situations for the companies, where they do want to comply with the guidelines, but they also know that a better packaging option is available or will be available in the coming years.

Although technological innovations are necessary, the chain should not merely focus on them. The whole system is currently diverging with new technologies to find the best way to a CE, and it is hard to prioritise one. It is important to realise that new technologies will not only have to perform well but also have to fit into the system. The developing technologies will result in better optical sorting, improved data collection of packaging, and more effective removal of labels and inks, but these new techniques still prefer and benefit from mono materials and well-recyclable packaging. Technological innovations are not going to solve all issues. It is a trade-off, between technical innovation and well-designed packaging (NTCP & HTP, 2022).

"If you throw in a bunch of rubbish, the sorting will become very complicated with little amounts of high-quality recyclate and a lot of mixed plastics as result. This understanding is not there enough, yes you can do a lot with

the recycling, but if you want a lot of high-quality recyclate, these types of solutions are not ideal. The chain perspective has to become clear, think in systems." (Expert 1)

Concluding, all stakeholders can start working on sustainability improvements, but if these do not align their added value vanishes.

"If there won't be collaboration across the chain, circularity will not be reached" (Expert 5)

4.3 Policies

There is a need for clear rules and regulations, to give structure to the market. Current policy that is in place to transition from a linear economy to a circular economy includes amongst others Extended Producer Responsibility (EPR) systems, Single Use Plastics (SUP) bans, Circularity targets, tariff differentiation, and eco-design (Afvalfonds Verpakkingen, 2021a; European Union, 2009, 2018, 2019). Many policy initiatives, both legal and voluntary have arisen in the past years (OECD, 2022). In general, most of these policies are aiming for more reuse and recycling of packaging, limiting the use of virgin plastics, and increasing the use of recycled plastics in new plastic products and packaging.

Leading policy instruments are the waste and packaging waste directives of the European Union (European Union, 2008, 2018). Part of these directives are the extended producer responsibility (EPR) schemes. The EPR framework extends the producer's responsibility for a product to the post-consumer stage of a product's life cycle. This includes financial and organisational responsibility for the collection, sorting, and treatment of products (OECD, 2016). By placing the responsibility at the producer they not only pay but are stimulated to reorganise their production to reduce or prevent pollution (Heijnen, 2022). This responsibility is taken over by producer responsibility organisations (PRO), in the Netherlands this policy is regulated by the AFV. Packaging producers and importers that put more than 50.000 kg of plastic packaging on the market have to pay for the amount of packaging they put on the market. To stimulate the production of more sustainable packaging, discounts are given to well-recyclable packaging, assessing the recyclability of packaging is done according to the definition of KIDV, which is mentioned in chapter three. Packaging producers can assess their packaging with the KIDV Recycle Checks.

The interviewees expressed a strong desire for clear policy and emphasized the effectiveness of financial cues in stimulating sustainable packaging practises. Currently, the financial cues are giving the wrong message, where it is about quantity and not quality. The tariff differentiation is helping with redirecting this focus, but it is not enough.

"The government should start to realise they cannot leave this to the market" (Expert 1)

Besides governmental policies, voluntary commitments are used to strive for a circular plastic economy. By committing to groups such as the Plastic Pact, companies feel the pressure to improve their packaging. Interviewees indicated that these commitments are not without obligations and that they are being checked. Research from the Changing Markets Foundation unfortunately on the contrary states that these commitments are often not met, and in some cases are used for greenwashing (A. Delemare Tangpuori et al., 2020). Once more emphasising the need for clear policy.

"It is not as if these commitments are without obligations, we are working hard on them, both nationally as internationally." (Company 2)

The government is aware of its responsibilities and new policy documents are being developed, late 2022 a new Packaging and Packaging Waste Directive (PPWD) was published, which presented the newest targets concerning packaging sustainability (European Union, 2022). Especially the recyclate use targets (Table 1) are expected to be challenging since there is a lack of high-quality recyclate and they cannot compete with the price of virgin plastics (SYSTEMIQ, 2022). The European Food Safety Authority (EFSA) is known for its strict assessments with regards to recyclate use in food packaging, which results in PET being the only usable recyclate for food applications currently (Thoden van Velzen et al., 2023). Although the new targets will be challenging, they are a great push to improve packaging recyclability since the quality of recyclate is directly influenced by how well a packaging can be recycled. This target bridges the waste and packaging industry, where a new role is created for the waste industry as a supplier of materials.

	Min % recyclate 2030
contact sensitive packaging made from PET	30%
contact sensitive packaging made from plastics other than PET	10%
Single-use beverage bottles	30%
Packaging other than above	35%

Table 1: *Recyclate targets of the PPWD, article 7*

"Packaging companies are not able to get enough high-quality recyclate, so they would actually benefit a lot from a better implementation of D4R." (Expert 1)

"Recyclate is becoming the new material input, so the quality is super important for the producers." (Company 3)

4.4 Current D4R guidelines

In order to structure the transition to more recyclable packaging, design for recycling guidelines exist. Multiple D4R guidelines are available to inform packaging designers about recyclability. None of these sources contain legal requirements, the guidelines are for voluntary use. A selection of institutes exists in Europe that provide similar information on D4R. An overview of three established sources can be read in Appendix 1. These guidelines are developed by indirect stakeholders, in collaboration with waste treatment facilities and the packaging industries. In the Netherlands, the D4R guidelines are provided by KIDV.

These guidelines all have the same goal, but they do not all contain the same rules. Once again there is no perfect sustainable packaging, which implies there does not exist a set of perfect guidelines. This is the challenge when trying to make rules for more than one country, as packaging is often exported. Many companies design for multiple countries, with multiple rules and guidelines that may differ. Attero experiences this confusion through the questions they receive from the packaging industry, these people want to see for themselves what happens in the waste treatment.

4 The Waste Chain

Figure 11: The desires of the packaging industry

From the previous chapters it became clear that the implementation of D4R is lacking. During the interviews it was asked what the missing information in the current D4R guidelines was, the interviewees indicated that they were familiar with the KIDV Recycle Checks, and all companies used a version of D4R guidelines, either Dutch or other guidelines. Points of critique were a lack of nuance and future perspective in the guidelines. The KIDV Recycle Checks were portrayed as very black and white, and only focussing on what is recyclable now. There is a strong desire for the implementation of new technologies in the guidelines, what will be possible in the coming years.

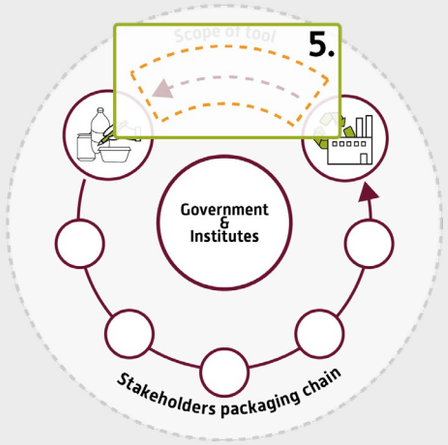
At the same time, the difficulties of giving this future perspective were expressed in the interviews. Organisations like KIDV cannot just implement a new technology without the certainty of it being implemented in time, and then having made false promises. Do you in that case keep off a new technology and accept a worse packaging alternative, or do you leave open the door?

In the end, the guidelines will not be able to give a perfect answer to each specific question, within such a complex system. The value of D4R guidelines, like the Recycle Checks, lies in the overview they provide. By visiting and working together with waste treatment companies, they collect the complete picture of D4R. By offering nation-wide advice they have to consider all waste treaters, inevitable differences between waste treaters have to be considered and merged into a nationwide representation. This leaves some responsibility for the packaging designer to use their common sense while applying the guidelines to their packaging.

The need for collaboration becomes clear when the whole cycle is analysed. Both the waste and packaging industry need to innovate towards more sustainable processes, but this proves to be challenging in a moving industry. The need for clear policy becomes apparent. Existing policy is working on steering packaging production towards more sustainable practices. Through EPR systems and financial triggers for more recyclable packaging, design for recycling is promoted. However, the implementation thereof is lacking. Despite the available guidelines, unclarity remains among the packaging industry. Summarizing a system that is in transition proves to be difficult.

5 Information Gap

The previous chapters explored the broader context of the packaging industry, the waste industry, and the combined system effort that is needed to reach a circular economy. From this analysis, it becomes clear that the packaging industry and waste industry are not sufficiently aligned and that an information gap around design for recycling exists.



5.1 Missing link in D4R guidelines

Concluding from the previous chapters an information gap can be formulated, this gap exists between the waste treatment and the packaging industry. All the necessary information about how packaging can be designed to fit the waste system is already available through D4R guidelines, but the implementation of these guidelines on a large scale must increase to reach a closed-loop recycling system.

What helps packaging designers to understand the guidelines is to visit the waste treatment and see the processes for themselves. A shortcoming of the current guidelines lies in the lack of visual content and a more in-depth explanation of the waste treatment processes. Now the guidelines are mostly textual and do not go into depth about the underlying reasons for their rules. When looking at the KIDV recycle check for flexible packaging from 2021 (KIDV, 2021), the main component is a decision tree with 13 yes-no questions. When a packaging is not fit for recycling, only a short statement is made on why this is the case, see Figure 12. For most cases this is then further elaborated with a textual explanation on a different page, where some of the waste treatment processes do get a short textual explanation. In some cases visual elements are added, but these do not cover the sorting or recycling processes, see Figure 13. Similar to the KIDV recycle checks, the Recyclass tool only presents the reasoning behind the questions in a short text box, only in a separate PDF document, more attention is given to the reasoning.

The sorting and recycling processes are mechanical processes that lay at the heart of the effectiveness by which packaging can be sorted or recycled, and of which the working could be clearly described through visual content. By explaining the mechanical working of each step, the user can understand that there is a physical reason why certain packaging is recyclable or not. Returning to the example question of Figure 12; the constraint of a minimal packaging size is based on the sieving step at the beginning of the sorting process. More specifically, the waste is sorted in a large drumsieve to sort out any remaining organic materials which often have smaller volumes than the packaging items. The smallest holes in the drumsieve are usually 3x3cm, which causes packaging items that are smaller than 3cm to be sorted out. Visualising this step and explaining the simple and practical reason for such a size constraint could help packaging designers to better understand the D4R guidelines. The emphasis of current guidelines lies on **what** is recyclable or nor recyclable, next to this there is a need for information on **why** things are recyclable or not.

Although there is a lack of visual content in D4R guidelines, visual content of the waste treatment does exist, and can easily be found on YouTube. See appendix 2 for an overview of several videos that were analysed for this research. The shortcoming of this content is that it does not explain the waste process as a whole but rather one or two elements from the system. Next to that these videos do not link the D4R guidelines to the waste processes. Several videos contained explanatory animations of the processes, which clearly describe their working. However, the use of video limits the option to use textual explanation to further explain the relevance of a process within the system. Another limitation of video is that the user has limited options to select the information that is relevant to them. By creating an interactive tool, does not only allow the use of textual explanation but also allows the user to navigate themselves to the information they are interested in.

Figure 12: Example question from the KIDV Recycle Check for flexible packaging

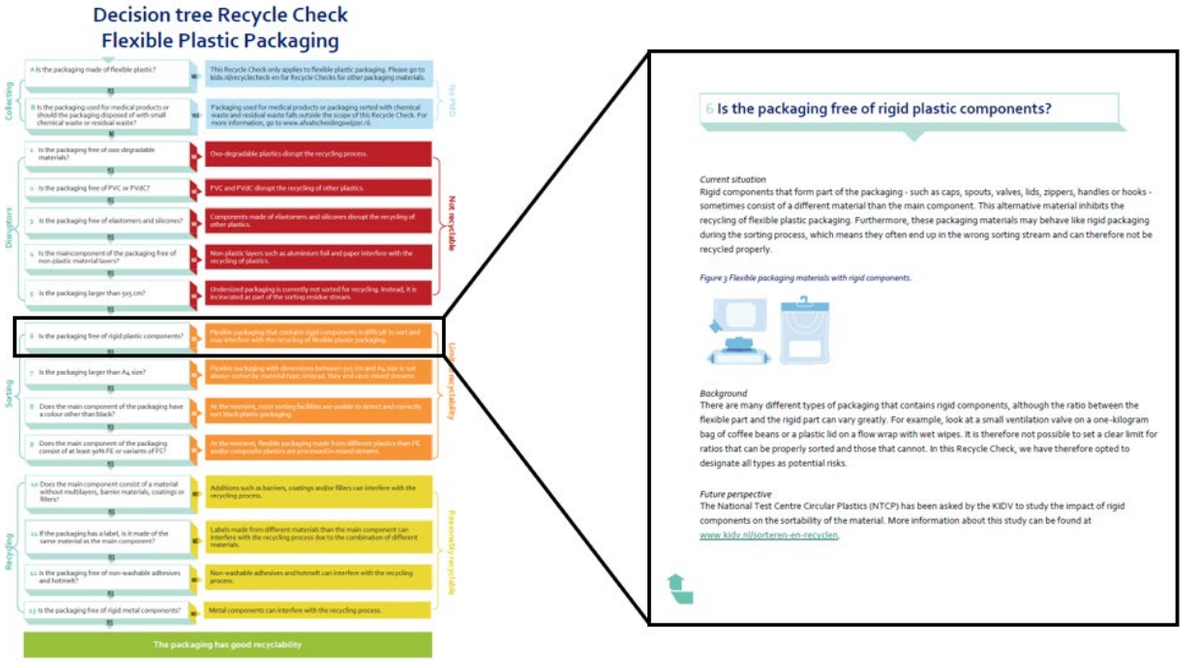


Figure 13: Example clarification from the KIDV Recycle Check for flexible packaging

5 Information gap

The interviews showed that having more knowledge on D4R does lead to a more elaborate and correct implementation of D4R, and the current knowledge level can certainly be improved. Smaller companies often do not have an R&D department where they can focus on improving their sustainability. One of the small brand owners indicated that they do not really know what the best option is, so they just keep doing what they are familiar with. Educating these actors could help them to implement D4R guidelines.

"In general, the knowledge level is low, even I (recycling manager) still experience eyeopeners even though it is my daily task to understand the chain." (Company 2)

Attero knows that showing the waste processes largely contributes to the understanding of packaging recyclability. The hypothesis is that a visual communication from the perspective of the waste treatment could improve the understanding of current D4R guidelines and increase their implementation. Most interview participants agreed on the added benefit of visual information, this is less prevalent in the existing guidelines. Furthermore, visual information is believed to create a larger potential to reach marketeers within a company. The current guidelines do contain some type of visual overview, both the Recyclass and the Ceflex guidelines provide a flowchart of the sorting and recycling processes, however the processes are captured in a single icon, which is not able to explain the full working.

5.2 Filling the gap

In order to fill this information gap, the development of a visual tool on the waste sorting and recycling processes is proposed. An opportunity for Attero lies in providing easily accessible information to the designers by creating a visual explanation, from the perspective of the waste treatment, on the basic principles of sorting and processing waste. The added benefit of creating a tool is that it changes the existing static list of problems in packaging design to an interactive discovery of the waste treatment.

In addition to the current guidelines, this tool would focus on a different way of portraying information, less static and more visually interactive. Using visual explanations for mechanical processes was proven to increase understanding. Their ability to include crucial yet invisible features makes them superior to using textual explanation only (Bobek & Tversky, 2016).

This tool could act as a bridge between the two industries, strengthening collaboration and communication. To further explore how this tool could take on this role, a user study with the packaging industry is done in chapter six to test the hypothesis and to research their wishes.

To help the packaging industry gain a better understanding of the waste treatment and the connection of packaging design to recyclability, the development of a tool is proposed. Specifically focussing on visualizing the sorting and recycling techniques to highlight the importance of D4R and on creating a direct communication between the end and the beginning of the waste chain.

6 Industry Perspective

An information gap has been defined, this chapter will explore this gap and find out how the proposed tool from chapter five could best fill this gap. This is done by interviewing players from the packaging industry in a user study. Input from these interviews has already been implemented in the previous chapters to strengthen the theoretical background. In this chapter the interview procedure is described, and the results of the interviews are analysed to identify the current knowledge of D4R, the enablers and barriers for D4R implementation, and overall input for the tool. This information will serve as concrete input for the development of the tool.

6.1 The goal

The goal of the user study is to give substance to the concept of a visual tool on the waste sorting and recycling processes. The previous chapters provided a literature background on the topic, but to test the hypothesis of the usability of this tool, input from the packaging industry is desired. This input is collected by interviewing players from the packaging industry. From this data, a set of requirements can be created which will give structure to the development of the tool in Part II of the report. Three main questions were set up to further investigate. Firstly, if the tool has to educate the users on D4R it is necessary to know their current knowledge, which will function as a starting point. From there it can be decided what information the target group is missing and what information the tool should provide. Secondly, it is useful to research how D4R is currently implemented, and if there are any enablers and barriers for the implementation of D4R. Lastly, the interviews provide a great opportunity to openly ask for input on the tool. Research questions:

- What is the (missing) knowledge on Design for Recycling within different packaging related companies?
- What are barriers and enablers for the use of Design for Recycling?
- What input do the interviewees have for the tool?

6.2 Target group

In the broadest term the target group is the beginning of the waste chain, the producing parties. This group covers everything between the waste treatment and the consumer, see Figure 14. This includes suppliers, designers, and retailers. During the user study, the designers will be referred to as brand owners, companies that produce and sell packaging. Within the category brand owners a distinction can be made between large and small brand owners. From conversations with Attero and KIDV, it became clear that large brand owners often have more knowledge and a more elaborate implementation of D4R guidelines compared to small brand owners. Which makes it interesting to test where the tool has most impact. Besides the direct stakeholders from the packaging industry, several “experts” from the inside of the diagram were also included in the target group. Interviewing them will help to create a chain-wide perspective and research what role the tool can play within the system.

Finding a more specific target group will help with deciding what information needs to be communicated and how this information should be communicated. Will it be more of an educational tool with in-depth technical knowledge, or should it be more generally used for spreading awareness. Or can the tool be used for both, offering layered information.

6.3 Interview methodology

A semi-structured interview approach was used for this study. The use of semi-structured interviews was chosen because of their explorative nature, therefor they can help with answering the research questions (George, 2022). Furthermore, they provide qualitative input rather than quantitative input. The goal of this study is to understand the current knowledge level and attitudes toward D4R, which is qualitative data. The semi-structured interviews allow for the possibility to investigate the topic in more detail. The downsides of these types of interviews are that they have a lower validity, it is hard to compare responses, and they are more biased (George, 2022).

Sampling strategy

The study sample was purposively chosen to cover multiple actors in the packaging industry in order to research where the tool could have the most impact. In total 13 interviews were conducted. A network sampling method was used to find the participants. Based on the network of Attero the first participants were found, from there a snowball sampling effect took place where the participants suggested new participants. To ensure that all intended groups were covered, the remaining participants were found by strategic sampling. (Skovdal & Cornish, 2015)

Interview procedure

The interviews were conducted online or on the phone, lasting somewhere between 30 minutes to an hour. Eleven interviews were in Dutch, two were in English.

Since the interviews were semi-structured an

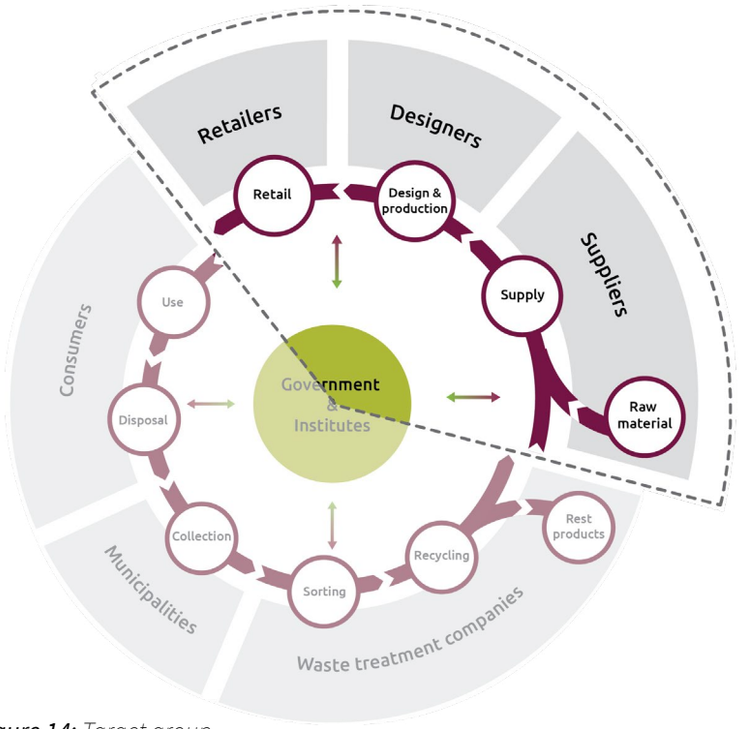


Figure 14: Target group

6 Industry Perspective

interview plan was used, this plan contained the main themes that were to be discussed but did not provide a fixed interview structure. Each theme contained several sub-questions to guide the conversation and to go more in-depth. Since the interviewees came from different sectors of the packaging industry, not all interviews contained the same questions. The semi-structured approach allowed for a go-with-the-flow process, being able to elaborate further on topics that came up. This also resulted in a tweaking of the questions later on in the interview phase since the earlier interviews gave insight into the interesting and less interesting topics. During the later interviews, it was clearer what information was still missing and the questions were more altered towards those topics. The full interview plan can be found in appendix 3.

Analysis

Most of the interviews were recorded, the recordings were used to construct a textual summary of the interviews. The interviews were not transcribed word by word. These summaries were then coded using Microsoft Word. By adding comments to the text, the important quotes of the participants were highlighted and categorised. These comments were then all transferred to Excel to create a large list of the findings that could be sorted on theme.

6.4 Results

Parts of the results have already been implemented in the first five chapters. Here a summary is given of the three research questions, after which the conclusions for the tool are presented. For the second research question, only the most important barriers that have not yet been mentioned in the previous chapters will be described.

The participant group existed of a diverse mix that covered the complete target group, a full overview of the interviewees and their characteristics can be found in appendix 4. Two groups can be identified from the interviewees. Firstly, the participants referred to as companies, who are handling directly in packaging. This group consisted of 8 companies and covered brand owners, retailers, and suppliers, varying in company size and operating both nationally and internationally. Secondly, the participants referred to as experts, who are active on a broader overarching level. These five participants are more involved with the complete chain and do not earn money from packaging directly.

Current D4R knowledge

All interview participants were aware of design for recycling guidelines and all but one (a European operating organisation) were familiar with KIDV. The D4R guidelines that were used by the companies were KIDV, Recyclass, and CEFLEX.

A difference between the use of D4R guidelines within the companies was noticed, ranging from full implementation to sporadic use. Some companies had their own guidelines, often based on existing guidelines but then altered to fit the company. All companies used at least one of the existing guidelines, several companies would use multiple guidelines or a combination of different guidelines. In general, the larger companies have a more elaborate implementation of D4R guidelines than the smaller companies, this corresponds with the existence of a packaging or sustainability expert within the company. Having a person within the company who is specifically there to research the developments on packaging and recycling helps to understand the complexity around sustainable packaging and enables a structured implementation of D4R. Smaller companies without specific packaging experts sometimes lack the knowledge and resources to delve into the topic, which is linked to a less structured implementation of D4R. Although, the presence of a single motivated person within the company can make a big difference and provide useful knowledge from their own motivation.

The experts confirm that there definitely is room for improvement for design for recycling, there are many examples in which adjusting the design of a packaging is an easy solution to increase the recyclability of a packaging. They can also confirm that the larger companies have the knowledge available, whereas small to medium sized enterprises (SMEs) are less knowledgeable.

Barriers and enablers

During the interview the participants were not asked to indicate enablers and barriers, these labels were assigned afterwards by the author. Often the presence of the theme would enable D4R and the absence would be a barrier. A rough estimation of the most mentioned themes was made to indicate their importance. Since not all interviews were recorded and since they were not transcribed word by word, no exact numbers of the number of appearances of the themes could be made, instead an indication is made existing of 3 scales ranging from often mentioned, regularly mentioned, and sometimes mentioned. Figure 15 shows the themes, most mentioned at the top, least mentioned at the bottom. The green bars show how often the theme was mentioned as a barrier or enabler on a scale from often, regularly, and sometimes.

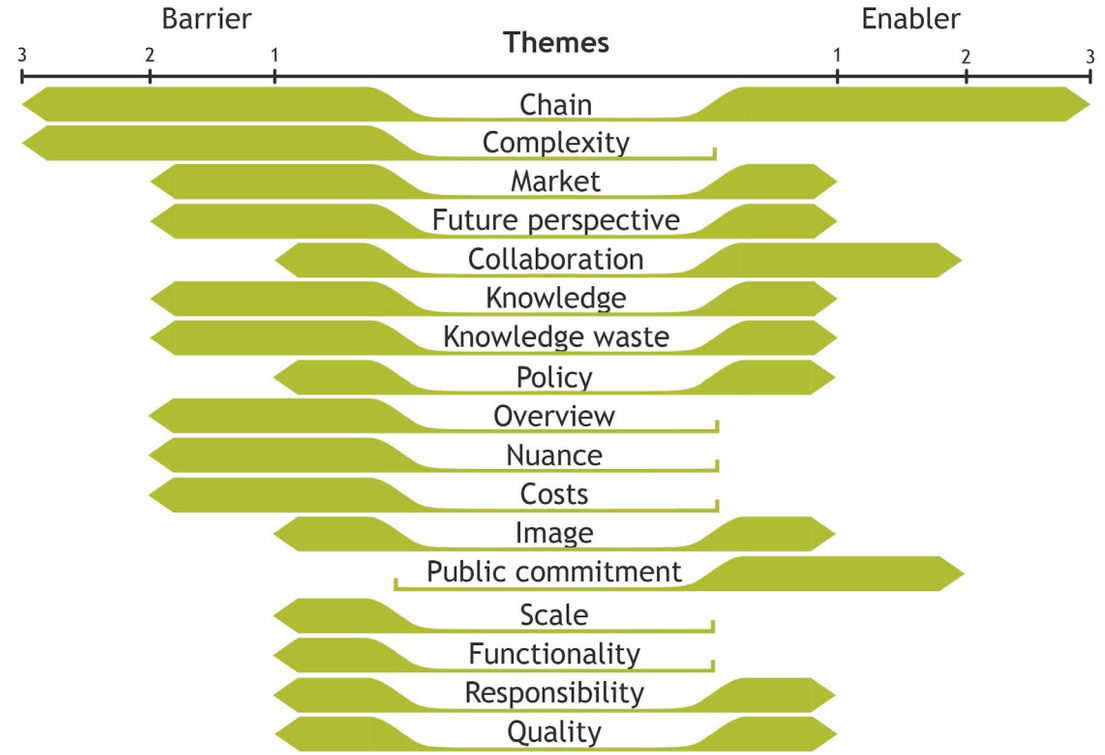


Figure 15: Barriers enabler graph

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Chain
The most mentioned themes were the chain, complexity, the market, future perspective, collaboration, and knowledge. The theme chain is both indicated as a barrier and an enabler. In general, the chain is seen as an enabler when the interests of the whole chain align and when collaboration between different parties exists. This is linked to sharing knowledge and communicating with each other. An example of how the chain can be an enabler is its role in gradually shifting business cases in a more sustainable direction. Changing the financial ques in favour of sustainable initiatives is something that should be done on a chain-wide level. Steering towards a chainwide mindset where people are aware that the quality and quantity of recyclate is directly linked to the quality and quantity that producing parties put on the market, you get what you give. Participants indicated that now that the market for recyclate is growing, the chain should stress the effect of packaging design on recyclate quality.

The chain was also seen as a barrier. The participants indicated that there are inequalities between the different players in the chain, producing parties felt as if they are seen as the ones that have to adjust. The D4R guidelines are very focussed on producing parties, while there might also be situations where the waste treatment or other parties are the most suitable party to adjust.

"Doesn't it make more sense to change the 12 waste treaters than to change the thousands of producers? Our packaging currently falls outside of the system, while it is beautifully recyclable material." (Company 4)

Complexity
Complexity is seen as a barrier; indications of complexity have both been given on the level of packaging design and on a system level. On the packaging level it is not always clear what actually is the best option with regards to recyclability, both because of the amount of information and the ambiguity of the context.

Market
Market dynamics have a big influence on the implementation of D4R, both as an enabler and as a barrier. It is an enabler because of the roles it addresses certain parties, creating a feeling of responsibility. Examples were given on how the big companies are more aware of the D4R guidelines and are pulling the D4R developments towards them, driving the innovations, whereas smaller companies need to be pushed to implement them. Furthermore, one brand owner saw market dynamics as a form of group pressure, when all retailers are asking for a certain type of packaging, it becomes hard for a packaging company to not follow this trend. This is confirmed by the retailer who indicated that they do hold some power when it comes to influencing the packaging suppliers. In other cases, market dynamics can be seen as a barrier. In the end, a product will have to sell regardless of its recyclability, a design choice in favour of sustainability does not always mean that the consumers will accept it.

Future perspective
Multiple interviewees mentioned the lack of future perspective within the existing D4R guidelines, which is seen as a barrier. This has already been indicated in chapter 4. The experts indicated that it is very hard for an organisation such as KIDV to offer this kind of information. When a certain technology is in development and is expected to be implemented within a certain timeframe, they still cannot give a set deadline. This could turn out to be a false promise, resulting in a load of new packaging that was supposed to be recyclable but isn't.

Collaboration
Collaboration can be seen as one of the biggest enablers of design for recycling. This theme is inherently linked to the theme chain since collaboration happens between different stakeholders in the chain. Participants indicated that they join new initiatives and collaborate with organisations like KIDV to boost innovation. When a company does not have the resources to research new possibilities itself, it can still contribute to innovation by joining other initiatives. Collaboration within a company, educating each other and involving marketeers with the sustainability teams, helps to improve D4R implementation.

Other themes have already been mentioned in the previous chapters.

Input tool
Overall, there was a positive reaction to the tool idea. Most participants agreed on the added benefit of visual information, this is something that is less prevalent in the existing guidelines. Furthermore, the visual nature of the tool is believed to create a larger potential to reach marketeers within a company.

As mentioned in the subpart knowledge, the people that have visited a waste treatment facility found this to be very helpful. Multiple participants indicated they would be interested in visiting a waste treatment facility, which shows that there is interest in learning more about the waste treatment industry, and that the current guidelines do not provide enough information about this yet.

Another wish is that the tool should be more accessible than the current guidelines. Most of the current guidelines are based on highlighting what is not possible, one of the participants explained how a more positive attitude could be beneficial. What are the design choices that do make things possible? A last remark was that if the tool should reach multiple people, there might be a demand for layered information.

From the interviews it came forwards that different groups of people desire a different kind of information. The packaging experts would benefit most from very detailed information, also elaborating on the situations that are currently not clearly described in the D4R guidelines. Specifically highlighting the technologies and sorting mechanisms from the waste treatment that have not yet been covered by KIDV. The less informed participants would benefit already from a general introduction of the waste treatment.

6.5 Conclusions

Target group
As mentioned before all the participants were aware of D4R guidelines, however the level of knowledge differs. The presence of a packaging expert was linked to a better knowledge and implementation of D4R, packaging experts are therefore not the main target group for the tool since they are already an enabler. Moreover, in order to educate the experts even more they desire very detailed knowledge on technical packaging specifications, this is not something that Attero can offer since they are no packaging experts. Instead, the target group is redefined to the non-packaging experts, within small companies these are the buyers, the product managers, directors, etc. The people that do handle packaging but are no experts. Within the large companies the tool can still be useful, the packaging experts might not learn much from it themselves, but they can use it to educate their less informed colleagues, the marketeers for example, the people without a technical background.

Content
The theme chain mainly illustrated the scale of the topic, improving plastic recyclability is a

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chain wide problem. It also showed overlapping content with the themes: complexity, collaboration, and market dynamics. The complexity of the chain shows that there is no simple answer on how to solve the plastic issue. The tool will have most impact if it is broadly applicable, meaning that the whole chain can benefit from it. To achieve this the KIDV Recycle Checks will be used as the D4R guideline source. Following these guidelines means that the desire for more nuanced and future oriented information might not be fulfilled, but it does allow the tool to fit in with the current system, creating more overview and not further complicating the already crowded field of D4R guidelines.

Given that the KIDV Recycle Checks are already well-known in the Netherlands, their incorporation in the tool will strengthen its credibility.

Impact

As mentioned, there is a need for more chain-wide knowledge and collaboration. The tool will not be able to answer all specific questions that companies have about their own packaging, it rather operates as an invitation for more collaboration. From the interviews it came forward that the producing parties felt as if they are seen as the ones to adjust, whereas they feel that the waste treatment could also be the one to adapt in some cases. The tool is not supposed to act as an accusing message toward the packaging industry that they are the ones to solve the recycling problem, instead it should explain what the waste treatment is currently offering and thereby opening the conversation. By creating this tool, it will encourage communication between these two parties, which can contribute to a better understanding of each other.

Another desire from the participants was the need for more policy. Attero is not able to create new policy by itself, but by educating others the tool can contribute to a fertile environment to create new policy.

Practical matters

Something to keep in mind is the non-harmonious system in Europe and the Netherlands. While providing knowledge on the waste treatment it should be made clear that the information is coming from the perspective of Attero. Within the Netherlands, most waste treatment facilities are similar to such an extent that the tool will be widely applicable, apart from any Attero-specific settings. Nonetheless, the users should be made aware that this is not the golden standard and that they should analyse themselves if the information can be applied to their working field.

Not all themes that were mentioned in the interviews will be incorporated in the tool, because they are not within the direct influence of Attero, for example image, costs, and functionality. The tool will not bring down the costs of changing packaging, and it will not directly motivate brand owners to change their brand image. But by educating the companies on the importance of D4R they can decide for themselves if they are willing to defer from their brand image, and by educating the government they might decide to redirect financial ques in favour of D4R.

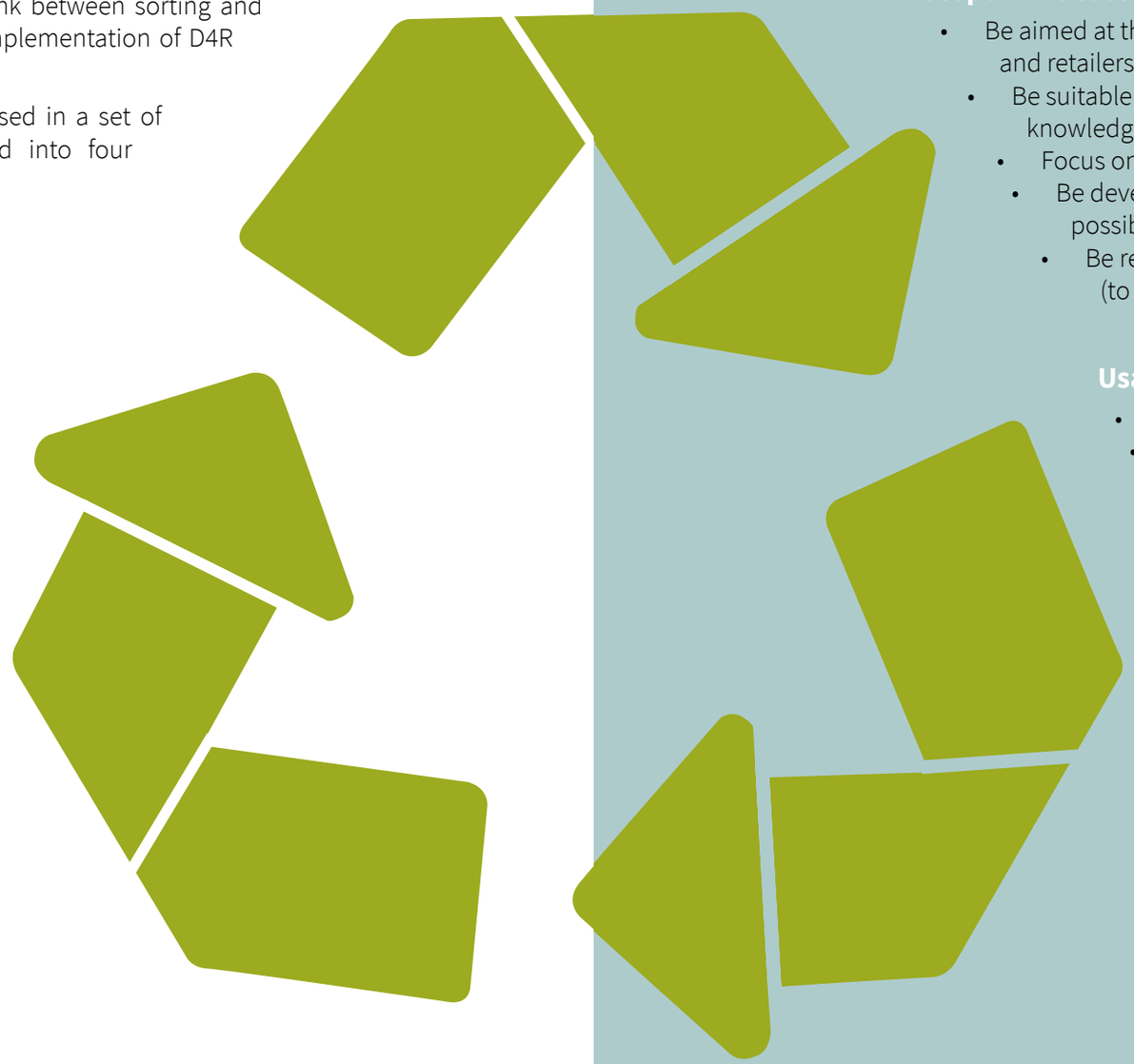
The user study gave insight into the wishes of the target group. It showed that there is room for the proposed tool of chapter 5, participants confirmed the complexity of sustainable packaging and desired more knowledge on design for recycling guidelines. The concept of a visual representation of the waste treatment was positively received and the general consensus was that this would be a valuable source of information.

Requirements

The theoretical background of chapters 1 to 5 and the results of the user study are concluded to propose a design brief for the development of the tool. The functionalities of the tool are summarised in a set of requirements.

The current guidelines on D4R do not show the waste treatment perspective although this perspective lays at the root of the guidelines and could improve people's understanding of the guidelines. From the experience of Attero and the results from the user study it became clear that the waste treatment perspective is not well understood in the field of packaging design. The packaging industry does show interest in this type of knowledge and confirms that the current guidelines are not always able to answer all their questions. By creating a tool that informs the packaging industry about the link between sorting and recycling processes and packaging design, the implementation of D4R could be motivated.

The findings of Part I of this report are summarised in a set of requirements. The requirements are subdivided into four groups, inform, scope, usability, and effect.



Inform - The tool should:

- Provide an overview of the plastic waste sorting and recycling processes
- Inform users about the connection between D4R guidelines and the waste treatment
- Link the KIDV Recycle Check guidelines to the associated sorting and recycling processes
- Educate users on the reasoning behind D4R guidelines
- Provide visual and animated images to illustrate the functioning of the sorting and recycling machines

Scope - The tool should:

- Be aimed at the beginning of the waste chain: suppliers, producers, and retailers
- Be suitable for people without expert packaging or recycling knowledge
- Focus on the Dutch market, where possible EU oriented
- Be developed for flexible plastic packaging at first, rigid when possible
- Be representative for all waste treaters in the Netherlands (to a certain extent)

Usability - The tool should:

- Be openly accessible
- Provide easy navigation
- Allow the user to complete the tool on their own pace
- Offer optional in-depth information on complex processes
- Encourage the user to stay critical and think for themselves, since there exists no perfect sustainable packaging

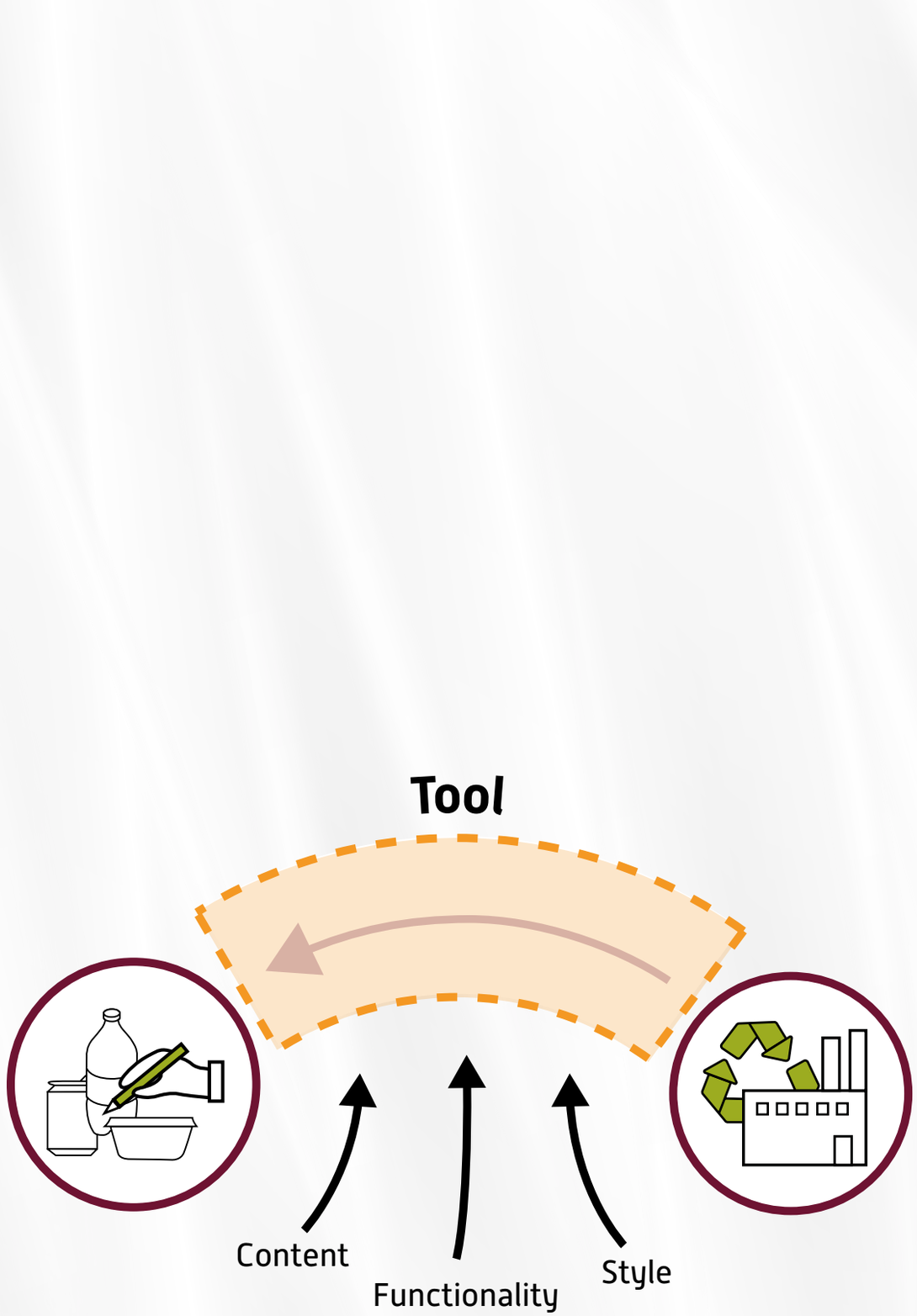
Effect - The tool should:

- Encourage the implementation of design for recycling guidelines
- Encourage more communication and collaboration across the chain

Part II

Tool Development

7. Content
8. Design and functionality
9. Final tool



7 Content

The theoretical framework and user study provided the incentive and input for the development of a tool to educate the packaging industry about the waste treatment and the importance of D4R. The next step is to use the requirements to shape the content of the tool. In order to best educate the users on the processes of the waste treatment a translation has to be made from the detailed technical sorting and recycling processes of Attero to a comprehensible summary that conveys the right amount of information to the user.

7.1 Contents and learning goals

As stated in the requirements the tool has amongst others an informative goal, this section of the requirements, together with the scope, will mostly determine the content of the tool. To structure the contents of the tool the informative and scope requirements are divided into five main themes.

First the scope of the tool is presented in an introduction. Then the tool should inform the user about the sorting and recycling processes, both on a process level as on an overview level, this leads to the themes sorting, recycling and overview. Furthermore, the tool should link the sorting and recycling processes to the design for recycling guidelines, resulting in a theme design for recycling. What information is presented and why this information is important to include in the tool is described for each theme in the following sections. The themes sorting, recycling and D4R guidelines hold most information and serve an educational purpose. A set of learning goals is developed to help structure the assembly of content.

The user can explain in general terms the different steps of the waste sorting process of plastic packaging. The user:

1. Is able to name and explain the processes: bag opener, drum sieve, windshifter, magnet, drinking cartons NIR, Eddy current, ballistic separator, plastics NIR and handpicking.
2. Is able to explain what disruptive packaging and the influence of packaging characteristics are during the sorting process.
3. Has an overview of the different sorting fractions that arise from the waste sorting process.
4. Understands the effect of packaging design on the sortability of packaging.

The user can explain in general terms the different steps of the flexible plastics recycling process. The user:

1. Is able to name and explain the processes: shredder, magnet, NIR, pre-wash, grinder, coldwash, hotwash, density separation, drying, and extrusion.
2. Is able to explain what contaminating aspects of packaging and the influence of packaging characteristics are during the recycling process.
3. Understands the effect of packaging design on the recyclability of a packaging.
4. Understands the importance of high-quality recyclate in the broader context of the waste chain and circularity.

The user understands the link between packaging design and waste sorting and recycling. The user:

1. Is able to link the design for recycling guidelines to the corresponding sorting and recycling processes.
2. Understands which choices in packaging design contribute to a more recyclable packaging.

7.2 Introduction

The introduction will explain the goal of the tool as is stated in the requirements, this includes the goal to inform the user about the connection between D4R guidelines and the waste treatment and how the KIDV Recycle Checks are used for this. Next to that the broader context in which this tool exists should be explained before the users continue into the sorting and recycling processes, so that they can correctly understand and apply the information. Because all this information together would result in a large amount of text it was chosen to explain the general goal and the use of the KIDV Recycle Checks first and then elaborate on the broader context by using hover over buttons to not overwhelm the user. These buttons explain the definition of recyclability and the importance of recycling, furthermore they emphasize that the tool specifically covers the sorting of PMD waste and the recycling of flexible packaging. Lastly is it is mentioned that the tool covers the sorting and recycling processes of Attero and therefor is not fully representative for the complete Dutch waste system.

7.3 Sorting

The sorting process in the tool is based on the Packaging Sorting Plant (PSP) of Attero, located in Wijster. Together with employees from Attero, the processes of the PSP were discussed to create a detailed understanding of the system. The full flow of the sorting process was explained, and the disturbing or challenging packaging characteristics for each sorting step were identified.

To help formulate the contents for the tool a set of learning goals is established to give more structure to the requirements:

The complete sorting system of Attero was analysed and translated to fit the tool. No confidential information of Attero could be included and the right level of detail had to be found to explain the processes to the target group. A sorting facility is a complex collection of processes that have been carefully selected and engineered together to create an optimal balance between sorting accuracy and material output. For the tool it is not necessary to explain the in-depth relations between processes, because these relations depend on the specific sorting flow which can differ between sorting facilities. Rather it should explain the goal and the general workings of each sorting step within the complete system. Together with the process improvement manager of Attero it was decided which details and steps were essential and which ones could be left out to create an understandable and realistic flow of the sorting process that does not contain unnecessary details or repetitive steps. The learning goals provided the criteria to which irrelevant information was filtered out. To meet the learning goals the tool should explain the working and goal of each sorting step, the waste streams that go in and out of the step, and the related D4R guidelines when applicable. This resulted in a sorting flow that contains nine processes, which not only represent the PSP of Attero but also depict an average sorting process for Dutch waste facilities. The processes are further explained in Table 2, here the goal, the working and the related D4R are shortly explained. A more elaborated explanation of the processes can be found in the final tool, in appendix 5.

7.4 Recycling

The recycling process in the tool is based on the Polymer Recycling Plant (PRP) of Attero. With a series of steps, the film is washed and processed into clean flakes that can be melted

7 Content

Sorting processes

1. Bag Opener	
Goal	Opening the bags in which the waste arrives so that the individual items become available.
Working	A rotating pulling motion tears open the plastic bags without damaging the individual items
D4R Guidelines	The sorting installation is built for packaging material with a maximum size of 5 litres.
2. Drumsieve	
Goal	Sieving the waste on size, creating three streams. A residual stream which consists mainly or residual organic content, a smaller packaging stream and a larger packaging stream
Working	The drumsieve is a large rotating cylinder with different size holes. The waste travels through the sieve and falls down the holes if it is small enough.
D4R Guidelines	• Packaging smaller than 3x3cm will be sieved out. • The sorting installation is built for packaging material with a maximum size of 5 litres.
3. Windshifter	
Goal	Making a separation between rigid (3D) and flexible (2D) packaging items, based on weight.
Working	By means of an airflow the light and large flexible plastic items are sucked into a different stream, while the heavy rigid items fall down.
D4R Guidelines	Flexible packaging items that contain rigid components may act as a rigid packaging, and will be sorted incorrectly.
4. Magnet	
Goal	Collecting ferrous materials.
Working	A large overband magnet attracts the ferrous metal components from the waste stream.
D4R Guidelines	Metal components that are enclosed in the packaging, or that are too small compared to the complete packaging are difficult to remove.
5. Drinking cartons NIR	
Goal	Collecting the drinking cartons.
Working	By use of infra-red camera the material spectrum of the packaging items is analysed. In this case the NIR selects the paper fibres of drinking cartons and then activates air jets to blow out the selected item once it falls of the conveyor belt.
D4R Guidelines	Packaging that has not been emptied cannot be sorted correctly, packaging design could motivate users to correctly empty the packaging.
6. Eddy-current	
Goal	Collecting the non-ferrous metals, aluminium.
Working	Using a magnetic field, the aluminium (non-ferrous metal) is sorted into a different stream.
D4R Guidelines	Non-ferrous metal components that are enclosed in the packaging, or that are too small compared to the complete packaging are difficult to sort.
7. Ballistic Separator	
Goal	Making another division between rigid and flexible packaging.
Working	Using a shaking and vibrating screens the packaging items are sorted on weight and shape. Rigid items bounce down, while foils climb up.
D4R Guidelines	Flexible packaging items that contain rigid components may act as a rigid packaging, and will be sorted incorrectly
8. Plastics NIR	
Goal	Sorting on plastic type.
Working	By use of infra-red camera the material spectrum of the packaging items is analysed. In this case a collection of NIR's is used to sort the most common types of plastic. The NIR selects one type of plastic and then activates airjets to blow out the selected item once it falls of the conveyor belt.
D4R Guidelines	• Packaging with carbon black colouring cannot be detected. • Packaging with full-body sleeves can be problematic. • Labels that are of a different material or that cover too much of the packaging's surface can be problematic.
9. Handpicking	
Goal	Filtering out any last contaminations.
Working	People analyse the sorted waste streams by hand on any remaining contaminations.
D4R Guidelines	-

Table 2: Sorting processes for in the tool

Recycling processes

1. Shredder	
Goal	Decreasing the size of the plastic foils to hand size pieces which will run smoothly through the other processes of the recycling plant.
Working	The foils are shredded by a set of rotating knifes.
D4R Guidelines	Only PE and PP packaging is accepted in the flexibles recycling flow.
2. Magnet	
Goal	Collecting any ferrous-metal components.
Working	A large overband magnet attracts the ferrous metal components from the waste stream.
D4R Guidelines	Metal components that are enclosed in the packaging, or that are too small compared to the complete packaging are difficult to remove.
3. NIR	
Goal	Sorting out any unwanted plastic flakes
Working	By use of infra-red camera the material spectrum of the flakes is analysed. In this case a collection of NIR's is used to sort out any materials that are not PE or PP. The NIR selects a plastic flake and then activates air jets to blow out the selected item once it falls of the conveyor belt.
D4R Guidelines	• Packaging with carbon black colouring cannot be detected. • Labels that are of a different material are problematic. • Mono material items give the best sorting results.
4. Pre-wash	
Goal	The pre-wash is used to wash of the external contaminations, mostly organic materials, sand, little stones and metals.
Working	The plastic flakes are transported through a water bath by a large screw.
D4R Guidelines	-
5. Grinder	
Goal	Further decreasing the size of the flakes, this allows them to be cleaned more efficiently
Working	The flakes are grinded by a set of rotating knifes.
D4R Guidelines	Shredded paper labels leave unwanted fibres for the remaining processes.
6. Coldwash	
Goal	Using friction and turbulence to wash of any remaining dirt, but mostly to wash of labels, inks and adhesives.
Working	The flakes are transported upwards in a cylinder, this cylinder is filled with water and contains a selection of peddles that rotate and agitate the plastics.
D4R Guidelines	• Labels other than PE labels are hard to separate, paper labels leave unwanted fibres. • Adhesives disrupt the recycling process if they are not soluble in cold water. • Inks should be removed to create a clear recyclate.
7. Hotwash	
Goal	Deep cleaning the flakes to remove any remains of labels, inks and adhesives.
Working	The flakes are transported upwards in a cylinder, this cylinder is filled with hot and soapy water and contains a selection of peddles that rotate and agitate the plastics.
D4R Guidelines	• Labels other than PE labels are hard to separate, paper labels leave unwanted fibres. • Adhesives disrupt the recycling process if they are not soluble in cold water. • Inks should be removed to create a clear recyclate.
8. Density-separation	
Goal	Filters the flakes on density and thus makes a separation between the lighter PE and PP flakes and heavier PET or multimaterial flakes
Working	The plastic flakes are put into a water bath, rollers make sure the flakes are submerged and that they move in the right direction. While PE and PP stay afloat, the other materials sink down.
D4R Guidelines	• Materials that change the density of a PE flake are problematic, only mono-PE is desired. • Packaging with multilayers, barrier materials, coatings or fillers is more difficult to recycle
9. Drying	
Goal	Drying the washed flakes
Working	First pressing the flakes, then using hot air to dry them.
D4R Guidelines	-
10. Extrusion	
Goal	Melting the washed and dried flakes into new granulate.
Working	The washed flakes are heated to 220 degrees, when melted they can be shaped into new plastic granulates. The molten plastic is slowly transported to the end of the extruder by a rotating screw, where it is cut into tiny granulates.
D4R Guidelines	• Only monomaterial PE is desired in the recyclate. • Remains of inks, multilayers, barrier materials, coatings or fillers lower the quality of the recyclate. • Remains of labels do not melt with the PE flakes and lower the quality of the recyclate. • Oxo-degradable materials lower the quality of the recyclate. • Any remains of adhesives lower the quality of the recyclate.

Table 3: *Recycling processes for in the tool*

into new plastic granulates. Similar to the sorting process the processes of the PRP were discussed with experts from Attero to create an understanding of the full recycling system, its processes, and any disturbing packaging characteristics. The same considerations as with the sorting processes apply, where the complete recycling system of Attero had to be adjusted into a more simplified version. Again, the learning goals were used to filter out any irrelevant information. This resulted in a recycling process that consists of ten steps, an overview can be found in Table 3.

7.5 Overview

An important desire from the target group was to gain more overview of the sorting and recycling processes, this has also been incorporated into the requirements and the learning goals. To achieve this the tool contains a visual overview of the PSP and the PRP, here all the sorting and recycling processes and their respective order are depicted. Rather than using a flowchart to depict the overview it was chosen to visualize the overview as if the user sees the layout of the plant. Using small illustrations of the processes in this overview will make it easier for the user to place the individual processes within the sorting or recycling flow after they have read and seen the detailed explanation.

Furthermore, it shows the different material streams that enter and leave the processes. This creates awareness of the valuable streams that are sorted out of the waste. A schematic overview of the processes and the material streams is shown in Figure 9 in chapter three, the visual overview is shown in chapter nine. The schematic overview shows how the processes are connected to each other and what material streams are sorted out. In the PSP the 3D fraction that comes from the windshifters goes through three additional steps compared to the 2D fraction. Furthermore, it shows how a collection of NIR's is needed to sort all the different types of plastics, since each NIR can only be used to create two streams.

7.6 Design for Recycling guidelines

The KIDV Recycle Check for flexible plastic packaging is used to acquire the official design for recycling guidelines. The guidelines were implemented in the tool with help from both Attero and KIDV, to ensure correct phrasing. The KIDV guidelines are based on the practice of all waste treaters in the Netherlands, which creates a summarised overview of the current state of packaging recyclability. An unavoidable implementation gap exists between the waste treaters and the KIDV Recycle Checks. Waste treatment companies will first implement a new technology and only after proven effectiveness and wide implementation in the Netherlands such a new technology will be included in the Recycle Checks. This gap was also present between Attero and KIDV, in some cases Attero provided additional content beside the Recycle Checks. This consisted both of situations where Attero was able to sort out a certain packaging item, while the Recycle Check states that this packaging items is not sorted out, and situations where Attero could pinpoint packaging characteristics that are disturbing but that are not taken up into the Recycle Checks.

From the user study it became clear that the target group is looking for a future perspective, and thus would benefit from the additional knowledge that Attero can provide. However, since the tool will become openly available, and since packaging producers have no influence on where their packaging is treated, it can be misleading to mention the newest technologies when they are not representative for the Netherlands. Both the official KIDV guidelines as the additional content from Attero was labelled valuable and were chosen to be implemented. To clearly communicate the difference between the official guidelines of the KIDV and the Attero content, the guidelines are mentioned on the textual information page, while the Attero content is incorporated as additional comments in the illustrations of the processes.

This chapter made the translation from requirements to contents. All requirements were placed in five content themes for the tool: introduction, sorting, recycling, overview, and design for recycling guidelines. To link the packaging and waste industry in this tool, the right level of detail had to be found in communicating the information. By thoroughly analysing the waste processes with Attero and KIDV and comparing these with the needs of the target group a more simplified version of the waste processes was made.

8 Design and Functionality

Now that the content of the tool is formulated, the visual design process can start. The design process is an important step that translates the content into a pleasant and functional interface for the user. This chapter describes the different elements to create a prototype, including the structural and visual design rationale.

8.1 Creating a prototype

Where the informative and scope requirements where important for the previous chapter, in this chapter the usability requirements are implemented.

The tool is created using the free user interface design tool, Figma. Figma allows the prototype to be made interactive using buttons and hover-over items, this allows the user to engage with the tool and it also offers the possibility to create layered information. The illustrations are partly made in Figma and partly in Adobe Illustrator. The animations are made using Adobe XD.

The tool will be web-based and will be implemented on the website of Attero. A web-based implementation makes sure that the information is available to anybody that would benefit from it. A resolution of 1920x1080 is chosen since this is the most common screen resolution. It was decided to focus on a desktop version only and to not create a mobile version. Since the tool contains a lot of information, both textual and visual, the usability will benefit from a large screen.

8.2 Flow and navigation

Since the target group of the tool is rather broad, the intentions of the tool can differ per user. The tool is first and foremost designed for non-packaging experts, since the user study showed that these can benefit the most from this type of information. Nevertheless, the tool can be useful for packaging experts, perhaps more in an educational manner to educate the people/colleagues around them. To cater for both users the tool is designed in such a way that a first-time user will naturally follow the chronological order

of the waste processes, but once a user is familiar with either the tool or the waste processes, he or she can skip processes and navigate directly to the desired processes. To further accommodate a second time user a packaging characteristics page is made. Here all the packaging characteristics that can be problematic are listed and linked to the

Figure 16: *Tool structure*

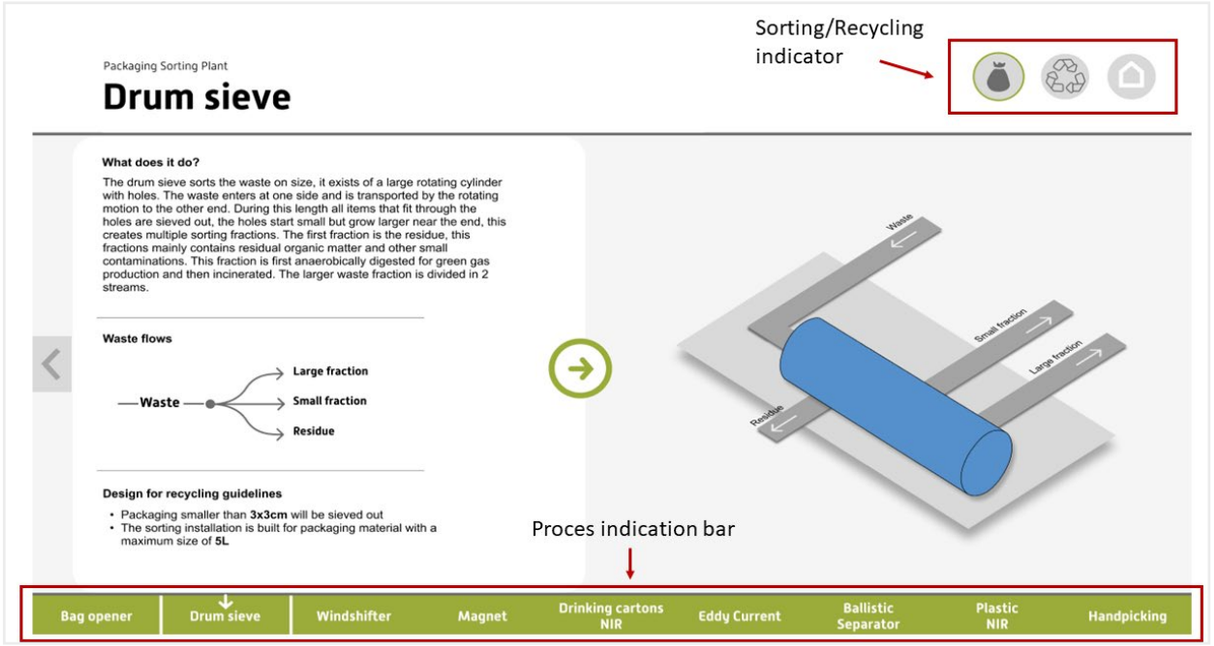


Figure 17: *Example information page*

processes where they are of effect. This way the user does not have to follow the chronological order of the processes but can navigate the other way around. The chronological flow of the tool is shown in Figure 16.

At any given moment the user will be able to see whether they are in the sorting or recycling flow thanks to an indication in the top right corner. Furthermore, they can see how far they are in the sorting/recycling process by looking at a green bar in the bottom which indicates what process they are currently viewing and where this process is located in the full sorting/recycling flow. These indications can also be used as buttons to navigate between the flows and processes, an example can be seen in Figure 17.

8.3 Visual language

To create a pleasant and attractive look for the tool a visual language is developed. The style of the tool is made to fit the style of Attero, to achieve this, elements of Attero's corporate identity are used. These include the font, graphic language and some of the colours.

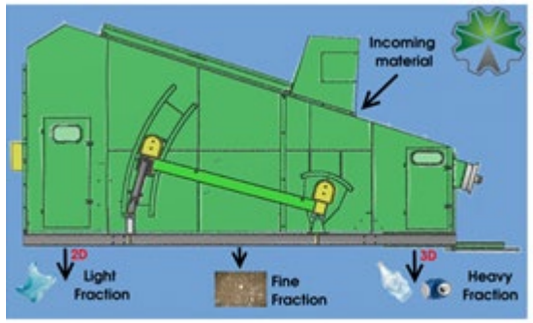
As mentioned in chapter five there is visual content available on waste treatment processes, either through videos on YouTube or through technical illustrations from machine suppliers, but this content has some shortcomings. Videos on waste treatment facilities do inform the viewers on the goal of the processes, but they do not always succeed in visualising the mechanical principles of the techniques. On the other side, the technical illustrations of machines do succeed in showing the mechanical working of a technique, but do not place the machine in the large picture of a complete recycling chain. Figure 18 shows a technical illustration and a video screenshot from a ballistic separator. In this example the technical drawing fails to show the overview of

8 Design and Functionality

the process. The video screenshot does show the process clearly, but the environment of a waste treatment is often messy, dirty and full which makes it hard to focus on the mechanical principles of the process.

For the illustrations of this tool a balance was found between showing the technical workings of the processes while also relating the individual steps to the complete sorting and recycling process. For most processes a 2D sideview proved sufficient to explain the process. By showing a sideview, the internal process, which is normally hidden inside the physical machine, is exposed. In some cases a sideview was not able to show the process, in these cases a 3D perspective was used or added.

The priority in designing the illustrations was to explain the function of each step, for this it was not necessary to portray the machine completely accurate, many elements could be simplified and details on buttons, frames,



Retrieved from https://www.parinisrl.it/en/portfolio/ballistic-separator/

Retrieved from https://www.youtube.com/watch?v=DASgKyaOoT4

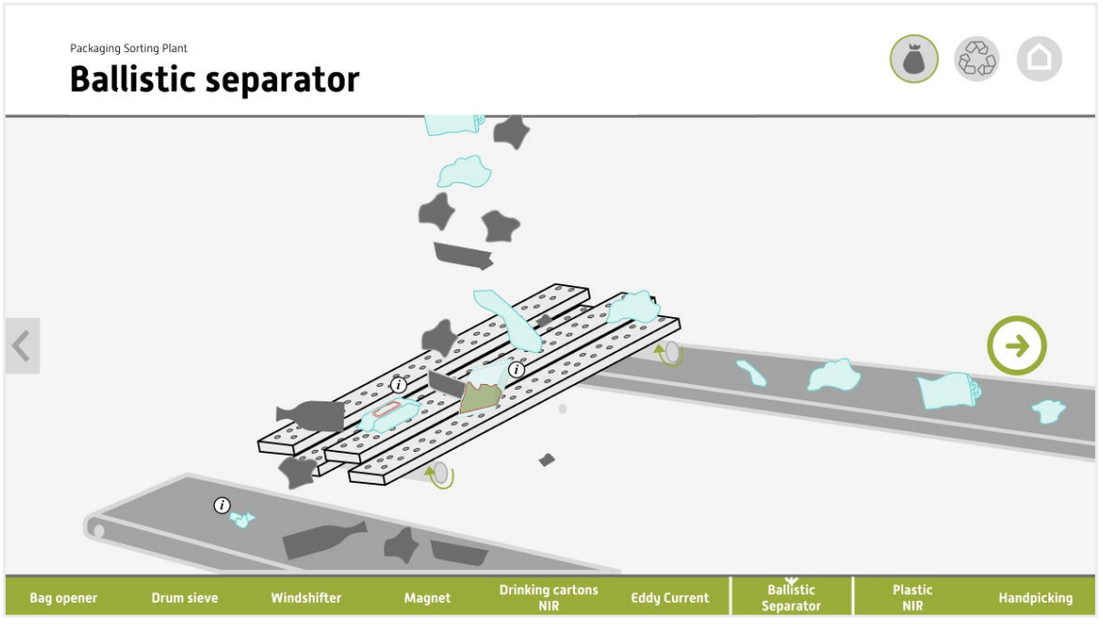


Figure 18: *Collection of visual content ballistic separator*

housing, were deliberately left out to focus on the inner workings of the machine. In reality large amounts of waste are processed at once, which result in a cluttered overview, for the illustrations fewer packaging items are visualized to be able to focus on the process. All illustrations are built up of a few simple elements. The factory elements consist of conveyor belts, dividers, and machines. These elements form the basis structure in which the packaging items are placed. A colour distinction is made between rigid packaging and flexible packaging, where the rigid packaging is shown in grey tones and the flexible packaging in light blue tones. In reality most plastic packaging items are transparent and have similar colors but adding a color distinction helped to emphasize the sorting processes into different materials streams. Given the focus of flexible packaging recycling at Attero it was chosen to give the flexible packaging a more “plastic” look while the rigid packaging is made grey.

Besides illustrations two animations were added in the tool, preferably all processes would contain an animation, but this was not found feasible within the scope of this research. Two sorting processes were labelled as more complex than the others, for these processes an animation was added to explain the working of the process in more detail. This was done for the ballistic separator and the plastics NIR. Whereas the other sorting processes work with familiar concepts like gravity, suction, and magnets these processes use less commonly understood physics, of which the working could not be explained fully with illustrations.

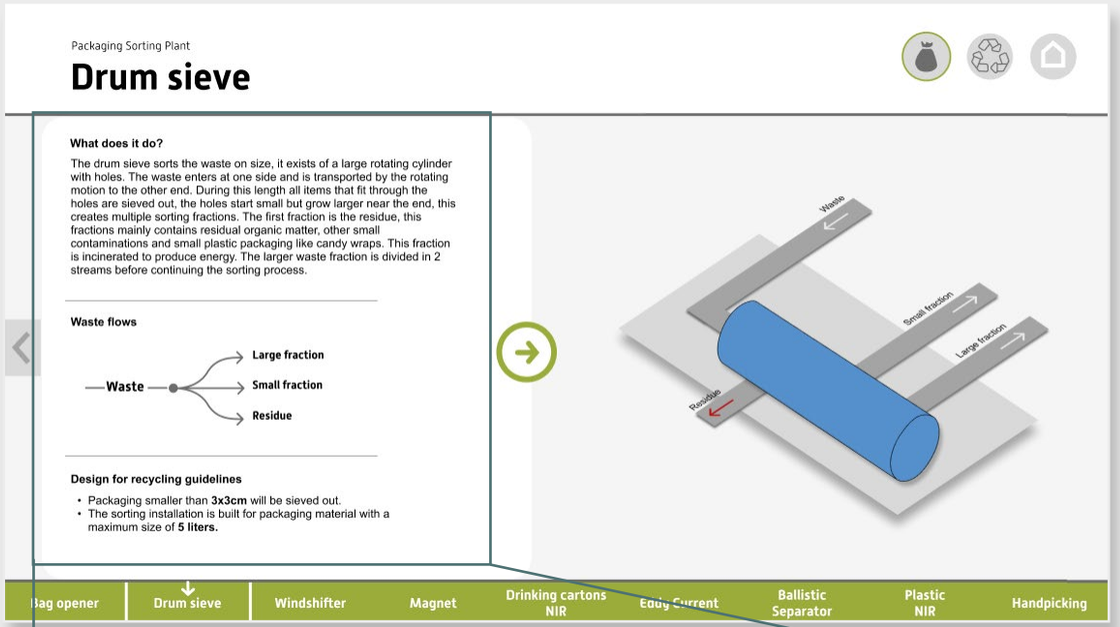
8.4 Page layout

The goal is to display the contents formulated in chapter 7 in a clear and concise way. Although the main goal of the tool is to present the waste treatment in a visual way, some textual explanation is necessary. Trying to fit both the textual information and the illustrations on one page proved difficult and created overfilled pages. To prevent this, the textual information and illustrations are displayed on separate pages. Each process is explained by both an information page and at least one illustration page. An example information page can be seen in Figure 19. Here the textual explanation is located on the left, and a preview of the corresponding process is shown on the right. The information page informs the user about the what the process does, which waste flows are created and what D4R guidelines are of importance.

The visual pages contain the same navigational features but now the complete page is used for the illustration of the sorting or recycling process, see Figure 20. In most cases one illustration was enough to explain the process, if not an extra page was added. Any desired explanation or the additional content from Attero that was described in chapter 7, will appear when the user hovers over the information dot with their cursor.

Designing the visual interface of the tool is an important step where complex information is made tangible and presentable for the target group. Creating an attractive and functional design will help with conveying the information. This chapter made the translation from theory to visual appearance.

8 Design and Functionality



What does it do?
The drum sieve sorts the waste on size, it exists of a large rotating cylinder with holes. The waste enters at one side and is transported by the rotating motion to the other end. During this length all items that fit through the holes are sieved out, the holes start small but grow larger near the end, this creates multiple sorting fractions. The first fraction is the residue, this fractions mainly contains residual organic matter, other small contaminations and small plastic packaging like candy wraps. This fraction is incinerated to produce energy. The larger waste fraction is divided in 2 streams before continuing the sorting process.
Waste flows
Waste
Large fraction
Small fraction
Residue
Design for recycling guidelines
Packaging smaller than 3x3cm will be sieved out.
The sorting installation is built for packaging material with a maximum size of 5 liters.

Figure 19: *Drumsieve information page*

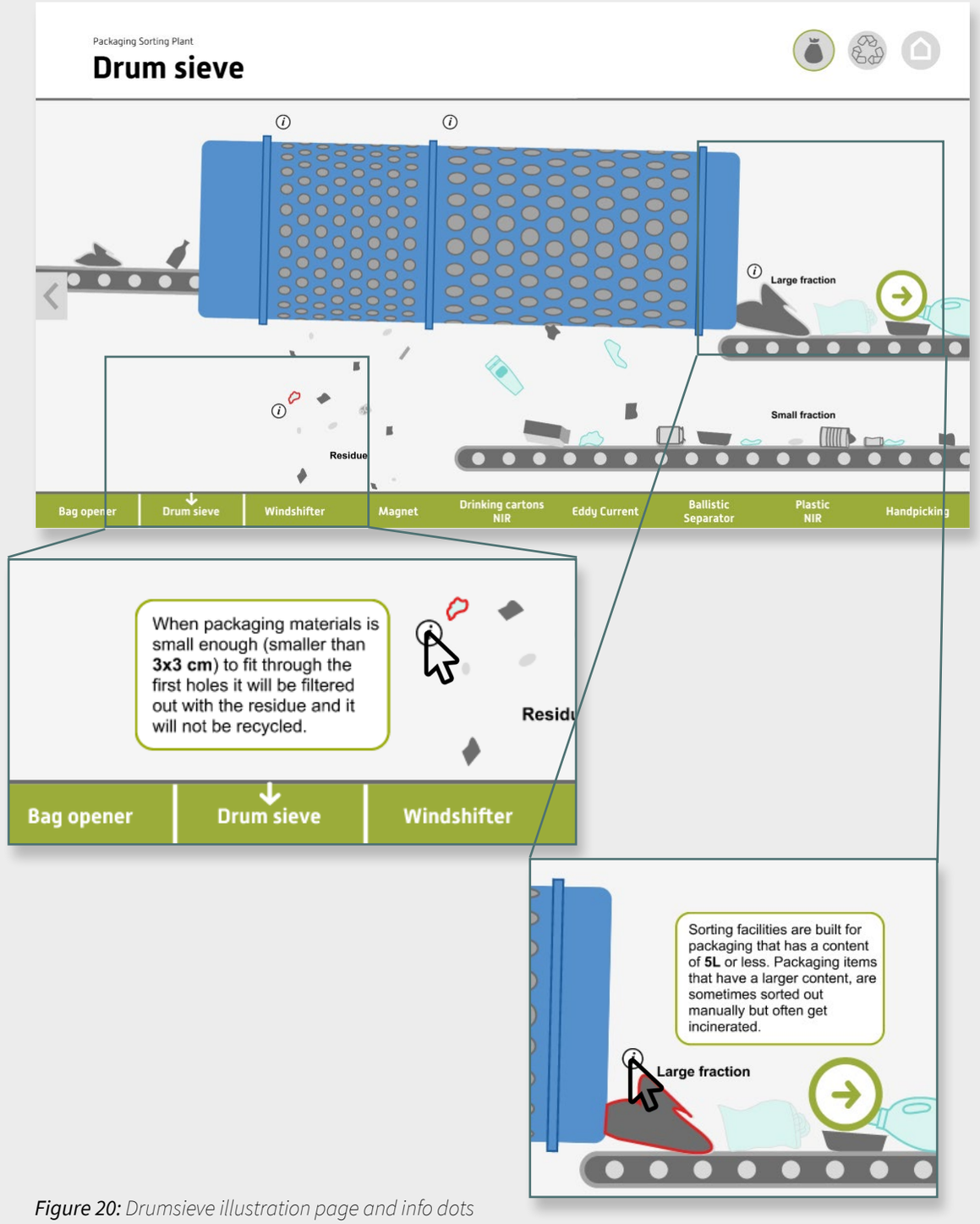


Figure 20: *Drumsieve illustration page and info dots*

9 Final Tool

This chapter presents the visual interface of the tool. Access to the complete tool can be found in appendix 5.

The structure of the tool is visible in Figure 21. the tool is divided in three parts, the introduction, the sorting process, and the recycling process.

The user is welcomed at the Landing page , after which they will be taken to the introduction page. After the introduction the user arrives on the home page where they can choose to see the sorting or recycling facility, also the additional sources can be reached through the more information page or the user can look up the packaging characteristics page. The interface of the tool will motivate the user to first explore the sorting facility and then the recycling facility. When a user returns to the tool, they will have the option to go to the recycling facility directly.

Once the user has selected the sorting facility, an overview of the facility appears. This shows all the steps of the sorting process and indicates the various flows of materials and their direction. The user can click on the steps to go directly to the selected process, for first time users the arrows and numbered processes indicate the start point and will prevent the user from accidentally skipping steps.

Once the user starts the flow, he/she will be directed along the sorting steps. As an example the windshifter is presented on the next page. First an information page is shown with textual information and a little image Figure 22. The text on the left explains the working of the sorting step, the different material streams that enter and leave the process, and the relevant design for recycling guidelines from the KIDV Recycle Checks. On the right side the same image of the windshifter that was used in the overview image is used. This way the user can recognize the step and place it within the flow of the whole sorting process. When moving the cursor over this image a preview of the more detailed illustration of the next page appears, Figure 23. At the bottom of the page a green bar is used to indicate the user at what step he or she is located. At the right top corner, the user can at any time return to the menu or the overview page from both the sorting and recycling plants

When the user has read the information, he/she continues to the visual explanation of the process, see Figure 24. The user can apply the before read information to understand the illustration. Any adidtional information about the process is given by the use of info dots. When the cursor hovers over these, a textbox appears and the corresponding item is highlighted to strenghten the message. The design for recycling guidelines were already shortly mentioned on the info page, but are explained in more detail on the illustration page. Here the textual information and the imagery come together to provide the link between design for recycling guidelines and the waste treatment.

This structure of pages is repeated for all the steps in the sorting and recycling proces. Some steps contain an extra page, because they needed more explanation. At the end of both the sorting and the recycling flow an overview page shows the results of the processes. At the sorting flow this overview shows all the different material streams that were sorted, at the recycling flow the overview shows the different products that can be made from the recyclate.

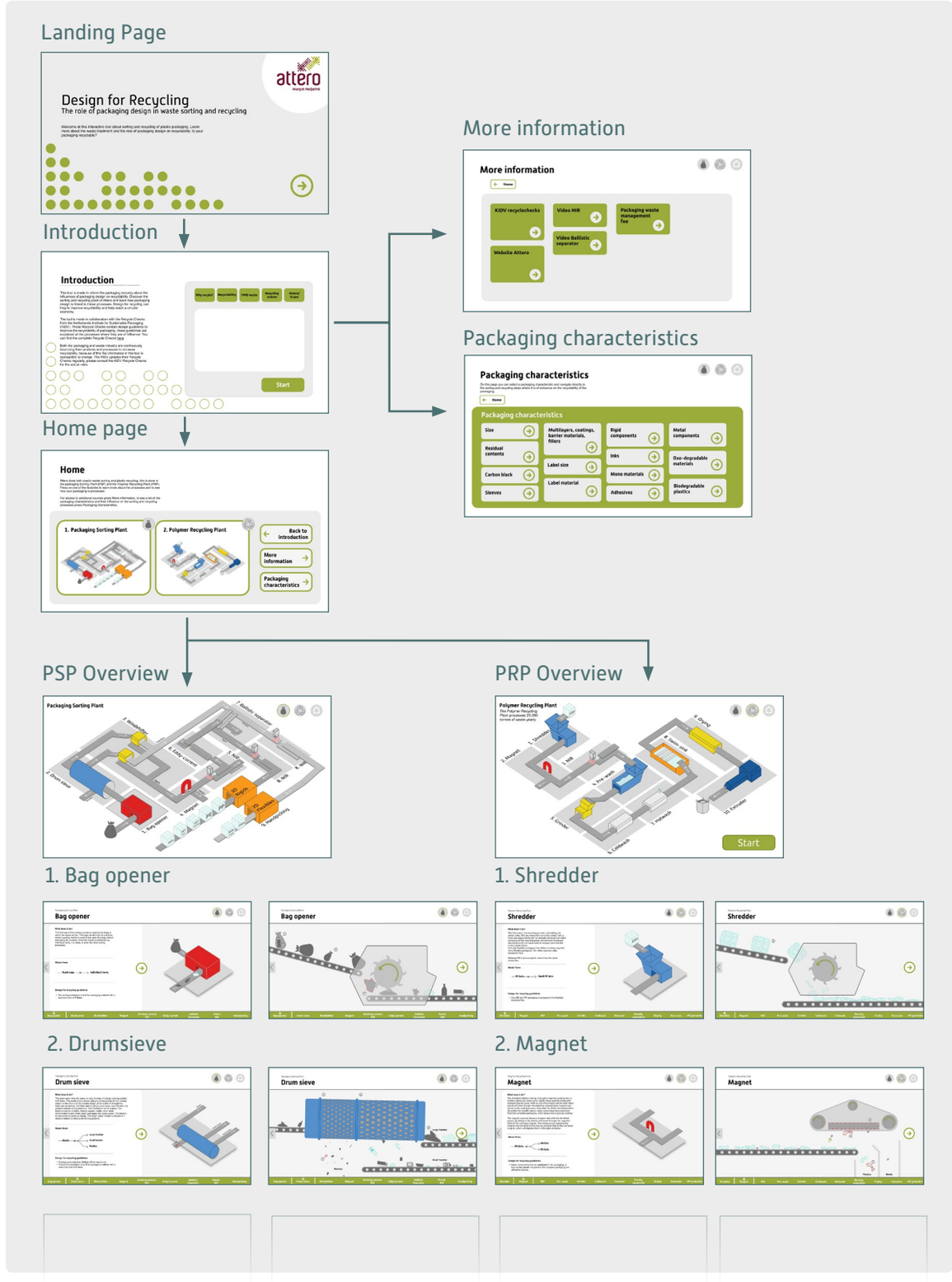


Figure 21: Structure of the tool

9 Design and Functionality

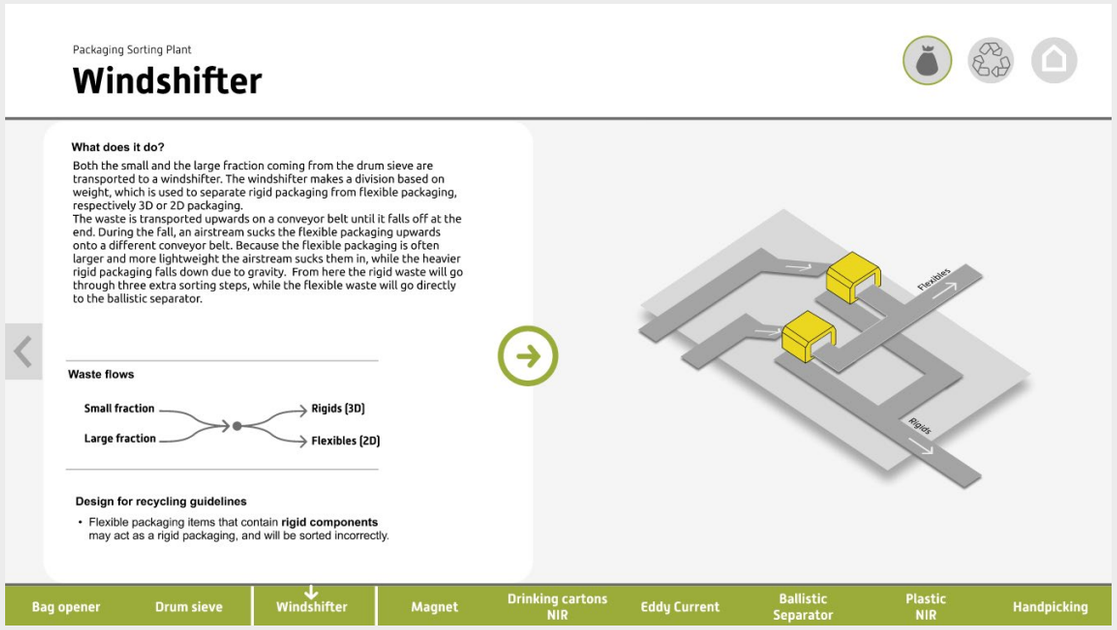


Figure 22: *Windshifter info page*

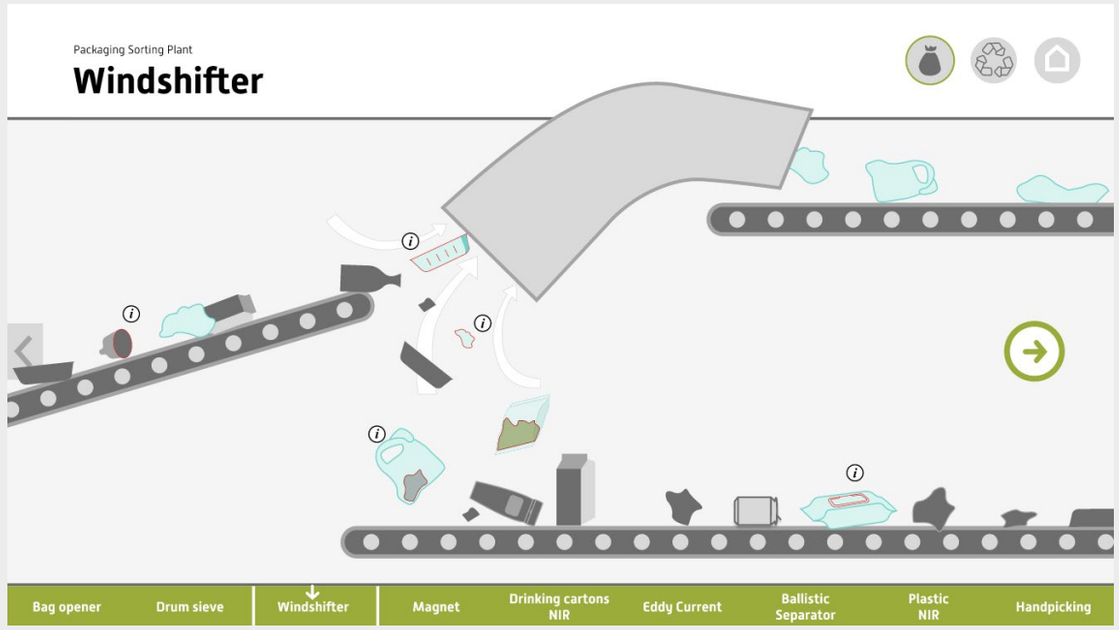


Figure 24: *WIndshifter illustration page*

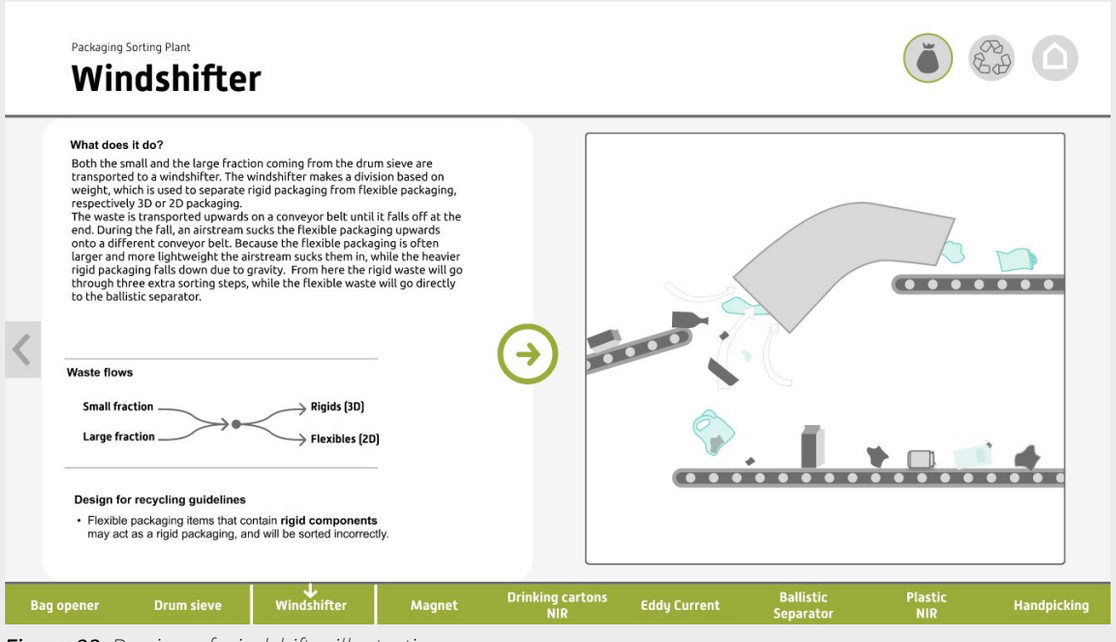


Figure 23: *Preview of windshifter illustration*

Part III

Validation

10. User test
11. Evaluation
12. Implementation

10 User Test

Now that a prototype of the tool is made it can be validated. In order to validate the functionality and the impact of the tool a user test is conducted with the prototype. The validation is divided in two parts, a user test with the target group on the usability, educational effect, and applicability of the tool, and an in-depth validation with experts in the overlapping area of packaging and waste treatment on the quality of information.

10.1 Test rationale and setup

The user test serves two purposes, it tests the functionality of the prototype as a working tool for Attero and it tests if the prototype fulfils the requirements and therefore answers the research question. In this chapter the results of the test and how they have been implemented in the tool are discussed. The next chapter will evaluate the tool on a broader scale and use the test results to see if the tool meets the requirements.

When executing the user test the prototype was almost fully functional, all sorting and recycling processes were included, the structure of the tool was complete, and the interactivity of buttons was working. All contents described in chapter seven were included, however not everything in their final form. Before doing the user test the tool was discussed with Attero, to check the validity of the waste processes and their textual explanations. Such a check was not done yet with KIDV, which resulted in a conceptual implementation of the D4R guidelines. Nevertheless, the tool was complete enough to be tested.

Because of the educational goal of the tool one of the main test aims was to see if the participants gained knowledge, both on the sorting and recycling processes and on design for recycling. To be able to test the knowledge gain of the test users it was chosen to use a self-reporting test method, where the participants indicate their own experiences. This was seen as a fitting method because of the broad target group. Since the target group covers the complete packaging industry, participants with different roles and knowledge levels participated. By using Likert scales the participants can rate the tool to their own experience, which allowed the use of the same questions for both an experienced recycling expert and a less-knowledgeable packaging designer. The test does not measure the absolute knowledge gain of the participants but rather their perceived knowledge gain. (Bhandari & Nikolopoulou, 2020)

User test

The goal of the user test was threefold, information on the usability, the educational effect and the applicability of the tool was collected. Furthermore, the option to leave additional feedback and comments was provided.

The test consisted of a questionnaire that was send to the interview participants from the user study, the questionnaire can be found in appendix 6. The participants were instructed to first go through the tool and then answer the questionnaire, which consists of five parts, an introduction, the usability questions, the educational effect questions, the applicability questions, and concluding questions.

Introduction

Before answering the main questions of the test the participants are asked to indicate their professional background and knowledge level on the waste treatment and design for recycling. Collecting this information will help with interpreting the results.

Usability

The goal of the usability test is to test the design and functionality of the tool. Is the user able to use the tool in its intended way without needing additional explanation? The test consists of seven questions that are based on the usability requirements and focus on the functioning, navigation, and interactivity of the tool.

Educational effect

Questions on the educational effect were asked to test to what extent the tool succeeds in educating the user on the sorting and recycling processes and the link between packaging design. The questions are based on the inform requirements and the learning goals. Besides testing the participants understanding of the contents of the tool, the participants can also indicate to what level the information in the tool was novel to them and if there were any processes that they did not understand after using the tool.

Applicability

In the applicability section the target group is asked if and how they see themselves using this tool in the future. The applicability questions are based on the scope and effect requirements and help to reflect on the effectiveness of the tool.

Expert test

In addition to the user test with the target group a test with experts in the overlapping field of packaging and waste treatment was done to assess if the information in the tool succeeds in linking the waste treatment processes to packaging design. This test functions as a verification on the correctness of the information. Since the tool will become available online it is important that the information is correct and in line with the existing guidelines.

10.2 Results (and implementation)

In total six people replied to the user test, this group existed of two recycling experts, one packaging designer, one sustainability manager, one CEO and one CE researcher. Five out of six have visited a sorting facility, four out of six have visited a recycling facility. The knowledge level of the participant of the waste treatment processes beforehand was quite high, all participants were already familiar with most of the processes that are explained in the tool. Lastly, five out of six participants were familiar with the KIDV Recycle Checks.

The test with experts consisted of a questionnaire and was answered by three people from KIDV. Unfortunately, no other experts participated in the test, which would have created a more divers response. Given that KIDV has been actively involved in the process of making the tool, their opinion was likely biased. In order to try to minimise the bias a third KIDV employee, that had not seen the tool before, was asked to participate as well. Despite their bias their feedback was still valuable, and they were still able to make an assessment on the quality of information.

In general, it took the participants between 10-20 minutes to go through the tool.

10 User Test

The results are indicated with the following color scheme.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	Not applicable

Usability Results

1	The tool functions easily	
2	The interactivity of the tool was clear and understandable	
3	It was clear how to navigate through the tool	
4	I had enough pre-knowledge to understand the language in the tool	
5	It was clear how to navigate between the overview pages and the sorting and recycling streams	
6	I was able to navigate back to the home menu	
7	I could easily differentiate between the sorting and recycling flow	

Table 4: Usability test results

Usability

The results (Table 4) show that most participants found that the tool functions easily, the interactivity was clear, they possessed enough pre-knowledge and for most participants it was clear how to differentiate between the sorting and recycling flows. The navigation of the tool was not clear to all the participants.

To improve the navigation an explanatory overlay page was added at the start of the tool that shows the function of the home and overview buttons.

Educational effect

From the results (Table 5) it became clear that there was a positive educational effect on the sorting and recycling processes. Most participants learned something new about the sorting process and all participants learned something new about the recycling process. There was no educational effect on the design for recycling guidelines, however, the participants did indicate that the tool is a useful addition next to the KIDV Recycle Check. The participants do indicate that they have a good understanding of the effect of packaging

Educational effect results

1	I gained new knowledge about the waste sorting processes	
2	I gained new knowledge about the recycling processes	
3	I gained new knowledge about design for recycling guidelines	
4	I feel like I now better understand the design for recycling guidelines	
5	The tool is a useful addition next to the KIDV Recycle Checks.	
6	I now have a good understanding of the waste sorting processes	
7	I feel like I can explain what packaging characteristics are disruptive in the sorting process	
8	I understand the effect of packaging design on the sortability of packaging	
9	I now have a good understanding of the plastic recycling processes	
10	I feel like I can explain what packaging characteristics are disruptive in the plastic recycling process	
11	I understand the effect of packaging design on the recyclability of packaging	
12	I am now able to link a design for recycling guideline to the sorting or recycling process where it is of influence	
13	I feel like I have enough background knowledge to understand the tool	
15	It was clear to me that the tool only covered PMD waste	
16	It was clear to me that the recycling process was specifically aimed at flexible plastics	
17	The tool helped me better understand the role of packaging design in recyclability	
18	The tool motivated me to improve packaging recyclability	
19	I now have a clear view of the material flows that go in and out of the waste sorting process	

Table 5: Educational effect results

10 User Test

design on packaging recyclability, but it cannot be proven from this test to what extent the tool added to this understanding. The tool succeeds in creating an overview of the material flows.

From additional questions it became clear that the most participants found the illustrations and animations the most informing element in explaining the sorting and recycling processes.

Improvements could be made on communicating that the scope of the tool only covers PMD waste and flexible packaging. All participants indicated to understand the processes, there were none they did not understand. A large difference was seen to what extent the information was new to the user, this ranged from 10% to 70% with the majority of answers being 40% new or less.

Results from this section that have been implemented in the tool are a more elaborate and clear description of the scope. This is done in the introduction of the tool.

Applicability

All participants indicated that they could see themselves use this tool in the future (Table 7), mostly to educate people around them, but some also see themselves use it to gain knowledge on waste and recycling. The results (Table 6) show that the tool scored positively on its potential to act as a bridge between the packaging and waste industry, to improve the implementation of D4R guidelines, and to improve the communication across the waste chain.

The tool scored both negatively and positively on its potential to influence the participants decision making in packaging design/buying. Given the background of the participants, which consisted of only one packaging designer, this negative score could also be the result of an inapplicable question for several participants.

When asked if this tool could function as a replacement for a real life visit the general conclusion was that it could do so to some extent. The tool was seen as a good introduction before visiting a facility and it could be used to create awareness, however it could not replace a real visit. It lacks interaction and the possibility to ask questions, furthermore it does not replace the seeing, smelling, and feeling of the facility and cannot present the full concept of a waste treatment facility.

I could see myself using the tool for:

Gaining insight in the waste sorting processes	■	■				
Gaining insight in the plastic recycling processes	■	■	■			
Basing packaging design on it						
Educating people around me	■	■	■	■	■	■
I do not see myself using this tool						

Table 7: Intended use

Applicability Results

1	I can see myself using this tool in the future	■	■	■	■	■	■
2	Using the tool will influence my decision making in packaging design/buying	■	■	■	■	■	■
3	The tool can be used effectively to improve the recyclability of packaging	■	■	■	■	■	■
4	The tool acts as a bridge between the packaging industry and the waste industry	■	■	■	■	■	■
5	The tool will improve the implementation of design for recycling guidelines	■	■	■	■	■	■
6	The tool will improve communication and collaboration across the waste/packaging chain	■	■	■	■	■	■
7	I expect to look up/use the tool again in the future	■	■	■	■	■	■

Table 6: Applicability results

10 User Test

Quality of information Results

1	The illustrations in the tool clearly explain the sorting and recycling processes.			
2	The two animations in the tool clearly show the functionality of the sorting processes.			
3	The illustrations in the tool realistically explain the sorting and recycling processes.			
4	The tool provides a clear overview of the plastic waste sorting and recycling processes.			
5	The tool informs the users about the connection between D4R guidelines and the waste treatment.			
6	The KIDV Recycle Check guidelines are clearly linked to the associated sorting and recycling processes.			
7	The tool educates the users on the reasoning behind D4R guidelines.			
8	The tool is representative for all waste treaters and recyclers in the Netherlands.			
9	The tool is representative for the European market.			
10	The tool is suitable for people without expert/with basic packaging or recycling knowledge.			
11	The tool is educational for people with expert packaging knowledge.			
12	The tool has potential to lead to better implementation of design for recycling guidelines.			
13	The tool will lead to more communication and collaboration across the waste chain.			
14	The tool is a novel addition to the field of design for recycling			
15	The tool is a useful addition to the field of design for recycling			
16	The tool illustrates the complexity of sustainable packaging within the waste chain			
17	The tool acts as a bridge between the end of the waste chain and the beginning of the waste chain.			

Table 8: Quality of information results

Quality of information

In general, the quality of information was positively rated, and the tool achieved most of its goals (Table 8). The experts confirmed that the tool clearly and correctly illustrates the sorting and recycling processes and that the tool succeeds in linking the D4R guidelines to waste treatment. It was seen as a novel and useful addition to the field of D4R.

A few aspects on which no confirmation could be given were if the tool was representative for the Dutch and European market. Mixed answers were given on the question if the tool could lead to more collaboration and communication between the packaging and waste treatment.

From the user test it can be concluded that the tool functions well and that the target group is able to use it successfully. The general reaction toward the tool was positive and it was seen as a useful addition to the field of D4R, which all participants could see themselves use again in the future. The educational effect on the waste treatment processes was confirmed but the educational effect on the D4R could not be proven. To what extent this influences the impact of the tool is described in the next chapter.

11 Evaluation

This chapter reflects on the requirements that were defined for the tool. By analysing the results from the user test an assessment can be made to what extent the tool meets the requirements. With this evaluation is can be checked if the tool succeeds in filling the information gap that was formulated in chapter five.

11.1 Requirements

The inform requirements stated that the tool should provide an overview of the plastic waste sorting and recycling processes, and that the functioning of these processes should be made visual. The complete sorting and recycling processes of Attero were analysed and then simplified to provide a suitable overview for the target group. From the user test it became clear that all processes were well understood, and that the visual representation helped with this.

The other main topic on which the tool should inform the user is design for recycling and then specifically the link between D4R and the processes of the waste treatment. Through linking these two together the users were to be educated on the reasoning behind the D4R guidelines. All D4R from the KIDV Recycle Check for flexible plastic packaging are implemented in the tool and are linked to their associated sorting and/or recycling process. This step was verified by KIDV and Attero so it can be concluded that they were correctly implemented. From the user test it cannot be concluded that the users gained new knowledge on or an improved understanding of D4R guidelines, the users did indicate to understand the effect of packaging design on recyclability. It should be noted that the participants of the user test already had a good understanding of the waste treatment and design for recycling, which could explain why no educational effect was measured on the D4R guidelines. The knowledge level of the target group varies largely between packaging experts and roles that have less extensive knowledge, for example buyers and marketeers, it is therefore logical that the latter will be more easily educated by the tool. In order to make the tool suitable for multiple users, much of the background information is provided in additional information dots, so that an experienced user can skip them.

From this it can be concluded that the tool succeeds in informing the user on the sorting and recycling processes, the D4R guidelines and the link between them. To what extent the user is actually educated on these topics depends on their pre-knowledge, the educational value is naturally higher for users that are less experienced in the topic of packaging and waste.

11.2 Scope

The scope of the tool was set to be aimed at suppliers, producers/designers, and retailers of packaging, and to be suitable for people without expert packaging or recycling knowledge. The fact that the user test group, which was quite knowledgeable, learned something new about the waste processes in can be concluded that less knowledgeable users will be able to learn even more. The participants of the test indicated that they had enough pre-knowledge to understand the tool. All in all, it can be concluded that the tool is fit for the intended target group.

The tool was intended to cover the Dutch market, and where possible be EU oriented. No clear distinctions have been made in the tool to what extent the processes cover a Dutch or a European market. Since KIDV will develop a new version of the tool it was decided to keep the processes Attero specific. However, since all waste treaters use the same techniques, the tool is generally representative for the Netherlands apart from any plant specific differences. According to KIDV and Attero the tool is representative for the Netherlands.

The rigid plastics have been taken into account in sorting, since they do make up a part of the PMD waste, the recycling process is only focused on flexibles.

11.3 Usability

The usability requirements stated that the tool should be openly accessible. The tool has been available on the website of Attero since the 6th of March, here it will stay for a period of several months. Once the e-learning module of KIDV will be published, the Attero tool will be taken offline to not provide double sources of the same information. Furthermore, it was stated that the tool should provide easy navigation and allow the user to complete the tool on their own pace. Since the tool is web-based and can be used individually, the user has the option to complete the tool on their own time. Any navigation problems have been adjusted based on the result of the user test and now it can be assumed that it works well. Layered information was built into the tool to provide optional in-depth knowledge on complex cases. Lastly, the requirements mentioned the need for the users to think for themselves, since there exists no perfect sustainable packaging. The tool is not made to provide tailored advice to packaging designers. Because of the more general approach in visualizing the waste treatment the users will have to apply the information to their own practices.

11.4 Effect

Lastly the requirements described the desired effect of the tool to encourage implementation of D4R guidelines and to encourage communication and collaboration across the chain. From both the user and expert test, it became clear that the tool has potential to meet these requirements. The tool itself is already a means of communication between the packaging and waste industry, any interaction that follows from using the tool will strengthen the collaboration between the two industries. As to an improved implementation of D4R guidelines, one third of the participants indicated that the tool motived them to improve packaging recyclability. The users also indicated that they could see the tool help with improving the implementation, however, when asked if the tool would influence their decision making in packaging design, positive, neutral, and negative answers were given. To put these results into perspective, the user test group consisted of only one packaging designer. To fully answer these requirements, it is recommended to do another test where the users can implement the tool first and then reflect on its added benefit after a certain time of use.

It can be concluded that the tool fulfils most of the requirements. It has been published on the website of Attero which proves its technical feasibility. The prototype is functional, and the target group was able to effectively use it. The tool covers the intended information and thereby informs and educates the users, the scope of the tool is clearly described. The effect that the tool will have in encouraging collaboration across the chain and an improved implementation of D4R could not be proven yet, but the potential to positively effect these topics is there and can be explored over time. These conclusions are used to provide an implementation advice for both Attero and KIDV

12 Implementation

Now that the tool is finished and it has been proved feasible according to the user test and evaluation, the tool can be implemented. The tool has already been implemented by Attero, advice on how they can maximise its effect is described. Furthermore, this chapter gives advice on how the tool can best be implemented at KIDV.

12.1 Implementation at Attero

The tool has been presented and published on the website of Attero on the 6th of March, here it is openly available. The tool was presented though a webinar where Attero, KIDV, and thirty people from the packaging industry were present. During the webinar a short presentation was given to explain the research rationale and the development of the tool. Then the tool was shortly introduced and presented, after which an interactive conversation was held where the attendants could ask questions, and these were then answered with the help of the tool.

Because Attero does not have the intention to keep the tool up to date, and because KIDV will at some point publish their version of the tool, the period of implementation is temporarily. For now, it is recommended that Attero uses this tool to inform their network about the importance of D4R in packaging. They can use it as a replacement for the guided tours they give in their facilities, but it is preferred to use it in addition to the tours. For example, when they receive a first request from the packaging industry, the tool can act as a great introduction into the waste treatment, after which further contact can emerge.

Something to keep in mind is the fact that Attero is spreading information about D4R guidelines, whilst they are not an expert on this topic. It is therefore important to clearly state that they are providing the perspective of the waste treatment and that they are not offering an alternative to the Recycle Checks. This message in already incorporated into the tool but it is advised that Attero emphasized this message when they are using the tool.

12.2 Implementation at KIDV

The developed tool in this research will not be implemented by KIDV as is but serves as the base on which they will develop their new e-learning module. The e-learning module will be an in-depth subpart of their existing E-learning module on the waste treatment, which is part of their training on sustainable packaging. This training program is paid, which means the e-learning will not be openly available.

It is advised to research how some of the visual elements could be implemented in the Recycle Checks. Because KIDV is the organisation who provides the Recycle Checks, they have the option to strengthen the link between the waste treatment and the D4R guidelines even more, by aligning their information sources. Where the tool links the D4R to the specific sorting or recycling processes, future Recycle Checks could link the sorting and recycling processes to the guidelines.

It is advised that Attero makes optimal use of the tool for as long as it is online by actively sharing it with their connections and implementing it in their current practices of informing clients about the waste treatment. For KIDV it is interesting to research how the visual elements of the tool could also be used to strengthen the Recycle Checks.

Discussion

This research resulted in a tool for Attero, and thereby the waste treatment industry, to contribute to improved design for recycling implementation in the packaging industry. All research is executed within a defined framework, and therefore knows limitations. In the discussion reflected is on both the relevance of the research and its limitations.

The tool's position the field

Because the field of sustainable packaging is such a complex one, it can be questioned if it is wise to add another source of information on the topic of design for recycling. A desire for overview was expressed by the target group, and adding another source of information, next to the national and European sources on D4R could create confusion to what source is leading. The goal of the tool is not to take over from the Recycle Checks and to emphasize the perspective of the waste treatment above other perspectives, but rather to strengthen the current D4R guidelines. Luckily, this limitation has been partly solved by the collaboration between Attero and KIDV. KIDV will remake this tool into one of their e-learning modules. By doing this the message of the tool shifts from Attero to KIDV, solving the beforementioned risk. This will also make sure that the tool will be updated, and that the information is topical. For the period of time that the tool will be openly available on the website of Attero, the tool, and Attero should make clear what the goal of the tool is.

This tool has been developed for Attero, thereby focussing on their specific sorting and recycling processes. The Dutch waste treaters work on a similar level, which gives the tool the potential to represent the whole industry instead of only Attero. Not only does this broaden the reach of Attero, it also strengthens the impact of the tool, since packaging designers do not have influence on where their packaging will get treated, so a national point of view is preferred. Although the waste treatment processes in the Netherlands are largely similar among different waste treaters, differences between plants will remain and the tool should state this clearly to prevent incorrect interpretations. Considering the waste sector as a whole would add to the credibility of the tool. Since Attero is one of the larger, and more advanced waste sorters, it was however chosen to not spend time and effort on researching other waste treaters Once again, the collaboration with KIDV will solve this limitation, because they will present the tool for all Dutch waste treaters.

The tool focusses on recycling, which is located at the bottom of the waste hierarchy and thereby promotes the production of recyclable packaging. The tool should however not be used to justify overuse of packaging, solely because it is recyclable. Attero and KIDV hold responsibility in realistically presenting the value of recycling in a CE.

The information in the tool represents the current state of sorting and recycling processes. When a packaging designer learns that their packaging is not recyclable, but they are not in a position to change their packaging due to critical functionality demands. It should not mean that the quest for more sustainable packaging ends there. Further research should be motivated, from both industries.

The role of Attero

Attero is not a packaging expert, and therefor comes short in fully understanding the considerations that packaging designers make during development. To prevent the spreading of inaccurate information on packaging development, it was chosen to stay in accordance with KIDV, so that the packaging information is credible. This lack of expertise resulted in a more general focus of the tool, which does not allow producers a final concluding answer on their packaging dilemmas. Noting that the questions remains if a final answer on what packaging is the most sustainable even exist. It would be very helpful to give the packaging industry a more specific option in the tool, where they could select their packaging type and see fitting information for that. The lack of this feature does not reduce the value of the current tool; however, it just means that the users of the tool have to apply the output of the tool in their own frameworks.

This tool communicates the perspective of the waste treatment, it should however not be interpreted as a way of putting the responsibility of creating more sustainable packaging at the beginning of the chain. The waste treatment is part of the transition as well.

Method

The coding of the interview results was done quite 'casually' because this data collection was not the main aim of the research and therefore was not supposed to take too much time. Because of this the data was interpreted in a loose matter and not an exact manner. It was not possible to extract exact numbers from the data, rather indications.

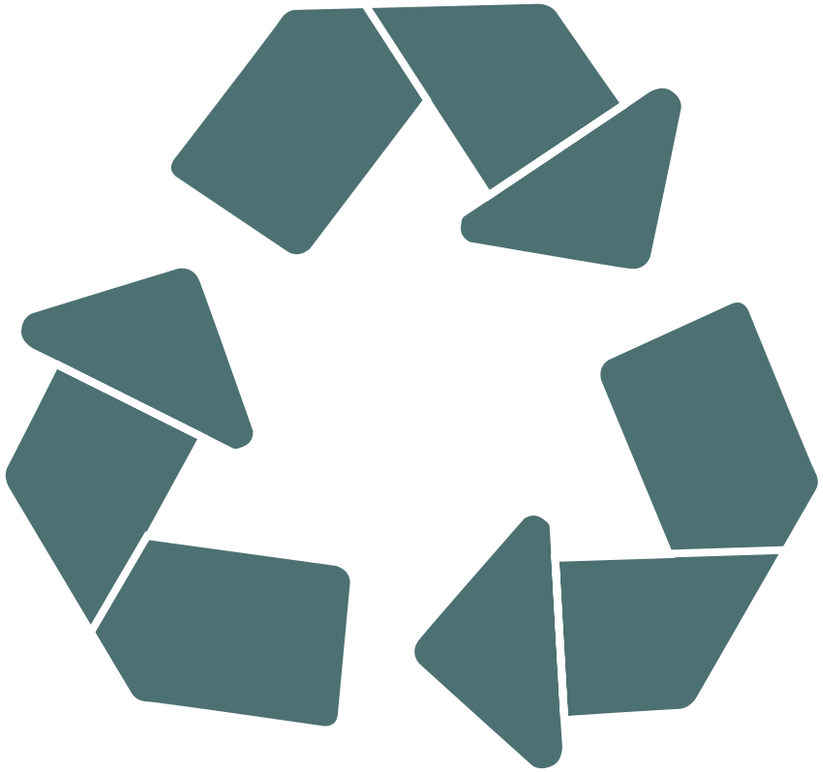
In part III of the report the tool was validated with a user test. The relatively small respondent group of six people did provide a diverse collection of players in the packaging industry but held a relatively high knowledge level and did not contain many non-packaging experts. A lack of educational effect on the D4R guidelines was measured, which might be explained by the high knowledge level of the participants, and the underrepresentation of non-packaging experts. Another possible explanation for the lack of educational effect on the D4R guidelines is the fact that the KIDV guidelines were not implemented in a final state during the user test. this could also explain the lack of educational effect on. No statistical analysis can be done on these results.

Circular context

The importance of a CE, and an integral implementation of sustainability were central in this research. By creating a tool from the waste treatment perspective specifically, it was however inevitable to simplify some aspects of the chain wide perspective to enable decision making. The challenge of a CE is that, although the need for a chain wide perspective in necessary, it is impossible to make decision while covering the whole chain. Within a constantly moving and changing system it is necessary to zoom in, to limit the scope, so that specific choices can be made, even though they might be incomplete. In this research, first the broader context was explored, to afterwards be able to filter out the less relevant aspects and to focus on the interaction between the packaging industry and waste industry. The dangers of this are that the end result is not re-evaluated within the circular mindset. It is needed to explore the limitations of the tool within the system and to know how to work further from them, this awareness will allow collaborations with other tools to strengthen the impact.

This tool will not solve the sustainable packaging problem by itself, a truly CE demands a holistic approach and cannot be achieved by solving packaging recyclability only. The implementation of sustainability is dependent on more than tools, it requires the willingness of people too. This tool cannot guarantee implementation of design for recycling guidelines, but it can help to facilitate implementation by bridging two industries and creating awareness among the target group.

As presented in the theoretical framework, sustainability is a broad and complex term that differs per context. Not only industries, but also individuals have varying understandings of what is sustainable. This understanding will inevitably affects one's approach to reach sustainability, including this research. The perception of sustainability of the author has inevitably influenced the tone of this research, resulting in the risk of confirmation bias. Therefor it is necessary to also consume this research with a critical view and to once again define sustainability, for oneself, and for the context.



Conclusion

This research explored the potential added value of the waste treatment perspective in improving design for recycling implementation in the packaging industry and then translated this into a tool for Attero which can facilitate improved implementation. First a theoretical framework was established to fully understand the context of the problem, from there the tool was developed and lastly the tool was evaluated and tested.

Understanding the context

The first part of this research was aimed to understand the potential of the waste treatment perspective in improving design for recycling implementation. By analysing both the packaging industry and the waste industry within a CE context, it was found that they do not sufficiently align to create an effective recycling system. An effective recycling system demands efficient infrastructure, modern recycling technologies, collaboration between stakeholders and recyclable packaging. Since the Netherlands has one of the more modern, effective, and elaborate recycling systems, this creates a large potential to improve packaging recyclability through communication and design. The different perspectives within these industries on sustainability and recyclability complicate their implementation and cause confusion. To combat the confusion as to what is a recyclable packaging among the packaging sector, design guidelines exist. Current guidelines on D4R, published by KIDV, inform the packaging industry about what packaging is recyclable, but these guidelines fall short in explaining why certain packaging is recyclable, creating an information gap. The sorting and recycling processes lay at the root of the guidelines and could help the packaging industry understand the importance of D4R. The hypothesis from the information gap was confirmed by researching the industry perspective through a user study with the intended target group. This confirmed the lack of knowledge on the waste treatment perspective and the potential added benefit of visually educating the packaging industry on the waste treatment processes. The result of the first part was the incentive to develop a tool that educates the packaging industry about the link between the sorting and recycling processes and packaging design, using the Recycle Checks of KIDV.

Developing the tool

In the second part of the report the requirements for the tool were translated into a prototype. Together with Attero the sorting and recycling processes were simplified to present an accurate and understandable overview of the waste treatment. First, textually explaining the goal, the working, the sorting fractions, and the related D4R guidelines, to then visually showing the process, while highlighting some of the previously mentioned textual information and D4R guidelines, was effective in informing the user. The combination of textual and visual information succeeded in linking the sorting and recycling processes to their related D4R guidelines from the KIDV Recycle Check, emphasizing the importance of packaging design in relation to recyclability. Adding interactivity to the prototype, using navigation buttons and hover over information dots, allowed the user to specifically look up the information that is relevant to them.

Validating the concept

In the last part of the report, the prototype was evaluated and improved before implementing it on the website of Attero. By means of a user test, the tool was tested on its educational effect, usability and applicability. The results showed that the tool satisfied the intended goal and succeeded in educating the user on the waste treatment processes. An improved understanding of the connection of the sorting and recycling processes was created but no educational effect on the D4R guidelines was found. To what extent the user is actually educated on these topics depends on their pre-knowledge and the educational value is naturally higher for users that are less experienced in the topic of packaging and waste. This relates to the applicability of the tool, which is expected to be highest for non-packaging experts that are not yet familiar with the waste treatment, although more knowledgeable test participants also indicated to see themselves using the tool in the future.

Furthermore, the quality of information was approved by experts in the overlapping field of packaging and waste, who indicated that the tool was a novel and useful addition to the field.

Finally, to answer the research question how the waste treatment perspective can contribute to supporting design for recycling implementation in the packaging industry, it can be concluded that visualising the waste treatment and linking the sorting and recycling processes to D4R guidelines is an important factor in improving the recyclability of packaging. This perspective fills the information gap within the D4R guidelines, it communicates novel information that neatly fits and strengthens the existing guidelines. An absolute answer on what is the most sustainable packaging does not exists but an improved understanding of the underlying reasons for the existing D4R guidelines can help the packaging industry to navigate their sustainability choices and ultimately increase the implementation of D4R methods, bringing us one step closer to a CE. Next to that, the importance of communicating this type of information through an interactive visual tool can be confirmed. Not only Attero has implemented a fully functional tool in their website, but also KIDV, the Dutch expert on D4R guidelines, has taken over the concept of the tool and will ensure that this type of information is available for the packaging industry through their e-learnings.

Recommendations

This thesis exists within the scope of Attero, with the goal to create cleaner waste streams and improve design for recycling implementation. This is however a goal that reaches beyond Attero. This chapter describes the possibilities for an improved tool and further research.

Recommendations for tool improvement

Firstly, providing animations for all processes would improve the consistency of the tool and would further increase the understanding of the waste treatment facilities. Showing the movement of the processes leaves less room for wrong interpretations. Furthermore, it would be interesting to investigate the use of more interactivity in the tool. Specifically using interactivity to quiz the user and motivate them to think about what they are reading and seeing. This could improve the educational effect of the tool.

It is also recommended to investigate to what extent the tool could provide more detailed advice to the users. As mentioned before, the transition towards a CE demands innovation from both parties. A recurring question was which industry should adapt to gain improved recyclability, the waste or packaging industry? This will differ per situation and it would be very valuable if a future tool could also indicate what changes are fir for each industry. Continuing on the aspect of providing more specific information, it would be valuable for the packaging designers to provide a more specific flow through the tool, based on their packaging type. Now they have to see the complete waste treatment, while maybe just a tiny bit is relevant for their packaging type. A future tool with the ability to specify packaging types could improve the usability of the tool.

Lastly it is recommended to further investigate the potential of the tool in a European context. The current waste system is very fragmented across the continent, which leads to country specific guidelines. Creating a tool that would present the different guidelines next to each other, linked to their respective countries would create a much-desired overview for the packaging industry.

Implications for further research

Besides improvements on the content and functionality of the tool the general concept of educating people about the waste treatment also has a potential beyond this thesis.

The waste treatment is an essential actor in a CE, and it could be interesting to further research the value of their perspective. This research focussed on using the waste treatment perspective to improve D4R implementation in the packaging industry, but the added value of this perspective is not limited to only one industry. In a CE all resources must be kept in the cycle, which means that all industries can benefit from understanding the waste treatment perspective and considering end-of-life in their design and production processes.

Besides broadening the scope on an industry level, the scope of the target group can also be broadened. This research was focussed on educating the beginning of the waste chain, the suppliers, designers, and retailers of packaging. Consumers have not been taken into account but also have an effect on the recyclability of packaging with their purchasing and disposal behaviour. It is recommended to research if and how the perspective of the waste treatment could influence buying and disposal behaviour of consumers to improve packaging recyclability.

References

A. Delemare Tangpuori, G. Harding-Rolls, N. Urbancic, & X. Purita Banegas Zallio. (2020). Talking Trash, The corporate playbook of false solutions to the plastic crisis. C. M. Foundation

Afvalfonds Verpakkingen. (2021a). Beleid Afvalfonds Verpakkingen.

Afvalfonds Verpakkingen. (2021b). Nederland Circulair, elke verpakking telt! Recycling Verpakkingen Nederland 2021.

AH. (2021). Missieverslag 2021 - Beter verpakken. https://missieverslag.ah.nl/missieverslag-2021/beter-eten-is-de-wereld-beter-achterlaten/beter-verpakken

Andrady, A. L., & Neal, M. A. (2009). Applications and societal benefits of plastics. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1977-1984.

Asgher, M., Qamar, S. A., Bilal, M., & Iqbal, H. M. (2020). Bio-based active food packaging materials: Sustainable alternative to conventional petrochemical-based packaging materials. Food Research International, 137, 109625.

Beitzen-Heineke, E. F., Balta-Ozkan, N., & Reefke, H. (2017). The prospects of zero-packaging grocery stores to improve the social and environmental impacts of the food supply chain. Journal of Cleaner Production, 140, 1528-1541.

Bhandari, P., & Nikolopoulou, K. (2020). What is a Liker scale? Guide & Examples. https://www.scribbr.com/methodology/likert-scale/

Bobek, E., & Tversky, B. (2016). Creating visual explanations improves learning. Cognitive research: principles and implications, 1, 1-14.

Brouwer, M., & van Velzen, E. T. (2017). Recyclebaarheid van verpakkingen op de Nederlandse markt: Huishoudelijke kunststof verpakkingen in sorteerproducten onderzocht op recyclebaarheid en hoeveelheid. Wageningen Food & Biobased Research.

Brouwer, M., van Velzen, U. T., & Workala, Y. (2021). Recyclebaarheid van Nederlandse kunststofverpakkingen: de status van 2021. Wageningen Food & Biobased Research.

Bruntland, G. H. (1987). Our common future. The World Commission on Environment 1 and Development, 45-65.

Cabernard, L., Pfister, S., Oberschelp, C., & Hellweg, S. (2022). Growing environmental footprint of plastics driven by coal combustion. Nature Sustainability, 5(2), 139-148.

Ceflex. (2023). Designing for a circular economy. https://guidelines.ceflex.eu/

Chen, M. (2020). The Zendesk Triple Diamond, visualizing the product design process. Zendesk. https://medium.com/zendesk-creative-blog/the-zendesk-triple-diamond-process-fd857a11c179

CIEL, Center for International Environmental Law, A. G., & Delphine Lévi Alvarès. (2022). Winter is coming, Plastic has to go. A case for decreasing plastic production to reduce the European Union's dependence on fossil fuels and Russia.

Coelho, P. M., Corona, B., ten Klooster, R., & Worrell, E. (2020). Sustainability of reusable packaging–Current situation and trends. Resources, Conservation & Recycling: X, 6, 100037.

De Koeijer, B., De Lange, J., & Wever, R. (2017). Desired, perceived, and achieved sustainability: Trade-offs in strategic and operational packaging development. Sustainability, 9(10), 1923.

Elkington, J., & Rowlands, I. H. (1999). Cannibals with forks: The triple bottom line of 21st century business. Alternatives Journal, 25(4), 42.

Ellen Macarthur Foundation. (2015). Towards a Circular Economy: Business Rationale for an Accelerated Transition. https://ellenmacarthurfoundation.org/towards-a-circular-economy-business-rationale-for-an-accelerated-transition

Ellen MacArthur Foundation, World Economic Forum, & McKinsey & Company. (2016). The New Plastics Economy — Rethinking the future of plastics. http://www.ellenmacarthurfoundation.org/publications

Engelman, R. (2013). Beyond sustainababble. State of the world 2013: is sustainability still possible?, 3-16.

European Union (2008) DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - on waste and repealing certain Directives, § Article 3.

European Union. (2009). DIRECTIVE 2009/125/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - establishing a framework for the setting of ecodesign requirements for energy-related products.

European Union. (2018). DIRECTIVE (EU) 2018/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - on packaging and packaging waste.

European Union (2019) DIRECTIVE (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment, (2019).

European Union (2019) Proposal for a REGULATION ON THE EUROPEAN PARLIAMENT AND OF THE COUCIL on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive

(EU) 2019/904, and repealing Directive 94/62/EC (2022).

eurostat. (2022). Packaging waste statistics. Retrieved 7-2-23 from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics#Waste_generation_by_packaging_material

Evans, D. M., Parsons, R., Jackson, P., Greenwood, S., & Ryan, A. (2020). Understanding plastic packaging: The co-evolution of materials and society. Global Environmental Change, 65, 102166.

Fraser, M., Haigh, L., & Soria, A. C. (2023). The Circularity Gap Report 2023.

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm? Journal of Cleaner Production, 143, 757-768.

George, T. (2022). Semi-Structured Interview - Definition, Guide & Examples. Scribbr. https://www.scribbr.com/methodology/semi-structured-interview/

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science advances, 3(7), e1700782.

Groh, K. (2018). Global definition of plastic's recyclability. Retrieved 6-2-2023 from https://www.foodpackagingforum.org/news/global-definition-of-plastics-recyclability

Halden, R. U. (2010). Plastics and health risks. Annual review of public health, 31, 179-194.

Heijnen, V. (2022). Beleid uitgebreide producentenverantwoordelijkheid [Letter of government]. Ministry of Infrastructure and Water Management. Retrieved 12-05-2022 from https://www.rijksoverheid.nl/documenten/kamerstukken/2022/04/21/beleid-uitgebreide-producentenverantwoordelijkheid

Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2115-2126.

IenW, Vang hha, Vereniging Afvalbedrijven, & Milieu Centraal. (2020). Wel/niet lijst voor huishoudelijk afval.

IPPC, Pörtner, H.-O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R. A., Betts, R., Kerr, R. B., & Biesbroek, R. (2022). Climate change 2022: Impacts, adaptation and vulnerability. IPCC Geneva, Switzerland:.

Jadhav, E. B., Sankhla, M. S., Bhat, R. A., & Bhagat, D. (2021). Microplastics from food packaging: An overview of human consumption, health threats, and alternative solutions. Environmental Nanotechnology, Monitoring & Management, 16, 100608.

Kadac-Czapska, K., Knez, E., Gierszewska, M., Olewnik-Kruszkowska, E., & Grembecka, M. (2023). Microplastics Derived from Food Packaging Waste—Their Origin and Health Risks. Materials, 16(2), 674.

Kakadellis, S., & Harris, Z. M. (2020). Don't scrap the waste: The need for broader system boundaries in bioplastic food packaging life-cycle assessment–A critical review. Journal of Cleaner Production, 274, 122831.

Kakadellis, S., Woods, J., & Harris, Z. M. (2021). Friend or foe: Stakeholder attitudes towards biodegradable plastic packaging in food waste anaerobic digestion. Resources, conservation and recycling, 169, 105529.

Károly, K. (2011). Rise and fall of the concept sustainability. Journal of Environmental Sustainability, 1(1), 1.

Kershaw, P. (2015). Sources, fate and effects of microplastics in the marine environment: a global assessment (1020-4873).

KIDV. (2021). Recyclecheck flexibele kunststof verpakkingen.

KIDV. (2023). KIDV Recyclecheck Verpakkingen. KIDV. https://kidv.nl/recyclecheck

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, conservation and recycling, 127, 221-232.

Kochanowska, M., & Gagliardi, W. R. (2022). The double diamond model: in pursuit of simplicity and flexibility. Perspectives on Design II: Research, Education and Practice, 19-32.

Koniecka, f. R. K. (2022). Falling into place: what future for plastic recycling in a circular and toxic-free economy?

Leenaars, Y., & Boer, E. (2017). Samenstelling Ingezameld Kunststof/PMD Verpakkingen - het effect van inzamelsystemen.

LIDL. (2023). Duurzame Verpakkingen. https://corporate.lidl.nl/duurzaamheid/duurzame-verpakkingen

Lima, M. (2023, 28-03-2023). LinkedIn. https://www.linkedin.com/feed/update/urn:li:activity:7046133182445854720/#

Lindh, H., Williams, H., Olsson, A., & Wikström, F. (2016). Elucidating the indirect contributions of packaging to sustainable development: A terminology of packaging functions and features. Packaging Technology and Science, 29(4-5), 225-246.

Löw, C., Manhart, A., Prakash, S., & Michalscheck, M. (2021). Design-for-recycling (D4R) - State of play. D. G. f. I. Z. G. GmgH. https://www.giz.de/de/downloads/2021-06%20Design%20for%20recycling_barrierefrei.pdf

Lutters, D., & ten Klooster, R. (2008). Functional requirement specification in the packaging development chain. CIRP annals, 57(1), 145-148.

MacArthur, E. (2013). Towards the circular economy. Journal of Industrial Ecology, 2(1), 23-44**.**

Meadows, D. H., Meadows, D. H., Randers, J., & Behrens III, W. W. (1972). The limits to growth: a report to the club of Rome (1972). Google Scholar, 91, 2.

Landelijk AfvalbeheerPlan, § B3, B4 (2021). https://lap3.nl/beleidskader**/**

Morelli, J. (2011). Environmental sustainability: A definition for environmental professionals. Journal of Environmental Sustainability, 1(1), 2.

NTCP, & HTP. (2022). Recycling pathways of post-consumer plastic packaging waste in Europe.

Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H., & Clement, J. (2019). Global resources outlook: 2019. International Resource Panel, United Nations Envio, Paris, France.

OECD. (2016). Extended Producer Responsibility: Updated Guidance for Efficient Waste Management. https://www.oecd-ilibrary.org/content/publication/9789264256385-en

OECD. (2022). Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. O. Publishing.

Oude Luttikhuis, E., de Lange, J., Lutters, E., & Ten Klooster, R. (2014). Using actor networks in decision making during content-packaging development. Procedia CIRP, 15, 419-424.

Pascual, O., Boks, C., & Stevels, A. (2003). Communicating eco-efficiency in industrial contexts: a framework for understanding the (lack) of success and applicability of eco-design. IEEE International Symposium on Electronics and the Environment, 2003.,

PBL, Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: measuring innovation in the product chain. Planbureau voor de Leefomgeving(2544).

Plastic Soup Foundation. (2022). Een Neokoloniaal Plasticschandaal - Nederland speelt hoofdrol in internationale handel in plasticafval.

Plastics Europe. (2022). Plastics - the Facts 2022. https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/

Ragaert, K., Delva, L., & Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. Waste management, 69, 24-58.

RecyClass. (2023). Design for recycling guidelines. RecyClass. https://recyclass.eu/recyclability/design-for-recycling-guidelines/

Reike, D., Vermeulen, W. J., & Witjes, S. (2018). The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resources, conservation and recycling, 135, 246-264.

Rijkswaterstaat. (2021). Samenstelling van het huishoudelijk restafval, sorteeranalyses 2020.

Ruggerio, C. A. (2021). Sustainability and sustainable development: A review of principles and definitions. Science of the Total Environment, 786, 147481.

Skovdal, M., & Cornish, F. (2015). Qualitative research for development: a guide for practitioners (Vol. Chapter 6). Practical Action Publishing.

SYSTEMIQ. (2022). ReShaping Plastics, Pathways to a circular, climate neutral plastics system in europe.

Ten Klooster, R. (2002). Packaging design: a methodological development and simulation of the design process.

Thoden van Velzen, E., Molenveld, K., Brouwer, M., van der Zee, M., & Smeding, I. (2021). Issue paper: recycling of different wastestreams.

Thoden van Velzen, E. U., Paillart, M., Hogeveen, E., & Smeding, I. (2023). Packaging: sustainable versus political gain. Retrieved 08-03-2023 from https://vakbladvoedingsindustrie.nl/en/article/packaging-sustainable-versus-political-gain

Urbanus, J. H. (2022). Microplastics are everywhere: 70% reduction achievable.

Vos, R. O. (2007). Defining sustainability: a conceptual orientation. Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology, 82(4), 334-339.

Wijngaard, M., Dortmans, A., Van Harmelen, T., Urbanus, J., De Ruiter, R., Schwarz, A., & Zondervan, E. (2020). Verspil het niet: pak de schaduwzijde van plastics met urgentie aan![don't waste it! solving the dark side of today's plastic].

Appendices

Appendix 1 – Different D4R guidelines

KIDV

KIDV is the Dutch source for Design for Recycling guidelines, advising, and inspiring companies with their knowledge on sustainable packaging. They offer multiple sources of information, consisting of Recycle Checks, a sustainable packaging tool and workshops. The Recycle Checks and the sustainable packaging tool are freely available.

The Recycle Checks are pdf documents that define the meaning of well recyclable packaging, there are currently 5 different checks for the material groups rigid plastics, flexible plastics, paper and cardboard, glass and metal. They all contain a decision tree, with which users can analyse their packaging and its recyclability. The check provides the necessary context on the and links relevant sources of information. Furthermore, additional information on each step of the decision tree is provided, sometimes with visual explanatory elements.

Recyclass

Recyclass is the European version of KIDV offering similar guidelines but then on a European level. Recyclass provides a wide range of documents helping with design for recycling. Their methodology describes their approach to assessing plastic packaging. They also have an online tool in which packages can be self-assessed on their recyclability without costs. For a quicker self-assessment, D4R guidelines are available on their website in a table format. The guidelines are offered for the most common plastic packaging types. The tool offers a more in-depth analysis based on a company's packaging, needing the input of the packaging's weight and materials.

Recyclass also offers certifications, these prove that a packaging is well recyclable.

Both sources handle a recyclability classes system,

Ceflex

Ceflex represents the full flexible packaging chain and strives for a circular economy on a European level. Their guidelines on flexible packaging design are a textual explanation of the different packaging characteristics that are disruptive. The Ceflex guidelines do contain an infographic with explanation on the sorting processes for plastic waste.

Appendix 2 – Visual sources on D4R

Source	Title	Views	Year	Notes
Attero	Afvalverwerking bij Attero (uitzending RTL-Z)	2567	2021	
Keuringsdienst van Waarde	Keuringsdienst Van Waarde - Plastic	80833	2020	Covers some of the complexity of the system, also mentions the importance of D4R, but does not go into depth.
Fostplus	Fostplus recyclage PMD	2133	2019	Good description of the NIR machine, a bit more elaborate. Good illustrations.
AVR	Zo werkt de AVR scheidingsinstallatie!	1902	2019	Very good illustrations. rather general.
Bram Loosen	Afvalverwerking	820	2018	Clear images of the processes
AVR	Video Scheiding Plastic - Afvalfonds (NL)	283	2019	General
SUEZ	Why separating waste matters! – SUEZ	8641	2018	General, but in English about the Dutch system.
Afvalfonds verpakkingen	Kijk in de keten (3 episodes)	1557 254 291	2021/ 2022	More in depth, covers the societal dilemmas around waste. Also uses conversation to adress the problem

Table 9: *Visual source on D4R analysis*

Appendix 3 – Interview plan

Intro

- Introduction of the topic and interview procedure
- Ask permission for audio recording

General

- What does the company do (with packaging)?
- What is your function within the company?

Design for Recycling

- What is the knowledge of D4R within the company?
- Do you use it, to what extent and what source?
- Who uses it within the company?
- How is it implemented?
- Which role does it play within the company? (Importance)
- Difference between national and international products?

Missing information/knowledge

- Do you see the D4R information as complete?
- What is your knowledge of the waste treatment?
- How could the effect of D4R become bigger?
- What groups can gain the most?

The tool

- Explanation of the tool
- Do you think this would be an added benefit on top of the existing information?
- Is there demand for this type of information?
- What would be a good format?
- Any input on the tool?

End

- Would you like to receive an update on the end result?
- Inform for possible other contacts

Appendix 4 – Interviewee characteristics

	Company	Type	Operational area	Position of interviewee	D4R Guidelines used
Brand owners	1	Large brand owner	International	Lead expert team sustainability	Recyclass and own
	2	Large brand owner	International	Recycling manager	KIDV, CEFLEX, and Recyclass
	3	Large brand owner	International	Issues & external affairs	CEFLEX and own
	4	Medium brand owner	International	Packaging technologist	KIDV & Recyclass
	5	Small brand owner	National	Director	KIDV
	6	Small brand owner	National	CEO	KIDV
Packaging Producer	7	Packaging producer	International	Head of sustainability	CEFLEX & Recyclass
Retailer	8	Retailer with own brand	NL and Belgium	Packaging expert	KIDV, CEFLEX, Recyclass, and own

Table 10: Interviewee characteristics companies

Expert	Type	Operational area	Position of interviewee
1	Educational institution	International	Researchers
2	Plastic packaging recycling initiative	European	Recycling analyst
3	Plastics innovation center	National	Director
4	Non-profit testing facility	International	R&D manager
5	Trade Association	National	Manager sustainable packaging

Table 11: Interview characteristics experts

Appendix 5 – Final tool access

Click on the image below to access the tool.

Appendix 6 – User test questionnaire

Introduction questions

The introduction questions help to paint the profile of the participants. What is their relation to packaging design and recycling, and what knowledge do they already have?

0.1 - What is your job:

- CEO/manager
- Packaging expert/technologist
- Packaging designer
- Packaging producer
- Retailer
- Sustainability manager/expert
- Other

0.2 - Have you ever been to a waste treatment facility?

0.3 – Have you ever been to a plastic recycling facility?

0.4 - How would you rate your knowledge level of the waste treatment and recycling before using the tool?

- I was completely unaware of what happened in waste treatment and recycling
- I had a slight understanding of the main processes in waste treatment and recycling
- I knew most of the processes in waste treatment and recycling
- I was familiar with all the processes in waste treatment and recycling and I understood their purpose

0.5 - How familiar are you with the KIDV Recycle Checks?

- Never heard of
- I know what they are
- I've seen them once or twice
- Regularly used
- Detailed knowledge

Educational effect

2.20 - What was the most informing/useful part in explaining the sorting and recycling processes?

- The explanatory text
- The illustrations and animations
- The combination of text and imagery

2.21 - Please indicate any processes that you were not able to understand completely:

2.22 – Please indicate to what level the tool contained new information for you

Sorting		Recycling	
Bag opener		Shredder	
Drum sieve		Magnet	
Windshifter		NIR	
Magnet		Pre-wash	
Drinking cartons NIR		Grinder	
Eddy current		Coldwash	
Ballistic separator		Hotwash	
Plastics NIR		Density separation	
Handpicking		Drying	
		Extrusion	

Applicability

3.8 - I could see myself using the tool for:

- Gaining insight in the waste sorting processes
- Gaining insight in the plastic recycling processes
- Basing packaging design on it
- Educating people around me

Closing of

4.1 - How long did it take you to complete the tool?

- Less than 10 minutes
- 10-20 minutes
- 20-30 minutes
- 30+ minutes

4.2 - In what detail level did you complete the tool?

- I quickly scanned through
- I skipped a few pages
- I have read all the information

4.3 - Was there any information missing?

4.4 – Was there any repetitive information?

4.4 - Any other remarks:

4.5 - Would you be interested to join the publication event of the tool? Later on in februari/march?