Master's Thesis Internship - MSc Sustainable Business & Innovation

INCREASING PLASTIC PACKAGING RECYCLING RATES:

A Comparison of the Dutch and British Post-Consumer Plastic Packaging Mechanical Recycling Systems and the Influence of Food & Agribusiness Firms

STUDENT:

Maaike Isabelle Blom
5488133
m.i.blom@students.uu.nl
+31614121811

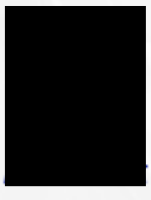
SUPERVISOR:

Laura Piscicelli
l.piscicelli@uu.nl

INTERNSHIP SUPERVISOR:

Rabobank: RaboResearch Food & Agribusiness, Supply Chains Team
Susan Hansen
[redacted]

Universiteit Utrecht



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Abstract

As little as 30% of the 28 million tonnes of plastic produced in the EU annually is collected for recycling, much of which is to be treated outside of the EU under less-strict standards. Furthermore, 150.000 to 500.000 tonnes of EU-originated plastic waste ends up in nature annually. European plastic recycling rates should thus increase. However, the exact barriers and opportunities involved in this increase remain unclear. Therefore, this research conducted an analysis of the post-consumer plastic packaging (PCPP) mechanical recycling technology innovation system. This specification was chosen as mechanical recycling is the mainstream recycling technology, and packaging is a large contributor to plastic waste. This analysis was conducted through the Technological Innovation System (TIS) Analysis Framework. This TIS, the system of actors and rules that impact the diffusion of a technology, when analysed, reveals the performance of the system and in turn the flaws present. Additionally, the research focussed on the role of Food & Agribusiness (F&A) companies on this innovation system due these companies' high packaging use and recent increase in collaborations and investments in PCPP mechanical recycling. To determine the level of impact by F&A companies, the concept of Dynamic Capabilities was used. Dynamic Capabilities are a firm's abilities to develop competitive advantages in a rapidly changing environment, the framework consists of three capability levels, from low to high level of competitive advantage creation. A combination of the TIS and Dynamic Capabilities Framework was used to analyse the innovation system of a laggard (the UK) and a frontrunner country (the Netherlands), in order to highlight the differences in barriers and opportunities present in a weak and a strong performing system. The results of this comparison show that both EU and national legislations should increase their focus on regulations regarding the use of recycled content; improved consumer awareness is necessary; there should be more knowledge sharing and value chain collaboration in order to innovate on current technological limitations. Additionally, demand-limiting factors such as low oil-price and quality-critical producers are a barrier. Furthermore, the analysis uncovered a vast amount of improvements necessary in the waste infrastructures, in the Netherlands, but even more so in the UK. In general, the influence of F&A companies is regarded as very positive and strong, but still shows room for improvement regarding long-term commitments. The paper concludes with several recommendations for the PCPP mechanical recycling system, for F&A companies, as well as for policy-makers.

Executive Summary

There is a rise in societal and regulatory pressures being placed on the plastics, Food & Agribusiness (F&A), and recycling markets recently. Consumers are becoming increasingly critical on the packaging use of their brands and retailers. Furthermore, the recent changes in EU Directives focussed on plastics and recycling are a strong driver towards change in the industry. Many have thus recognised the ongoing global challenge of plastic waste and low plastic recycling levels. For example, in the EU, only 30% of plastics is collected for recycling, much of which is shipped abroad to eventually not be recycled. Additionally, 150.000 to 500.000 tonnes of European-originated plastic still end up in nature annually. There is thus a strong need for driving up European plastic packaging recycling rates and additionally there is a necessity to increase knowledge into the plastic packaging recycling systems present in Europe, in order to gain knowledge on what improvements are exactly necessary.

This global challenge was recognised by the F&A RaboResearch department at Rabobank International, who offered an internship researching the European plastic packaging recycling industry in order to gain insights into this rapidly evolving field. In order to specify this broad topic, the final research focussed firstly on post-consumer plastic packaging (PCPP) mechanical recycling. Furthermore, the research laid an additional focus on the role of F&A companies on the PCPP mechanical recycling industry as Rabobank noted the recent trends of increasing collaborations between the industries as well as a rise in F&A investments in the industry. Finally, the focus of this research was drawn on the PCPP mechanical recycling systems in the Netherlands, a frontrunner, and the United Kingdom (the UK), a laggard, in order to facilitate the identification of barriers and opportunities in the system and how these differ between lagging and frontrunning cases.

Flaws related directly to industry (both PCPP mechanical recycling as well as F&A), and are thus most influenceable by Rabobank through her client-base, are:

- The negative influence of consumers. While consumers are strongly pressuring their brands and retailers to switch to sustainable packaging this is not reflected in consumers' buying and waste sortation behaviour. It is thus advisable for Rabobank to stimulate its corporate clients that are directly involved with the PCPP mechanical recycling system to focus on consumer awareness regarding the positive aspects of the use of recycled content in packaging as well as the necessity, and necessary knowledge, of plastic sortation. Furthermore, it is recommended for Rabobank to conduct further research into the possibility of investing in so-called 'reversed vending machines', currently found at Dutch supermarkets for returning plastic bottles that have a return-fee (or a DRS fee) for the consumer. As many European countries, including the UK are looking into implementing these DRS fees, it is favourable to look into companies involved in such machines as demand is likely to increase.

- Technological limitations are an additional factor currently limiting the further growth in recycling rates. It is therefore recommended for Rabobank to look into a broad selection of innovations that intend to eliminate these technological limitations. Many of the current innovations in the market focus on design for recyclability, it is thus recommended for Rabobank to both stimulate its clients to invest or collaborate on these innovations as well as possibly looking into an investment in such technologies. In addition, enzymes or additives that facilitate the mechanical recycling of multi-layer PCPP are another important innovation focus.
- While value chain collaboration, and additionally value chain collaboration by F&A companies, is increasing, it is said to have to increase even more. Rabobank can play a role in this by setting up platforms such as the current 'Rabo Circulair Ondernemen Desk' (the Rabobank Circular Business Desk). This platform should aim to advise clients on increasing value chain collaboration for sustainable packaging.
- Governmental-related issues concern that of a lacking legislation regarding the compulsory use of recycled content, or taxing packaging that does not contain recycled material. Furthermore, the waste infrastructure across the UK and the Netherlands, is extremely scattered, causing confusion amongst consumers and unpredictability of feedstock quality for PCPP mechanical recyclers. While Rabobank has a reduced impact on these issues, it is advisable to direct its clients towards lobbying for these issues at both national and EU governments as this, in the long-term, will lead to advantages for both the PCPP mechanical recycling as well as the F&A industry.

Furthermore, while chemical recycling is not considered to be a strong competitor for PCPP mechanical recycling, it is predicted they will both grow in the coming years and result in approximately equal market share. Therefore, it is recommended to Rabobank to continue its current investment in chemical recycler Ioniqa, and possibly consider investments in other chemical recyclers.

All in all, it is highly recommended to Rabobank to increase its client-base, and investments, to more PCPP mechanical recyclers, as the current trend predicts an increase in demand for this technology.

Disclaimer: The above-stated recommendations as well as any other recommendations for Rabobank stated in this thesis are recommendations developed by Maaike Blom individually. Rabobank is in no way obliged to follow these recommendations.

List of Acronyms

- DRS = Deposit Return Scheme
- EPR = Extended Producer Responsibility
- EU = European Union
- F&A = Food & Agribusiness
- HDPE = High-Density Polyethylene
- LDPE = Low-Density Polyethylene
    - LLDPE = Linear Low-Density Polyethylene
- M&A = Mergers & Acquisition
- PCPP = Post-Consumer Plastic Packaging
- PET = Polyethylene Terephthalate
- PP = Polypropylene
    - BOPP = Biaxially Oriented Polypropylene
- PVC = Polyvinyl Chloride
- TIS = Technological Innovation System
- UK = United Kingdom

1. Introduction

1.1 Plastic Waste & Packaging

The European Union (EU) generates approximately 25.8 million tonnes of plastic waste each year. Of this amount, 31% ends up in a landfill and 39% ends up on an incineration plant, the latter waste treatment method globally emitting 400 million tonnes of CO_2 annually. The remaining 30% is collected for recycling; however, a large amount of this plastic waste is transported to third countries where recycling standards may have less strict environmental regulations (European Commission, 2018a). Additionally, not all plastics may end up being collected to go to landfills, incineration or recycling plants; approximately 150.000 to 500.000 tonnes of EU plastic waste ends up in nature, on land and, predominantly, in the oceans. It is thus clear that the potential for plastic recycling remains unexploited (European Commission, 2018a).

The vast majority of global plastics, and thus global plastic waste is packaging. Between 1950 and 2015, 146 of the 407 million metric tonnes plastic produced concerned plastic packaging, this accounts for 35.9% (Geyer et al., 2017). Furthermore, the top 6 polymers contributing to plastic waste are all key polymers for packaging applications (Geyer et al., 2017). Plastic packaging thus accounts for a large contribution to the global plastic issue.

1.2 Tackling the Plastic Waste Challenge

As a reaction to this high contribution of packaging to plastic waste, there is a rising awareness of consumers regarding sustainability issues related to plastic packaging (Joyce, 2018), and recycling. This additionally results in increasing societal as well as regulatory pressures on some of the largest global plastic producers. Examples of this include the 'Plastic Monster' that Greenpeace gifted to Unilever in March 2019 (BlikOpNieuws, 2019) or the increasing recycling target of Coca-Cola as a response to pressure from environmentalists (Taylor, 2017).

The plastic waste issue was not just picked up by society, but it has recently also been recognised by the EU, which has implemented a number of policies and strategies to tackle the problem. Strategies aim both at decreasing plastic waste as well as developing an integrated EU-wide infrastructure for waste management.

A policy-reaction by the EU was first done in 2014, when the EU established the Circular Economy Package (European Commission, 2018b) and implemented a strategy to reduce the use of plastic bags (European Commission, 2018c). The EU Plastics Strategy, adopted by the Commission in early 2018, also set the ambition to make all plastic packaging on the EU market recyclable by 2030 (European Commission, 2018c) and ban single-use plastic and microplastic by 2021 and 2020, respectively (European Parliament, 2018). Furthermore, the EU Plastic Strategy increased the Extended Producer Responsibility (EPR)

schemes (European Commission, 2018a), meaning that prices for putting plastic packaging on the market will increase. Finally, the EU Plastic Strategy aims to increase the amount of recycling facilities as well as improve the standardised recycling system in place regarding plastic waste sorting and collection (European Commission, 2018c).

1.3 The Mechanical Recycling Industry Structure

While the European Commission is aiming to improve plastic waste recycling, partly through improving the recycling infrastructure, very little detailed knowledge concerning the issues present in the existing recycling infrastructure in the EU is available. While the general plastic recycling process (Figure 1) is known, it is unknown where specifically, for each separate EU member country, the barriers to increased recycling rates lie. Additionally, as the market environment is changing rapidly due to the aforementioned strong societal pressure and fast-paced adaptations of legislation, these conditions and barriers may be currently undergoing change.

The standardised recycling process as presented in Figure 1 consists of a number of elements: (1) the collection schemes present in each country (e.g. presence of recycling bins, recyclables being picked up by the municipality or not), as well as the different technologies used in each country to (2) sort and (3) reprocessing the plastic waste (Figure 1). This schematisation of the plastic infrastructure in the EU is, however, a generalised representation and thus serves as a broad overview of a possible final infrastructure.

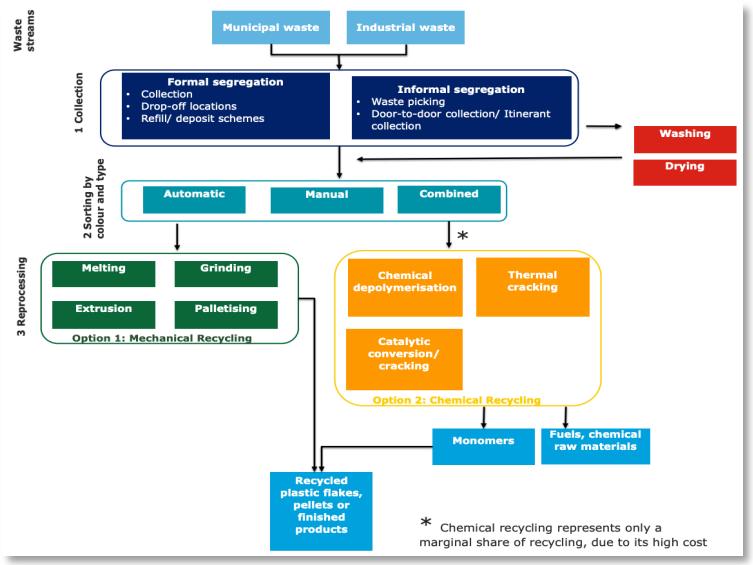


Figure 1: Recycling chain in the EU (taken from Hestin et al., 2017)

Table 1: Plastic Packaging Collection rates (%) and share of total plastic packaging waste in 28 Member States (taken from Hestin et al., 2017)

Countries	Collection rates			% of EU-28 waste generated in 2014
	2012	2013	2014	
EU-28	**35%**	**37%**	**40%**	**100%**
Belgium	42%	39%	42%	2.1%
Bulgaria	41%	41%	64%	0.7%
Czech Republic	58%	60%	58%	1.4%
Denmark	26%	29%	30%	1.2%
Germany	50%	49%	50%	19.2%
Estonia	30%	28%	29%	0.4%
Ireland	40%	40%	40%	1.3%
Greece	32%	32%	32%	1.2%
Spain	35%	41%	42%	9.3%
France	25%	26%	25%	13.5%
Croatia	45%	45%	38%	0.3%
Italy	38%	37%	38%	13.6%
Cyprus	45%	45%	47%	0.1%
Latvia	24%	25%	36%	0.3%
Lithuania	39%	43%	51%	0.4%
Luxembourg	37%	32%	37%	0.2%
Hungary	28%	31%	37%	1.7%
Malta	33%	23%	33%	0.1%
Netherlands	48%	47%	50%	3.1%
Austria	35%	34%	34%	1.9%
Poland	22%	20%	29%	5.9%
Portugal	30%	35%	40%	2.3%
Romania	51%	52%	44%	2.2%
Slovenia	65%	82%	69%	0.3%
Slovakia	57%	55%	56%	0.6%
Finland	25%	23%	25%	0.8%
Sweden	35%	46%	47%	1.5%
United Kingdom	25%	32%	38%	14.5%

According to the infrastructure visualised in Figure 1, the first element in the recycling chain is the collection schemes present in each country. As shown in Table 1, EU plastic collection rates differ greatly per country, with the lowest collection rate being 25% in France and Finland and the highest being 69% in Slovenia (Hestin et al., 2017). However, one should keep in mind that this data refers to the 2014 collection rates, meaning that the current collection rates may have improved considering the preceding trend of increase.

Collection does not, however, necessarily mean that the plastics are later recycled. As aforementioned, 31% of EU collected plastics end up in a landfill and 39% end up on an incineration plant (European Commission, 2018a). Moreover, there is a large variance in the recycling and landfill rates between countries, as depicted in Figure 2 and Figure 3 below.

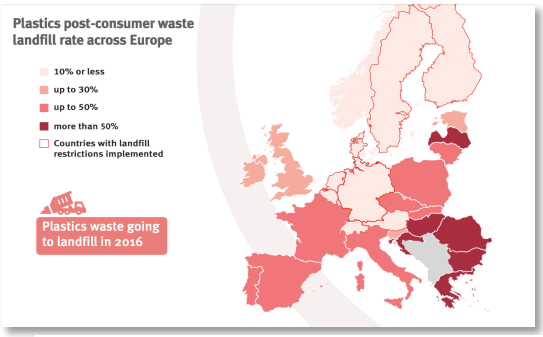


Figure 2: Plastics waste going to landfill, 2016 (PlasticsEurope, 2018)

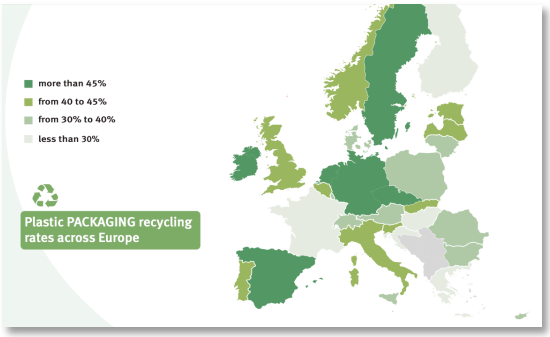


Figure 3: Plastic Packaging recycling rates across Europe, 2016 (PlasticsEurope, 2018).

Additionally, some countries with a high collection rate may in turn have a relatively poor recycling rate. Apart from that there is not a direct relation between the collection rate and the recycling rate, illustrating the complexity of the system, this data also exemplifies the vast differences present within all the separate EU waste management systems, legislations and thus factors limiting the increase of EU recycling rates.

The next phases (if destined to be recycled) are sorting and recycling. As sorting can also be grouped within the recycling phase (Hestin et al., 2017), specific sorting processes will not be further discussed. Regarding the recycling phase, there is a larger availability of literature present on the varying technologies used.

One can distinguish between several types of recycling: primary (re-extrusion), secondary (mechanical), tertiary (chemical) and quaternary (energy recovery) technologies[1]; energy recovery is often referred to as chemical recycling as well. The vast majority (if not all) of current recycling practices is done through mechanical recycling (PlasticsEurope, 2018).

Mechanical recycling "[…] is a method by which waste materials are recycled into "new" (secondary) raw materials without changing the basic structure of the material" (EUBP, 2015). Additionally, "mechanical recycling of plastics is a multi-step process, which starts with collection, sorting, and ballistic separation into washed milled goods and, subsequently, the conversion into pellets or products." (Luijsterburg, 2015). When referring to the mechanical recycling technology in this research, it will thus encompass all these mentioned steps in the process.

A possible upcoming competitor of mechanical recycling is chemical recycling. However, mechanical recycling currently dominates the market and chemical recycling is expected to take quite some time to further develop (Hundertmark et al., 2018). Thus, the initial increase necessary to reach the EU recycling targets will have to come from scaling up mechanical recycling rates.

[1] Primary technologies involve the re-introduction of scrap to the extrusion cycle enabling the creation of similar products. Secondary technologies generally break down end-of-life and production waste to, for example, pellets. Tertiary technologies include, amongst the others, thermos-chemical treatments of Plastic Solid Waste (PSW). Quaternary technologies include energy recovery techniques from PSW and Municipal Solid Waste (MSW).

Therefore, one can first conclude that the recycling infrastructure must differ greatly per country due to the varying collection and recycling rates. Second, it is clear that the knowledge on the recycling industry structure (e.g. Figure 1) is largely generalised, thus failing to highlight the exact barriers or opportunities present in the system in order to increase recycling rates, thus revealing a gap in the current research on this topic.

In order to gain insights into some possible barriers or opportunities in increasing performance of mechanical recycling, one can compare a case of a laggard with a case of a frontrunner. In the case of this research, a comparison will be done between the United Kingdom (hereon the UK) and the Netherlands. These two countries show vast differences in their mechanical recycling performance. The Netherlands performs relatively well on recycling rates of plastic packaging waste with a rate of 51,5% in 2016 (Eurostat, 2018), while the UK is viewed as a laggard with 44.9% of plastic packaging waste being recycled in 2016 (Eurostat, 2018). Finally, the UK recycling system has displayed several flaws and necessary improvements in the past (Laville, 2018) and is generally said to perform quite poorly for a West-European country (Cole, 2018). Analysing the differences in the mechanical recycling industries of a laggard and frontrunner country will highlight the barriers or opportunities present in the industry that influence the performance of mechanical recycling.

Currently, most studies are conducted at a European or global scale. Hestin et al. (2017) uncovered several challenges and opportunities when analysing the structure of the plastic recycling system. Amongst the identified challenges were the difficulty of recycling complex packaging, high landfilling rates as high levels of waste exports and fluctuations in quality and quantity of waste as well as the negative image that there is regarding the use of recyclates. Furthermore, Hestin et al. identified increased awareness, the implementation of more design for recycling and use of recyclates, the increase in separate collection schemes, the current standards and certificates as well the increasing awareness of the need for a circular economy model to be opportunities for the European recycling system. Hestin et al. also highlighted the need for involving all steps of the value chain for improvement.

Furthermore, Hopewell et al. (2009) recognised several challenges associated to plastic packaging recycling. One of the identified challenges for plastic recycling is increasing the ability to recycle waste streams that consist of mixed plastics, this can be achieved through keeping recyclability in mind when designing plastic packaging. Furthermore, Hopewell et al. identified the necessity of increasing collection, sorting and recycling rates of flexible plastic packaging, which are difficult to sort and recycle due to their low-weight. Furthermore, the large variety of plastic types used in packaging should be limited to make recycling easier.

While these studies analysed the structure of the plastic recycling value chain and through such analysis highlighted several challenges and opportunities, they did not do an analysis of the system surrounding this value chain, such as including the role of industry

associations, or regulatory changes. Furthermore, these studies were conducted at EU-wide level but do state that there are vast differences present within the EU (Hestin et al., 2017), hence why the analysis of a laggard and frontrunner within the EU as suggested above can uncover differences between national PCPP mechanical recycling systems and thus analysing barriers and opportunities may uncover more significant differences and outcomes.

1.4 Post-Consumer Plastic Packaging

As aforementioned, packaging accounts for the majority of global plastic waste (Geyer et al., 2017). Thus, much gain can be bought from focussing on improving the recycling of plastic packaging. However, while being the largest contributor to the plastic waste issue it is also one of the most difficult to recycle group of plastic. This is due to the fact that plastic packaging is often contaminated, as it origins from household use and is thus contaminated with, for example, food residue. Additionally, as plastic packaging serves the purpose to keep products inside the packaging intact, it often consists of multiple layers, all of which have a different purpose for keeping the product inside intact (e.g. one layer for avoiding humidity, the other preventing UV-damage). The combination of this multi-layer design and contamination make plastic packaging extremely difficult to recycle. Additionally, plastic packaging may have quite a low collection rate as it is often sorted by the consumer, who may be unaware or unwilling to cooperate in collection and sorting of waste. While post-consumer plastic packaging waste is extremely difficult to recycle, in order to increase the overall recycling rates, the biggest gain is to be bought in the growth of mechanical recycling of post-consumer plastic packaging waste (hereon: PCPP mechanical recycling). The technology analysed thus concerns mechanical recycling of a variety of polymers (e.g. LDPE, PET, HDPE) and all the aforementioned steps involved in this process (Luijsterburg, 2015). As PCPP waste always consists of a combination of polymers and the treatment methods per polymer does not differ when it comes to mechanical recycling, the research will focus on the mechanical recycling of a general group of household polymers[2].

1.5 Food & Agribusiness Companies and Mechanical Recycling

Large contributors to the placement of plastic packaging onto the market are food & agribusiness[3] (F&A) companies (IEEP, 2018). This is due to the fact that plastic packaging serves the purpose of keeping food fresh for a longer period of time (American Chemistry Council, 2018). As the F&A industry is strongly linked to the aforementioned plastic issues, so-called 'brand-owners' such as Unilever (BlikOpNieuws, 2019) or Coca-Cola (Taylor, 2017) experience strong societal pressure to focus on preventing their plastic packaging from ending up in the environment. Additionally, as stated earlier, the F&A industry will also have to the commit to the EU Plastics Strategy and this amendment in the EU legislation has

[2] LLDPE, LDPE, HDPE, PP, BOPP, PVC, PET (RaboResearch, 2019)

[3] Food & Agribusiness (F&A) companies is the Rabobank term that includes food, beverage or agri-product companies that, in the case of this research, put consumer products on the market packaged in plastic.

caused a larger focus on Extended Producer Responsibility schemes, meaning prices and consequences of putting plastic packaging on the market is bound to increase across the EU.

Thus, the F&A industry has to take action. Many F&A companies have decided to set plastic recycling targets to increase the recycling rates of their plastic packaging. In order to reach these targets, companies are taking a number of actions. As companies are largely dependent on the presence of a well-functioning plastic recycling infrastructure, many of these actions are directly aiming at improving the existing recycling system. Actions include the recent loan granted by Coca-Cola and Unilever to Dutch recycling company Ioniqa in order to finance research in hard-to-recycle PET (an often-used food packaging) technologies (Ayala, 2018). In the UK, Walkers Crisps (PepsiCo) has partnered with recycling company TerraCycle in order to collaboratively set-up a collection scheme (Haylor, 2018).

The influence of external firms on the development of the PCPP mechanical recycling technology is, thus, arising. Yet, their impact is very diverse with regards to magnitude; a collaboration with a collector may have a different impact than investing into a recycling facility for example. Therefore, we currently cannot be sure to what extent the F&A sector is influencing the growth of PCPP mechanical recycling, this is thus an additional analysis that can be conducted.

While there may be some studies focussing on several aspects of F&A's impact on recycling rates, such as increasing consumer awareness through packaging alterations (Klaiman, 2017), due to the recent involvement of F&A companies with PCPP mechanical recyclers there are no studies yet that focus on the overall influence of F&A companies' actions on the performance of PCPP mechanical recycling, or their impact on moving towards increasing plastic recycling rates.

1.6 System Analysis

To comprehensively capture the structure and dynamics of complex systems such as that of the PCPP mechanical recycling system, a systemic perspective is necessary to sufficiently analyse the performance, diffusion and effectiveness of the system. The Technological Innovation System (TIS) analysis (Hekkert et al., 2011) has proved useful to gain insights into the system in which a technology develops as well as the potentials and barriers the diffusion of this technology can face. For example, the TIS has been used to map the transition of the Swedish wastewater sector (McConville et al., 2017), the diffusion of renewable energy technologies in Africa (Tigabu, 2018) and the diffusion of biomass technologies in the Netherlands (Negro, 2007). However, currently the TIS analysis (Hekkert et al., 2011) does not allow to explicitly account for the variety of influence of external firms, such as the aforementioned F&A companies, on the PCPP mechanical recycling system as there is no indicators provided to measure the variance in magnitude of such impacts.

1.7 Research Aim & Question

The research will provide insights into the barriers to improving the performance of the PCPP mechanical recycling technology by comparing the conditions present in a laggard country (the UK) with those in a frontrunning country (the Netherlands). Additionally, as the focus lies on the mechanical recycling of post-consumer plastic packaging, the research will also focus on the role of the food, beverage & agribusiness (F&A) industry in the scaling up of PCPP mechanical recycling, due to their significant contribution to post-consumer plastic packaging waste, resulting in the research question to be:

> *What causes the differences between the Dutch and British PCPP mechanical recycling performance and how do F&A companies impact the performance of this technology?*

The scientific relevance of this analysis is through the integration of an additional layer of analysis into the TIS. This layer of analysis allows the differentiation between firms' abilities to create a competitive advantage in a rapidly changing environment, such as the current PCPP mechanical recycling innovation system, this addition is able to draw conclusions on the exact extent that external firms, such as F&A firms, impact the innovation system through their different type of actions. This aids in drawing more in-depth conclusions on the strength of impact that these external firms are having on the innovation system rather than merely analysing whether they have an impact or not. This research will thus offer a theoretical contribution to the TIS by integrating an additional layer of analysis.

This research will also significantly contribute to the knowledge base on the performance of European PCPP mechanical recycling by creating a broad, yet detailed, overview of the current European PCPP mechanical recycling systems in the Netherlands and the UK including all the processes and actors involved, as well as the barriers and opportunities impacting the performance of the PCPP mechanical recycling technology. As the characteristics of each country's PCPP mechanical recycling systems will be assessed, final recommendations can be developed regarding necessary measures to take in each industry. These final recommendations will thus carry a strong societal and practical relevance due to the fact that it will offer the F&A industry an insight into the characteristics of the current PCPP mechanical recycling innovation system and additional strategies, or alterations to strategies, necessary to improve the performance of this system. As well as offering both policy-makers and recycling companies an insight into what is necessary to overcome identified barriers. Furthermore, due to the aforementioned difficulties involved in recycling post-consumer plastic packaging, increasing these recycling rates will carry a high societal relevance as it will aid both F&A and recycling companies as well as EU Member States to the set EU targets as well as that it can be utilised in taking necessary measures to address the aforementioned plastic waste challenge.

This research is structured as follows: section 2 elaborates on the two theoretical frameworks utilised and how these are operationalised into the final theoretical framework of this research. Section 3 explains the research methodology, focussing separately on the desk research phase and the interview phase. Section 4 presents the results and is structured according to the theoretical framework steps. Section 5 presents a discussion reflecting on the results, the implications of these results as well as the research limitations. Finally, section 6 is the conclusion of this research.

Summary Section 1: Introduction

- → Plastic recycling in Europe remains unexploited, only 30% of the plastic is collected for recycling.
- → There is an increasing societal and regulatory pressure to increase plastic recycling rates, the EU has announced several Directives targeting plastic recycling.
- → The knowledge necessary to increase the plastic recycling rates is lacking, it is necessary to gain insight into the barriers and opportunities present in the system.
- → Mechanical recycling is the main approach to plastic recycling. Additionally, Post-Consumer Plastic Packaging (PCPP) accounts for the majority of plastic waste and this research will thus specifically look at the mechanical recycling of PCPP.
- → Impact of Food & Agribusiness (F&A) company engagements with PCPP mechanical recycling will be analysed due to their significant contribution to PCPP waste.
- → This research will compare a laggard (the United Kingdom) with a frontrunner (the Netherlands) to analyse the cause of differences in PCPP mechanical recycling performance and the influence of F&A companies on this performance.

2. Theory

The proposed theoretical framework for this research is a combination of the Technological Innovation System (hereon: TIS) and the dynamic capabilities framework. Both the TIS framework and the Dynamic Capabilities framework are elaborated on below followed by a description on how the merging of these two frameworks will be operationalised in the final theoretical framework of this research.

2.1 The Technological Innovation System Analysis

In short, a TIS can be defined as "the set of actors and rules that influence the speed and direction of technological change in a specific technological area" (Hekkert et al., 2011, p. 3). The TIS concept recognises the fact that innovation is a collective activity and takes place within a wider system, the TIS. It recognises the influence that people, enterprises and institutions have on innovation processes and highlights the impact of interactions between these multiple actors on the success of an innovation in the market (Hekkert et al., 2011). Mapping all actors and processes involved in the TIS reveal both the performance of the functioning of the system and the processes that support the innovation diffusion, and subsequently the system flaws, or failures.

A TIS analysis follows several steps: first, the structural components are mapped. Second, the system functions are evaluated in order to determine the functioning of the TIS. Finally, the system failures are identified (Hekkert et al., 2011). Below, the theoretical elements and each step of analysis will be elaborated on and the relevance of each component in regard to mapping the UK and Dutch PCPP mechanical recycling innovation systems will be clarified.

2.1.1 Structural Components of the TIS

The TIS consists of a number of elements: actors, institutions, networks of actors, and technology (Hekkert et al., 2011).

Through their decisions and actions, actors are the ones that actually generate and diffuse the technologies and thus have a strong impact on the TIS (Hekkert et al., 2011). When mapping the PCPP mechanical recycling innovation system it is highly relevant to analyse the involved actors in the industry, this is relevant due to the aforementioned fact that actors are the ones that define the TIS by means of their decisions and actions with regards to diffusing and utilising new technologies (in this case the diffusion of the PCPP mechanical recycling technology).

Institutions in the case of the TIS can be defined as "the rules of the game in society, or, more formally as the humanly devised constraints that shape human interaction" (Hekkert et al., 2011, p.5). Mapping institutions can be of relevance for the case at hand by, for example, mapping the institutions and rules in place for plastic waste collection schemes in each country.

One of the main ideas of the TIS framework is that the earlier identified actors function together in networks to facilitate technology diffusion (Hekkert et al., 2011). Analysing the networks of actors in the PCPP mechanical recycling innovation system will highlight the cooperation present in the system.

The technological factors in the TIS consist of all the technologies present in the system and the technological infrastructure in which they are embedded. They are of relevance for the case as the introduction of new technologies could lead to competition in the diffusion of mechanical recycling as well as that new technologies in the system can aid the diffusion of mechanical recycling (e.g. sorting technologies can increase feedstock and thus increase diffusion).

2.1.2 The System Functions and the Phase of Development of the TIS

The first phase of the TIS analysis consists of identifying the above-stated structural elements. However, the diffusion of technologies is not a structural, rigid element, but a continuous process. In many cases, these structural elements are not in place but are in the formation process. Due to this, the next step of the TIS analysis considers all processes involved in the development and diffusion of the technology, these being 'system functions' (Hekkert et al., 2011). Determining the system functions in place is highly relevant in the current case because, despite many actors and institutions may be in place, the functions in the TIS determine the actual activities and performance of the TIS and, eventually, the performance of the Dutch and British mechanical post-consumer plastic packaging recycling industries.

However, determining the exact functioning of the system depends on the phase of development that the technology is in at the time. If the technology is in an early phase, the system has a different structure and different functions in place than when the technology is more mature (Hekkert et al., 2011). Determining the phase of development of the technology is highly relevant with regards to comparison of the Dutch and British mechanical recycling industries as it is of significant importance what level of development has been reached in order to determine the state of the industry and what is yet to be done with regards to mechanical recycling technology development and diffusion.

2.1.3 Step 1: Structural Analysis

The first step is the structural analysis where all actors and rules present in the system are identified. There are four components taken into account in the structural analysis: actors, institutions, networks and technological factors (Hekkert et al., 2011).

The TIS distinguishes between a number of actors' categories, namely knowledge institutes, educational organisation, industry, market actors and government bodies and supportive organisations.

In mapping institutions one can distinguish between formal and informal institutions, formal institutions being the one enforced by an authority, and informal ones being shaped by the interaction between actors. The latter are difficult to map, thus the structural analysis

only focusses on formal institutions. All actors mapped in the TIS are presented in Figure 4 below.

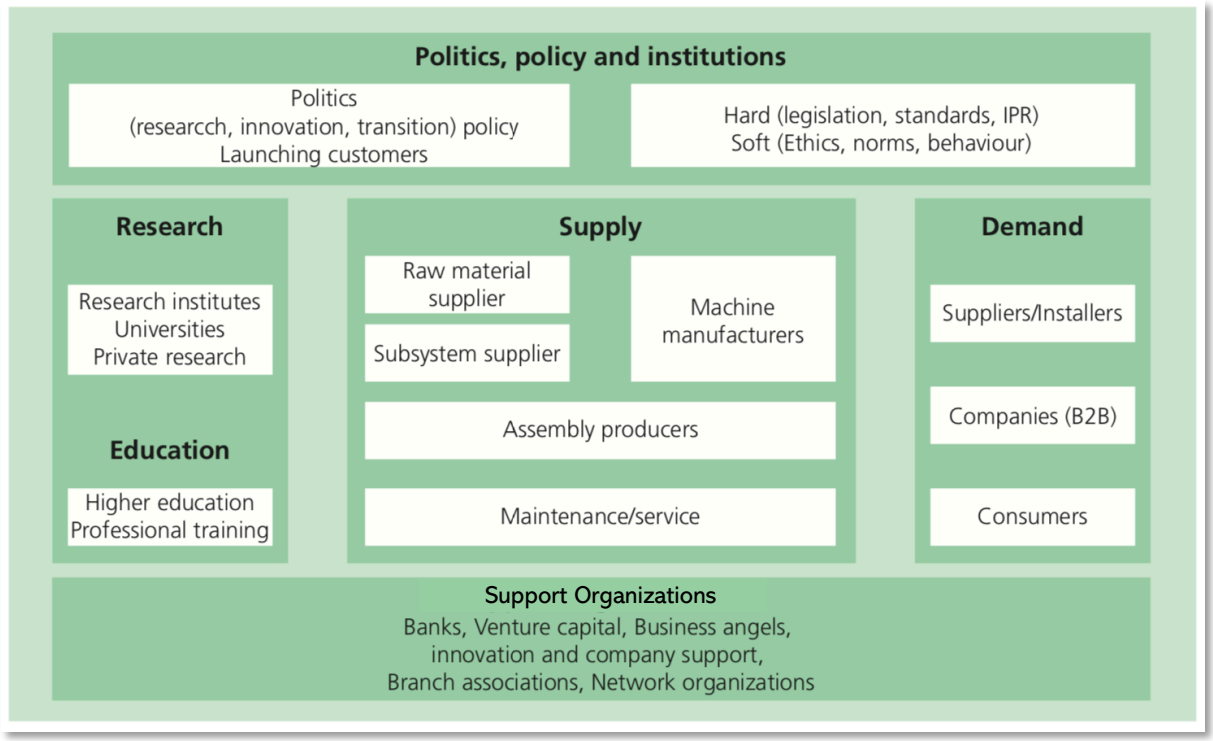


Figure 4: Actors of the TIS (Hekkert et al., 2011)

Mapping networks of actors can focus on the geographical scale, such as if the networks are functioning at a local or global level.

Technological factors of the TIS are mapped by defining the technological trajectories present in the system, thus analysing the evolution of the technology itself over time. As well as analysing possible additional, or competing, trajectories present. Additionally, the technological analysis of the TIS takes into account techno-economic aspects such as costs, safety and reliability as this is "crucial for understanding the feedback mechanisms between technological change and institutional change" (Hekkert et al., 2011, p. 6).

2.1.4 Step 2: Determining the Phase of Development

In reality, newly developing technologies do not have fully developed structures in place yet. Thus, a follow up on the structural analysis is determining the phase of development of the technology. The phase of development is defined in terms of the international diffusion of the technology, mapped on an S-curve (Figure 5) consisting of a number of phases of development.

First, the pre-development phase is the phase where a prototype is produced. Second, the development phase is the time of the first commercial application of the technology. Third, the take-off phase, being the phase where the technology or product will be widely diffused. The take-off phase leads to the acceleration phase of the diffusion of the

technology until the final phase, the stabilisation phase, is reached, in which diffusion stabilises (Hekkert et al., 2011).

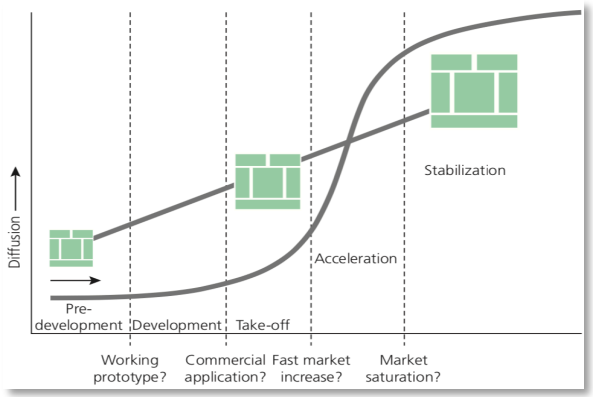


Figure 5: S-Curve Phase of Development (Hekkert et al., 2011)

2.1.5 Step 3: Mapping the System Functions

Part of determining the phase of development is deciding the fulfilment of several system functions, this in turn being the third step of the TIS analysis. The performance of system functions gives an insight into how the TIS is actually functioning. The following system functions are considered (Hekkert et al., 2011): entrepreneurial experimentation, knowledge development, knowledge exchange, guidance of the search, formation of markets, mobilisation of resources, counteracting resistance to change. The performance of these system functions is determined in this step through a number of indicators per system function.

The entrepreneurial experimentation can be determined by the type of actors present in the industry. Knowledge development can be measured by the number of patents and publications found in the system during the structural analysis (step 1). Knowledge exchange can be measured by the amount as well as the nature of the networks present between actors. Guidance of the search can be determined by the "regulations, visions, expectations of government and key actors" (Hekkert et al., 2011, p.10) present. Determining the functioning of the market formation is based on, for example, the number of projects or initiatives present in the TIS. Resource mobilisation can be based on the amount and type of physical, human and financial resources previously mapped. Finally, counteracting resistance to change can be determined by, for example, the amount of time that it takes to implement a new project.

2.1.6 Step 4: Determining the Structural Cause for Functional Barriers

After mapping the performance of the seven system functions, the fourth step is determining what is the structural cause for the functional flaws in the system. One must follow a number of steps to determine the system flaws: first, one must determine which system functions are the ones forming barriers. Second, one must determine for each of the system functions that cause a barrier what structural component is the cause of this. These being the aforementioned structural components (actors, institutions, networks, technological factors)

as well as possible factors external to the TIS (e.g. competition with another TIS) that may cause a barrier. Finally, one must determine the relation between the structural cause and the barrier formed.

The TIS perspective is thus well equipped to map the actors directly involved in the diffusion of mechanical post-consumer plastic packaging waste recycling technologies in the EU and identify the current barriers to increasing European recycling rates. However, while the TIS briefly states to take into consideration indirect influences (e.g. financers), these are not systematically accounted for by means of the indicators and diagnostic questions utilised in mapping the system. For example, the market actor only takes into account the impact of demand that other firms could have (Hekkert et al., 2011), thereby disregarding the role of companies that are not direct users or innovators of the technology but do impact its diffusion through other mechanisms than demand. Furthermore, as aforementioned, one should be able to distinguish differences in the magnitude of impact that external companies, such as F&A companies, have on the system. The magnitude of impact of, for example, a long-term venturing arm is a lot stronger than that of a short-term, or one-time, investment. Therefore, the TIS shows some limitations in its capability to capture the influence of firms that are not directly involved in the performance of mechanical recycling technologies but do engage with the system through other means than utilising the technology itself, as the TIS does not make a distinction in the different types, or magnitudes, of impact that these firms may have. Hence, an additional, firm-oriented, system function would be useful in adapting the TIS framework in order to distinguish the different types, and magnitudes, of external firm influence on the innovation system. The dynamic capabilities framework by Teece et al. (1997) could aid in this.

2.2 The Dynamic Capabilities Framework

Dynamic capabilities are "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments", namely to what extent the firm is able to develop new competitive advantages in a changing environment (Teece et al., 1997, p. 516). In other words, dynamic capabilities aid a firm in successfully adapting to the changing environment it is in. In the case of this research, analysing the dynamic capabilities of F&A companies with regards to recycling can offer insight into the type of actions F&A firms are taking in order to adapt to the rapidly changing market and legislation, and their magnitude of impact on the mechanical recycling industry. According to Teece (2018), the highest-order dynamic capabilities are sensing, seizing and transforming.

First, sensing is the identification of new opportunities through scanning, learning and interpretation. It can arise, for example, through the acquisition of new kinds of information and knowledge (Teece, 2007). In the case of the PCPP mechanical recycling innovation system this could be applicable when F&A companies are engaging in working groups or discussions related to PCPP mechanical recycling.

Second, when the new opportunity of engagement with the PCPP mechanical recycling industry is identified through these above-stated processes, the opportunity must be seized. In the case of PCPP mechanical recycling this can be done, for example, through the creation of new products designed in such a way that they increase the efficiency of the mechanical recycling. Additionally, opportunities can be seized through the development of new processes and services (Teece, 2007), the latter two of which being applicable to the case of PCPP mechanical recycling technologies as the introduction of, for example, new collection services for customers will increase the capability of firms to achieve their targets and adapt to the new policies.

Finally, the transforming dynamic capability concerns the adaptation of the firm to the developments established in the seizing phase. Change in corporations can often be difficult, but successful adaptation is necessary to remain competitive in a constantly changing environment (Teece, 2007). Firms taking transformative action will have a longer-lasting impact on the performance of PCPP mechanical recycling as it will continue to influence it in the long-term. Firms taking transformative actions will thus have a stronger impact on the performance PCPP mechanical recycling than firms merely engaged in sensing or seizing activities due to the long-term nature of transformative actions.

One can imagine that measures taken through different levels of dynamic capabilities impact the technological innovation system in different degrees, so not al F&A firm actions influence the technological innovation system to the same extent. Thus, incorporating the sensing, seizing and transforming activities of the identified external firms is of relevance in establishing the structure of the industry as it shows the level of impact of the F&A industry on the PCPP mechanical recycling industry.

2.3 Theoretical Framework and Operationalisation

The Theoretical Framework will consist of both the TIS framework as well as the Dynamic Capabilities Framework in order to take into account the discussed differences in impact of external firms. Thus, in addition to the aforementioned seven system functions of the TIS framework, integrating the dynamic capabilities will lead to the addition of an eighth system function: the 'external firm influence' function, which is characterised by sensing, seizing and transforming. As the previous seven system functions were all determined by certain indicators, the external firm influence system function will consist of the three dynamic capabilities as indicators. Sensing will be the amount of single, one-time actions influencing the system. These can be of, for example, cooperative or monetary nature. The seizing indicator will be decided by the amount of long-term actions that influence the system; this could include amongst others a long-term investment or long-term logistic cooperation. The transforming indicator will be decided by the amount of firms that have made efforts to increase recycling rates as part of everyday business rather than an action point, for example companies that have a closed plastic loop or that have their own venturing arm focussed on developing mechanical recycling.

The final framework will thus be an integration of the TIS with the dynamic capabilities complementing the theoretical gap present regarding external firm influence. The theoretical framework is depicted in Figure 6 below.

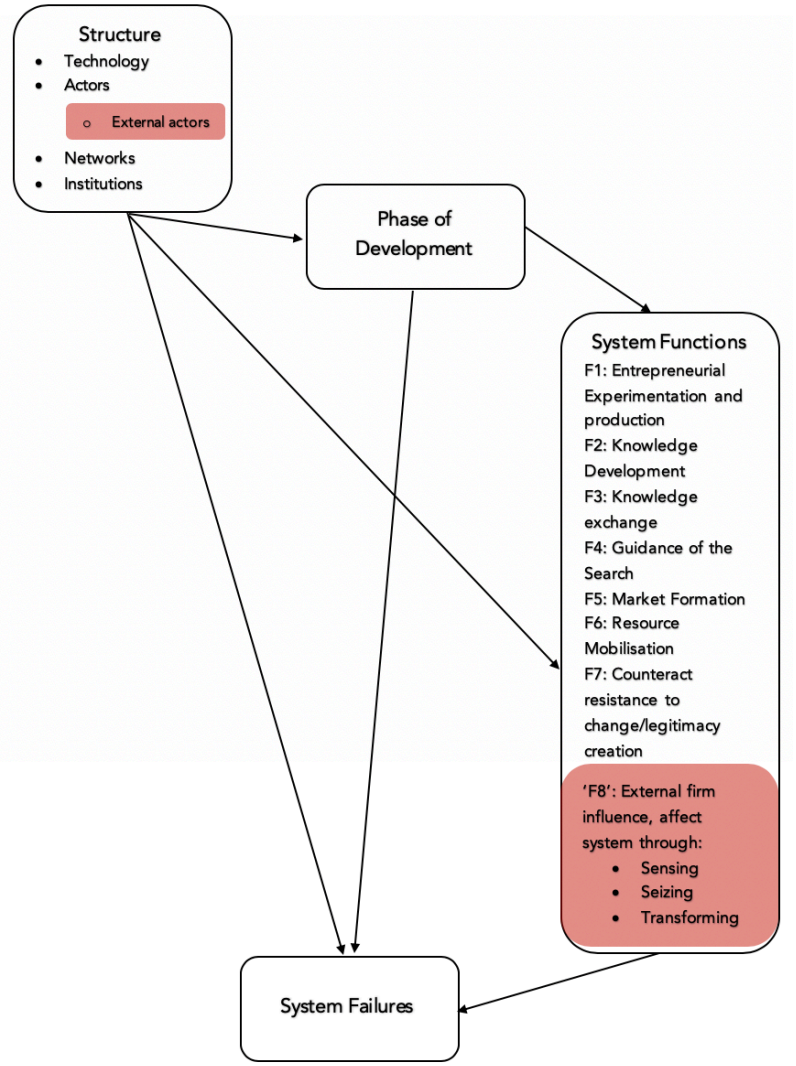


Figure 6: Theoretical Framework

Summary Section 2: Theory

→ The theoretical framework of this research will consist of the Technological Innovation System Analysis (TIS) and the Dynamic Capabilities Framework.
→ The TIS is useful to analyse a system in which a technology develops and identify the barriers and opportunities involved in the diffusion of this technology.
→ The TIS analyses the structure of the system, the phase of development of the analysed technology, 7 system functions giving insight into the functioning of the system and finally the system flaws present.
→ Dynamic Capabilities are the extent to which firms can develop new competitive advantages in order to adapt to a rapidly changing environment.
→ The Dynamic Capabilities Framework distinguishes between 'sensing', 'seizing' and 'transforming' activities by firms, in order of increasing magnitude of change.
→ The Dynamic Capabilities Framework is integrated as an 8th system function in the TIS in order to distinguish the level of impact F&A firms are having on the PCPP mechanical recycling system.

3. Methodology

3.1 Research Design

The research design consisted of a desk research phase and an interview phase. Each step of the phases contributed directly to one, or more, of the elements of the theoretical framework (Figure 6). All methodological steps and their relation to the theoretical framework are visualised in the chart below (Figure 7). Data collection took place during a four-month period at the Rabobank International Food & Agribusiness Supply Chain Research department and was for a small part supported by current data in place in the department. Below, the methods used for data collection and analysis are elaborated upon for each methodological step.

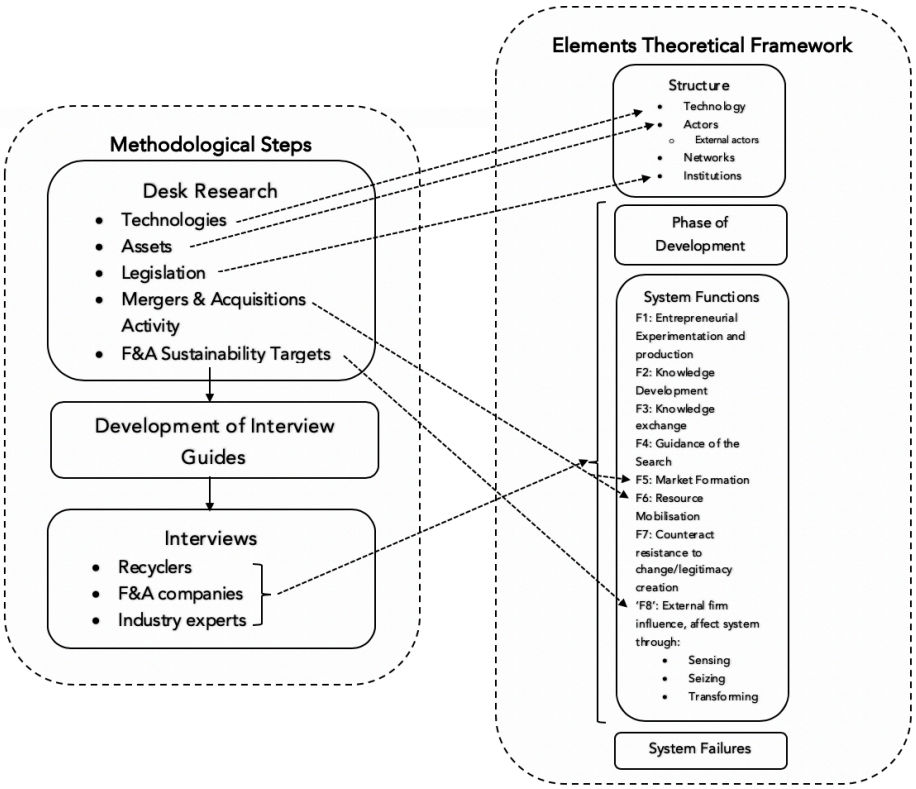


Figure 7 : Methodological Steps & Relation to Theoretical Framework Elements

3.2 Desk Research

The data collection phase started using the online article search engine 'Meltwater' in order to highlight firms active within the industry and possible important contacts as well as highlighting barriers and opportunities regarding mechanical recycling of post-consumer plastic packaging waste in the media. 'Meltwater' analyses a vast amount of online newspaper and industry articles for search terms applied by the researcher. In this case, a collection of relevant articles was made on the basis of the search terms 'plastic packaging' and 'recycling'. Based on the daily list of articles presented by 'Meltwater' a selection was made that was relevant in presenting barriers or opportunities in the recycling industry, legislation that may

be of impact or new technologies that may be a competitor for mechanical recycling or technologies that aid the further diffusion of mechanical recycling. Additionally, Meltwater highlighted a number of key online sources posting relevant updates regarding the industry (e.g. Packaging Online) that could be utilised in subsequent stages of the desk research.

3.2.1 Legislation

As articles found through Meltwater highlighted that the ongoing changes in EU legislation were related to the EU Circular Economy packaging, the in-depth analyses of the ongoing transformations in the European plastic waste and recycling legislations were conducted with the EU Circular Economy Package serving as a starting point of the analysis. This research was done through examining official documents as well as press releases posted on the websites of the European Commission and the European Parliament. Further analysis of legislator changes stated on these websites were analysed by using the European law database 'Eurlex'. Legislations that applied directly to mechanical post-consumer plastic packaging recycling or companies putting plastic packaging onto the market was grouped in a hierarchy graph to create a clear overview of all relevant regulations and laws.

Additionally, through the four months, relevant articles related to waste and packaging legislation or structural issues regarding recycling that were found on 'Meltwater' were noted if relevant to the national legislations of the Netherlands or the UK. Further research into national legislation was done through existing data of Deposit Return Schemes provided by Rabobank. Extended Producer Responsibility (EPR) Scheme fees and regulations were found through the EPR Alliance (EXPRA) website and websites of national waste organisations Afvalfonds Verpakkingen (the Netherlands) and Valpak (the UK). Further national legislation changes were found through searches in Google on 'plastic legislation the Netherlands' and 'plastic legislation the UK', newspaper articles from May 2018 onwards mentioning legislation relevant to mechanical post-consumer plastic packaging recycling or plastic packaging regulations were regarded as relevant and verified through national government websites.

3.2.2 PCPP Mechanical Recycling Assets & Actors

A database of PCPP mechanical recycling assets was created, aiding both in the analysis structure by highlighting relevant actors within the system as well as offering a glimpse into the differences between the PCPP mechanical recycling systems in the Netherlands and the UK. The database started with a research report provided by Rabobank bought from global plastic industry consultancy firm AMI consulting. From this database, only recyclers that are engaged in plastic packaging recycling were incorporated into the final asset database. Recycling assets were analysed on the basis of a vast amount of parameters[4], the ones utilised

[4] Company Name, Owner, Country of Location, Capacity, Number of Employees, Recycling Sector, Source of Packaging Waste, Polymer Types, Other Materials Recycled (in addition to plastics), Collection Service,

in this research are presented in Table 2 along with an explanation on the relevance of use of this parameter. The final asset database was extended over the course of the entire four-month research period by adding missing mechanical recycling locations through an analysis of merger & acquisition activities (elaborated on below), visiting industry conferences (Empack 2019 and the PRS[5] 2019), as well as through the aforementioned search engine 'Meltwater'.

These latter two activities also contributed to the list of relevant non-PCPP mechanical recycler actors in the innovation system (e.g. knowledge, institutions, industry associations, governmental organisations, the industry actors), many of which were also derived from the interview phase, elaborated on below, or through existing Rabobank knowledge on, for example, relevant industry associations or other relevant actors.

Table 2: Utilised Parameters Database Mechanical Recycling Companies in the Netherlands and the UK

Parameters Recycling Assets	Categories (if applicable)	Relevance
Company Name		Companies highlight relevant actors in the industry.
Owner		Owners highlights relevant actors in the industry
Country	The Netherlands/The UK	Relevant to compare the two cases.
Recycling Sector	Household/municipal, Commercial, Production, Agricultural	The distribution of recyclers across the different recycling sectors within a country can give an indication of the level of PPCP mechanical recycling present in a country (the higher the amount of household/municipal recyclers, the more PCPP mechanical recycling).
Collection Service	Yes/No	The presence of a collection service (offered directly by the mechanical recycler) gives an indication of the integration of the waste collection within the PCPP mechanical recycling industry.
M&A Activities	Linked to M&A database as described above	Gives an indication of financial resources present in the system.

Collection Partners, Activities, Output, Minimum Volume Accepted, Accepted Contamination Level of Waste, Revenue, M&A Activities, Address, Longitude, Langitude, Contact details, Website

[5] The Plastic Recycling Show

3.2.3 Technologies

'Meltwater' was searched for relevant technology articles between May 2018 and May 2019, through which articles related to new recycling technologies were found. Articles were deemed relevant if they included a technology that had the potential to directly stimulate the PCPP mechanical recycling innovation system (through influencing one of the chain steps of mechanical recycling aforementioned) either as a stimulant or as a barrier to the diffusion of the PCPP mechanical recycling technology. The type of technology (e.g. enzymes, chemical recycling) did have to occur more than once in order to be deemed as relevant. Additionally, a number of relevant sources[6] were found through 'Meltwater'; sources were deemed relevant if they reported on technologies related to mechanical recycling on a weekly basis. As saturation with other sources was often found, the other sources were only analysed for additional relevant articles published between January 2019 and May 2019. On the basis of the analysis of relevant articles, a number of categories of currently developing technologies that either inhibit or stimulate the further development of mechanical recycling were identified.

3.2.4 Mergers & Acquisitions Activity

Mergers and acquisition (M&A) activities were mapped using databases provided by Rabobank through their subscription at M&A database provider MergerMarket. M&A activities that took place between the 1st January 2005 and the 5th March 2019 in the EU were taken into account. Reason for this timeframe being extended compared to the timeframe taken in the 'Meltwater' search is that this longer timeframe allows a clear insight into the level of activities before and after the EU regulatory changes and increasing consumer pressure. All activities between this time period of which the MergerMarket deal description contained the words 'LDPE', 'HDPE', 'PET', 'Plastic Recycling', 'Polypropylene', 'Recyclers' and 'Recycling' were filtered using MergerMarket and grouped into one large database. Parameters for each case included the announcement date, the completion date, the target company, the buyer company and in some cases the seller company as well as the deal description. This search resulted in 777 M&A cases, these were then manually filtered for relevance on the basis of whether it concerned a recycler or waste management company engaged in mechanical plastic packaging recycling. This relevance could be identified in the deal description; if this was not the case, additional online research into the target and buyer companies was conducted by analysing the companies' websites. This resulted in 146 relevant M&A cases regarding plastic packaging recycling that were then analysed on the basis of year, type of buyer, type of target and type of seller if available[7], which could again be concluded from the deal description or additional research into the companies. This M&A activity data provides insight into the system function 5 (Market Formation) and 6 (Resource

[6] Plastics in Packaging, Packaging News, PlasticsToday.

[7] Categories targets, buyers & sellers: 'Logistics', 'Plastic Recycler', 'Plastics, Chemical', 'Recycler', 'Waste Management', 'Food & Beverage', 'Investor', 'Packaging', 'Plastic Products', 'Private Equity', 'Other'.

Mobilisation) as it provides an insight into the growth in investments, capital and overall financial activities occurring in the European mechanical recycling industry over time.

3.2.5 F&A Company Sustainable Packaging Targets

Rabobank previously conducted research into a sample of Food, Beverage & Retail companies and their sustainable packaging targets, which offers valuable insights into the transformations currently occurring in the F&A and in turn the PCPP mechanical recycling industry. This database thus serves as a form of data triangulation to compare with the results of the interviews regarding F&A commitment and industry interaction. The database was based on a sample group of 62 companies across three categories, namely Food companies, Beverage Companies and Retail Companies[8]. The targets of these companies were found through press releases and online newspaper articles published in the period between January 2018 and May 2019. These targets were in turn labelled as 'concrete', 'expressing intent' (indicating a possible future concrete commitment) or as 'existing commitment' (whereby the company had successfully implemented a commitment already). This research focussed on the targets relating to recyclability and recycled content and thus serves as an indication of F&A company interaction with the recycling industry, rather than a hard conclusion.

3.3 Interview Guides

The desk research phase contributed to the development of the interview guides utilised in the interview research phase (see Appendix I & Appendix II).

The legislation analysis specified the areas of focus for the questions related to legislation and collection infrastructure for both the Recycler & Waste Management (Appendix I) as well as the F&A guide (Appendix II) and the focus on EPR questions in the F&A guide.

The analysis of recycling assets resulted in specific questions on recycling activities, collection mechanisms, contamination levels, and feedstock source as well as feedstock-related issues in the Recycler & Waste Management interview guide. Furthermore, the knowledge acquired in the asset analysis proved useful in some discussions that emerged during the interviews.

The knowledge acquired in the analysis of technologies resulted in specific questions regarding the potential of competing or stimulating technologies currently emerging in order to gain insight from those experiencing the influence of these technologies in practice.

[8] The sample of food companies included: Danone, FrieslandCampina, Nestlé, Unilever, 2 sisters, Campbells', Cranswick, Danish Crown, General Hills, Bimbo, Hershey, Kellogg's, KraftHeinz Mars, McDonald's, Mondelez, Princes, Tyson. Sample of beverage companies: ABInBev, Bacardi, Bavaria, Carlsberg, Coca-Cola, Coca-Cola FEMSA, CB, Diageo, Douwe Egberts, Heineken, MillerCoors, PepsiCo, Segafredo, Starbucks, Arla, Danone, FrieslandCampina, Nestle, Unilever. Sample of retail companies: Ahold Delhaize, Aldi, Alibaba Group, Amazon, Carrefour, Coles, Coop, Co-op, Countdown, Iceland, JD, Kaufland, KIWI, Makro, Marks & Spencer, Morrisons, Netto, Plus, Sainsbury's, Sligro, Target, Tesco, Waitrose, Walmart.

The M&A analysis did not directly contribute to the development of the interview guides as this was aimed to serve as data for system function 5 and 6. However, knowledge acquired from the M&A analysis may have been utilised in conversations during the interviews if necessary.

3.4 Interviews

17 interviews were conducted based on the previously established interview guides. The interviews were semi-structured, thus allowing for open discussions and contributions by the interviewees. Originally, this research phase consisted of two categories of interviewees: recyclers and F&A companies. However, during the sampling process a third category of interviewees emerged, this is a category of individuals that do not work for either a PCPP mechanical recycler or for a F&A company but that have significant experience in the industry. These individuals were thus grouped into a third category of interviewees, the 'Industry Experts', that are considered to have knowledge both on the PCPP mechanical recycling innovation system as well as the influence of F&A companies on the PCPP mechanical recycling innovation system. Five of these Industry Experts worked in relevant industry associations and one of them gained experience in the PCPP mechanical recycling innovation system through the process of developing a competitive technology, for which he/she collaborated closely with PCPP mechanical recyclers as well as F&A companies engaging in recycling. Elaboration on the sampling of interviewees can be found in sections 3.4.1 to 3.4.3 below.

Interviews were largely conducted by phone after which the recordings of these calls were transcribed and thematically coded using NVivo 12 through several steps in line with the thematic analysis processed developed by Braun & Clarke (2006), often referred to in guides on the thematic analysis process (Maguire & Delahunt, 2017; QSR International, n.d.)

Firstly, the transcripts were read to get familiar with the data. Following, the transcripts were coded resulting in several nodes that were then revised to be grouped into overarching themes in order to start the development of the coding frameworks, using the mind map function in NVivo 12. Following, these themes were checked, and the nodes grouped in each of these themes revised by checking the data grouped in each of the themes and nodes. This process resulted in a coding framework for each interviewee category (Appendix III, Appendix IV, Appendix V).

Additionally, all interviewees were sent a grading scheme (Appendix VI) following the interview in order to quantify the performance of the eight system functions. The interviewees were asked to rate each system function on a scale from 1 to 5, using provided guiding questions for each system function. The averages of the grades were then mapped on a system function fulfilment web as depicted in Figure 8 below. Eight interviewees did not fill out the grading schemes following the interviews, these were thus not taken into account. The final nine interviews taken into account in the grading scheme had an equal distribution across interviewee groups (three recyclers, three industry experts and three F&A employees).

This grading method highlights the structural barriers in the system and furthermore helps in determining the phase of development (Figure 5) that the PCPP mechanical recycling is currently in in the UK and the Netherlands. This method of analysis is chosen regarding the system functions as they are difficult to analyse through documentation due to their evaluative nature (Hekkert et al., 2011) and also offers a form of data triangulation after the interviews in order to verify the conclusions established from the coding of the interviews.

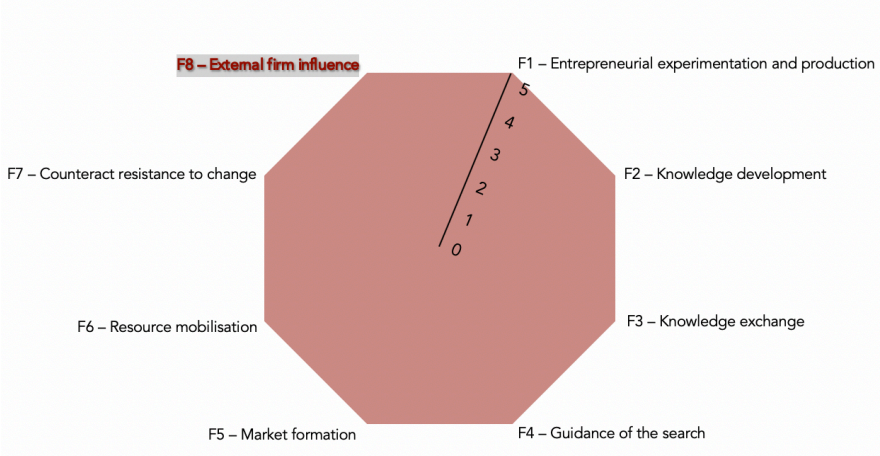


Figure 8: System Function Fulfilment (adapted from Hekkert et al., 2011)

3.4.1 Recyclers & Waste Management Interviews Sampling and Execution

The majority of the recycling interviewees were approached at the Empack conference (Den Bosch, 3rd April 2019) and the PRS (Amsterdam 10th & 11th April 2019). One contact was approached through its client-relationship with the Rabobank. Additionally, some interviewee contacts were established through the snowball sampling method. Company contacts were deemed relevant if they worked for a recycling company that mechanically recycled PCPP waste. The company size varied greatly in this category ranging from small-scale recyclers (e.g. *TUsti)* to large-scale recyclers and waste management companies (e.g. *Attero, RPC bpi).*

All five interviews were conducted by telephone, one was conducted at the headquarters of the recycling company. All but two interviews were recorded due to privacy preferences. Subsequently, all interview transcriptions, or notes in case recording was not possible, were coded as stated above.

3.4.2 F&A Companies Interviews Sampling and Execution

The six F&A interviewees were approached both through Rabobank colleagues as well as personal contacts. Requirements for suitable F&A contacts were that they operated within either or both the UK and the Netherlands and put food or drink products on the consumer market that were packaged in plastics. Furthermore, companies had to have expressed commitment to increasing recycling, recyclability of products or use of recycled content in products. This selection was done by using the list of signatories of the recent New Plastic Economy Global Commitment. This commitment was initiated by the Ellen MacArthur Foundation and has been signed by businesses (these business signatories together account for 20% of global plastic production), NGOs, universities, governments and other parties

committing to a circular economy for plastic (Ellen MacArthur Foundation & New Plastics Economy, 2018). Suppliers of signatories were also deemed relevant as they have to directly contribute to this commitment. Due to the global nature that F&A companies often operate at, company sizes in this interviewee were generally very large (e.g. *Coca-Cola, Danone*).

As aforementioned, data resulting from interviews with regards to commitment and interaction of F&A companies with the recycling industry was triangulated using an existing Rabobank database on sustainability targets by Food, Beverage & Retail companies. Gaining insight into the targets and actions by F&A companies contributes to analysing the newly-added eighth system function: external firm influence. All but one of the interviews (due to privacy reasons) were recorded, transcribed and coded as previously discussed.

3.4.3 Industry Experts Interviews Sampling and Execution

As previously mentioned, some interviewees had knowledge expanding beyond merely a recycler perspective or an F&A perspective as they worked for, for example, industry associations related to packaging or plastic production. As this category was introduced later, these interviewees were interviewed using the Recycler & Waste Management interview guide, excluding questions on recycling practices of the company and including a question on the role of the individual and the association with the recycling industry and their collaboration with the F&A industry. The majority of the interviewees thus worked for relevant industry associations (e.g. *PlasticsEurope, Dutch Rubber and Plastics Association NRK*).

An anonymised overview of all interviewees and additional details are presented in Table 3.

Table 3: Interviewee Overview and Details

Interviewee	Company	Interviewee Function in Company	Geographical Scale of Operations[9]	Interview Type and Duration
Recycler 1	PCPP Mechanical Recycler	Assistant Business Development	NL	Telephone, 55 minutes
Recycler 2	PCPP Mechanical Recycler	Sales & Purchase, Recycling	EU (UK)	Face to Face, 75 minutes
Recycler 3	PCPP Mechanical Recycler	Manager Plastics	NL	Telephone, 52 minutes

[9] Geographical Scale of Operations: NL = Interviewee or company of employment of interviewee operates only in the Netherlands; UK = Interviewee or company of employment of interviewee operates only in the United Kingdom; EU = Interviewee or company of employment of interviewee operates at European level, a specification (NL/UK) is given to indicate whether this European area includes the Netherlands, the United Kingdom or both.

Interviewee	Company	Interviewee Function in Company	Geographical Scale of Operations[9]	Interview Type and Duration
Recycler 4	PCPP Mechanical Recycler	Innovation Director Recycling	UK	Telephone, 53 minutes
Recycler 5	PCPP Mechanical Recycler	Chief Technology Officer	NL	Telephone, 53 minutes
Expert 1	Industry Association	Board Member Industry Association	EU (NL)	Telephone, 60 minutes
Expert 2	Industry Association	General Director Industry Association	EU (NL + UK)	Telephone, 59 minutes
Expert 3	Governmental Organisation	Policy Maker, Waste	NL	Face to Face, 50 minutes
Expert 4	Industry Association	Board Member Industry Association	EU (NL + UK)	Telephone, 41 minutes
Expert 5	Industry Association	Director Industry Association	EU (NL + UK)	Telephone, 67 minutes
Expert 6	Company Competing Technology	CEO	EU (NL)	Telephone, 52 minutes
F&A Employee 1	International Food & Beverage Brand	Packaging Development	EU (NL + UK)	Telephone, 30 minutes
F&A Employee 2 Stephanie	International Retailer	Specialist Product Innovation & Sustainability	EU (NL)	Telephone, 53 minutes
F&A Employee 3	International Food Brand	Packaging Procurement	EU (NL + UK)	Telephone, 62 minutes
F&A Employee 4	International Beverage Brand	Sustainability Director Europe	EU (NL + UK)	Telephone, 65 minutes
F&A Employee 5	International Food & Beverage Brand	Packaging Research & Development	EU (NL + UK)	Telephone, 40 minutes
F&A Employee 6	International Food Brand	Plastics Sustainability Manager	EU (NL + UK)	Telephone, 30 minutes

Summary Section 3: Methodology

- → The research methodology consisted of a desk research phase, conducted at the Rabobank F&A RaboResearch department, and an interview phase.
- → The desk research phase started with a general search for relevant articles using search engine 'Meltwater', also used for the technology analysis. Additional sources utilised were AMI's recycler research report (for relevant PCPP mechanical recyclers), 'MergerMarket' (for M&A data visualising financial resources) and existing Rabobank data (on F&A sustainable packaging targets).
- → Further relevant actors and PCPP mechanical recyclers were established through conference talks and based on data from the interviews.
- → The desk research phase contributed to the development of the interview guides.
- → The 17 interviews were semi-structured, leaving room for discussion.
- → Interviewees were approached at conferences, through Rabobank colleagues, through personal contacts, or through the snowball sampling method. Most were conducted through telephone.
- → There were 3 interviewee categories: Recyclers (and Waste Management companies), F&A companies and 'Industry Experts', the latter offering insight into both the PCPP mechanical recycling industry as well as the role of F&A companies.
- → All but three interviews were recorded and transcribed. Transcriptions were thematically analysed, to create 3 separate coding trees.
- → 9 out of 17 interviews filled out an additional grading scheme on the performance of the eight system functions.

4. Results

The results are structured according to the TIS framework as presented in Figure 6. A distinction is made between the Netherlands the UK when deemed relevant, all other data is presented at EU level.

4.1 TIS Step 1: Structure

4.1.1 Technology

Through the aforementioned analysis of articles found through 'Meltwater' and packaging or recycling related sources, a number of technology trends were identified that impact the PCPP mechanical recycling innovation system either acting as a stimulant or a barrier:

- Chemical Recycling, which breaks down plastic into virgin materials such as monomers or oils. In this way the quality of virgin plastic material will remain, rather than degrading the plastic quality as done in mechanical recycling. While this technology is expected to grow strongly, the vast majority of actors involved in chemical recycling remain in the technology development phase. Furthermore, chemical recycling can be very cost and energy intensive.
- The use of enzymes can aid in both multi-layer plastic separation as well as with difficult decontamination processes. This also largely remains in the research phase, but tests have been very successful so far. It would solve many issues associated with the PCPP mechanical recycling technology.
- Using additives for solving incompatibility issues in mixing different polymer types during recycling (such as is the case with multi-layer plastics). This technology is used at a small scale already but remains very expensive. It could aid in making mechanical recycling more efficient.
- Furthermore, there are several technologies being developed that could aid in (consumer) sorting of plastic packaging. This includes Near-Frequent-Communication inlays, watermark, RFID chips and 'spray-ons' serving as an information source for both consumers and sorting machines in order to improve sorting and collection rates. This could aid in improving mechanical recycling technology diffusion as it would increase available feedstock.
- The final category of currently developing technologies impacting the mechanical recycling industry is that of 'design-for-recyclability' innovations. Many companies are focussing on designing packaging in such a way that it is more recyclable. Innovations include adapting density or chemical composition to aid in sorting to transitioning from multi-layers to single-polymer plastics in order to aid mechanical recycling.

4.1.2 Actors and Networks

The following section analyses the structural aspects of actors and networks. Firstly, an insight is given into the relevant industry actors (Knowledge and Educational Institutes, Industry Actors, Market Actors, Government Bodies and Supportive Organisations), which is followed by insights into the networks in which these actors operate. This section is finalised with a table giving an overview of all the actors and networks presented.

4.1.2.1 Knowledge and Educational Institutes

Much of the knowledge creation is done inhouse, within recycling or waste management companies, but very little of this information is disclosed. However, there are several institutional actors within the system that stimulate knowledge creation openly, and through collaboration.

At EU level, significant knowledge institutions concern that of large, sometimes global-scale, projects and initiatives of which one of their aims, or their main aim, is knowledge creation fostering the increase of plastic recycling rates. An example of such projects or initiatives are *CEFLEX*, a European association focussed on stimulating the circular economy within the flexible packaging industry. It fosters knowledge creation through collaboration amongst the value chain of flexible packaging actors (flexible plastics are very often used in plastic packaging). Another example of such an initiative is the *Ellen MacArthur Foundation*, which is mainly focussed on accelerating the circular economy (Ellen MacArthur Foundation, n.d.). However, they recently established the 'New Plastics Economy Global Commitment', in which multiple industry actors involved with plastic, or recycling, are active. According to the interviewees involved, the foundation has set up multiple working groups as part of this commitment in order to collaborate on knowledge exchange amongst actors.

Additionally, knowledge creation and exchange happens through several industry associations at European level. For example, the Plastics Recyclers Europe association has a project called *RecyClass* that aims to increase the recyclability of plastics. This is done both through knowledge exchange as well as on a tool that plastic packaging companies can utilise to measure the recyclability of their products, through which *RecyClass* aims to inform, or educate, the involved companies. Furthermore, another EU association focussed on knowledge creation or sharing is *PlasticsEurope*, of which one of their focus areas is innovation on making plastic packaging more circular.

At national level, the most significant knowledge institutes are that of industry associations.

In the UK, the *WRAP UK* association, focussed on collaborating with governments and business as well as communities to increase resource efficiency, creates knowledge to share with its partners in order to foster increased efficiency of plastics use, and thus also focusses on plastics recycling. Furthermore, *PlasticsEurope* also has a UK location engaging in similar activities as the EU-wide *PlasticsEurope*.

Educational institutions in the innovation system, such as Universities, are mainly focussed on creating knowledge with regards to technological innovation. This can be done in collaboration with existing recycling companies. For example, the *University of Portsmouth* (in the UK) conducts research on the use of enzymes.

In the Netherlands, there appear to be more associations focussed on knowledge creation and exchange. In addition to *PlasticsEurope's* national location, several other specific recycling and plastics sustainability associations operate in the country. Firstly the 'Federatie Nederlandse Rubber- en Kunststofindustrie' (the Dutch Federation of Rubber and Plastics, NRK) has several projects whereby its members collaborate on knowledge creation and exchange. Furthermore, they have launched a *Rethink* campaign that targets consumers to think more positively about plastics and engage more in recycling, thus serving as an informative, or somewhat educational, institution. Additionally, NRK has its own NRK recycling department that works both on engaging with several PCPP mechanical recycling partners but also publishes knowledge through, for example, industry reports. Something that does not seem to occur as often in the UK. Furthermore, the Netherlands has a research institution focussed purely on sustainable packaging (Kennisinstituut Duurzaam Verpakken, KIDV), that has published several research reports on the sustainable packaging industry, and in turn the PCPP mechanical recycling system.

Regarding educational institutions in the Netherlands, this seems to be largely driven by the need of industry actors. For example, the company TUsti was established as a collaboration between the recycler *Stiphout Plastics* and the *University of Eindhoven*, which focusses on technological innovations. Additionally, several recyclers or F&A companies have stated to increasingly seek collaboration with Universities to gain insight into industry developments. Institutes that have previously conducted research on this include the *Copernicus Institute of Sustainable Development* at *Utrecht University*.

4.1.2.2 Industry Actors

An important first step in identifying the industry actors is the mapping of the value chain surrounding the PCPP mechanical recycling technology. The following value chain, presented in Figure 9, was established.

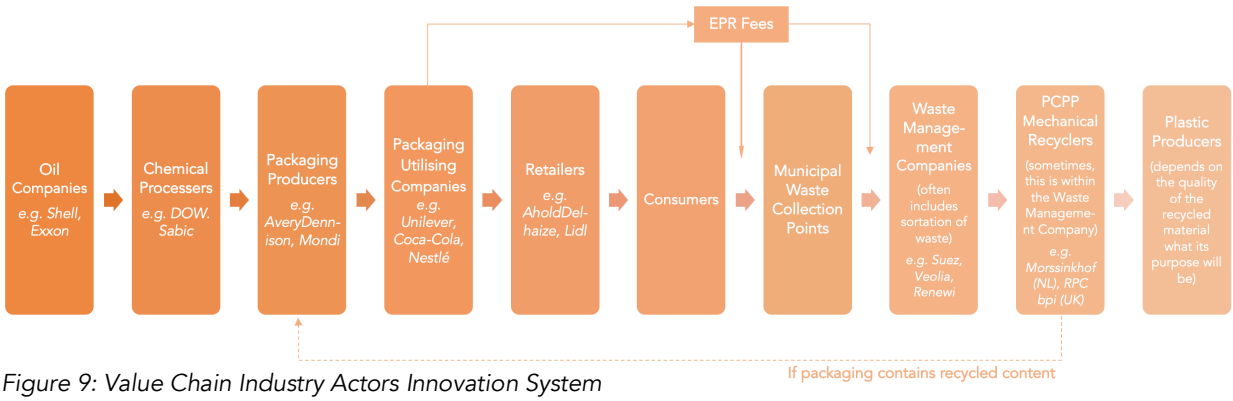


Figure 9: Value Chain Industry Actors Innovation System

This value chain can be applied to both the Netherlands as well as the UK. However, this does not mean there are no differences between the two systems regarding industry actors. Differences can clearly be seen when looking at the type of industry actors present, and the types of activities they engage in.

Firstly, the chart below (Figure 10) displays the source of waste of all mapped plastic recyclers in the Netherlands and the UK. As it could be expected, due to the higher population, the UK has a higher amount of recyclers. However, the category of waste recycling that concerns post-consumer plastic packaging, namely 'household/municipal', shows a similar amount of locations. This being 20 in the Netherlands and 22 in the United Kingdom. Since the Netherlands has a population of 17 million people, and the UK a population of 66 million, the amount of post-consumer plastic packaging recyclers in the UK is extremely low compared to the Netherlands.

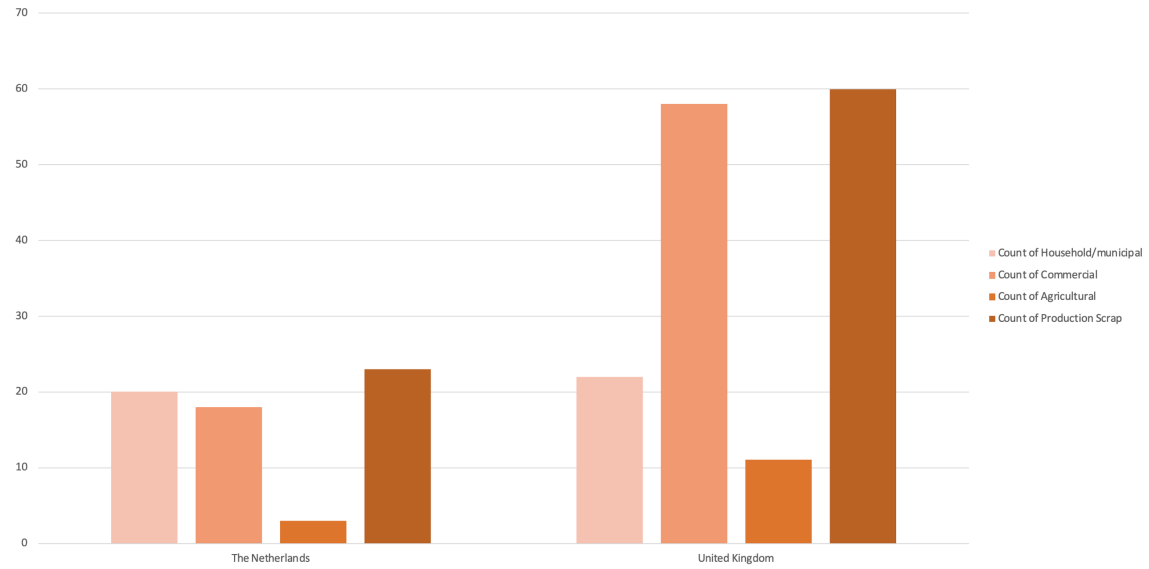


Figure 10: Source of Plastic Packaging Waste for Recyclers in the Netherlands and the UK

Furthermore, the integration between the waste management infrastructure and the PCPP mechanical recyclers can be analysed by looking at the amount of PCPP mechanical recyclers in a country that have their own feedstock collection service in place, for example through picking it up from waste management companies, or possibly even municipality sortation points. Figure 11 below displays the amount of PCPP mechanical recyclers that have their own collection service in place in the UK, whereas Figure 12 displays this data for the Netherlands.

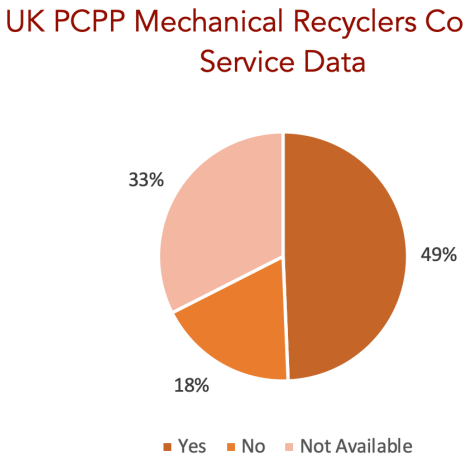


Figure 11: PCPP Mechanical Recyclers with Collection Service in the UK (%)

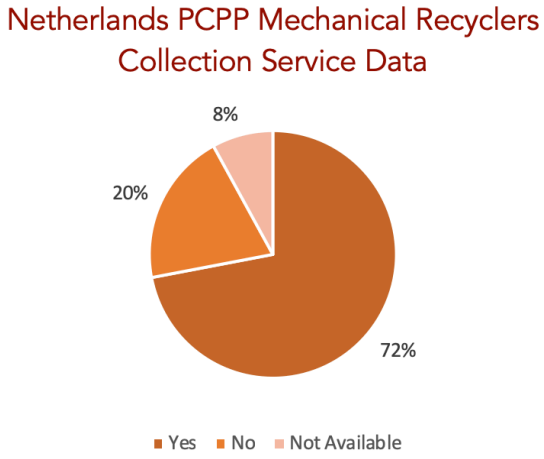


Figure 12: PCPP Mechanical Recyclers with Collection Service in the Netherlands (%)

It can be derived from the charts above that the Netherlands has a stronger integration between the waste management infrastructure and the PCPP mechanical recycling system. While this does not directly cause the higher recycling rates (as it does not give data on the amount of PCPP waste collected), it is an indication of the efficiency of PCPP mechanical recyclers' gaining access to feedstock. This can be of importance when trying to scale up recycling rates, as logistics between waste management and PCPP mechanical recyclers is already of a higher quality than in the UK.

4.1.2.3 Market Actors

Market actors in the innovation system driving demand are strongly represented in the value chain visualised earlier in Figure 9. From this figure it can be derived that the main market actors influencing demand are plastic (packaging) producers as well as plastic packaging utilisers. However, what is not visualised in this value chain is the strongest force driving demand for the PCPP mechanical recycling technology: legislation. Legislations drive both the national, and European, demands for PCPP mechanical recycling due to plastic recycling

targets. Moreover, legislation act as a driver through imposing regulations on plastic (packaging) producers and packaging utilisers regarding recycling of products put on the market, or even use of recycled content. In order to gain a deeper understanding of the legislative changes driving this demand, section 4.1.2.4 on government bodies and supportive organisations provides an in-depth analysis of the changes happening at EU, as well as at UK and Dutch national level, regarding legislation on plastics and recycling.

4.1.2.4 Government bodies and Supportive Organisations

One can distinguish between government bodies at EU level and at national (the UK and the Netherlands) level. As aforementioned, regulatory changes at EU level have had a strong impact on the ongoing changes within the PCPP mechanical recycling system. This section, 4.1.2.4, will largely focus on these legislative changes at EU level and additionally zoom in on legislations in place at UK and Netherlands level, as well as highlighting current changes occurring in these national governmental bodies.

4.1.2.4.1 The EU Circular Economy Package

The main legislative change instigating the current trends in the plastic recycling industry is the implementation of the EU Circular Economy Package (CEP). The CEP was implemented in 2015 (European Commission, 2015) and consisted of a number of focal points and sections, all of which are depicted in the Figure 13 below. The sections highlighted in dark red contain elements that influence the plastic packaging or mechanical post-consumer plastic packaging recycling industry. All relevant sections of the CEP will be elaborated on below.

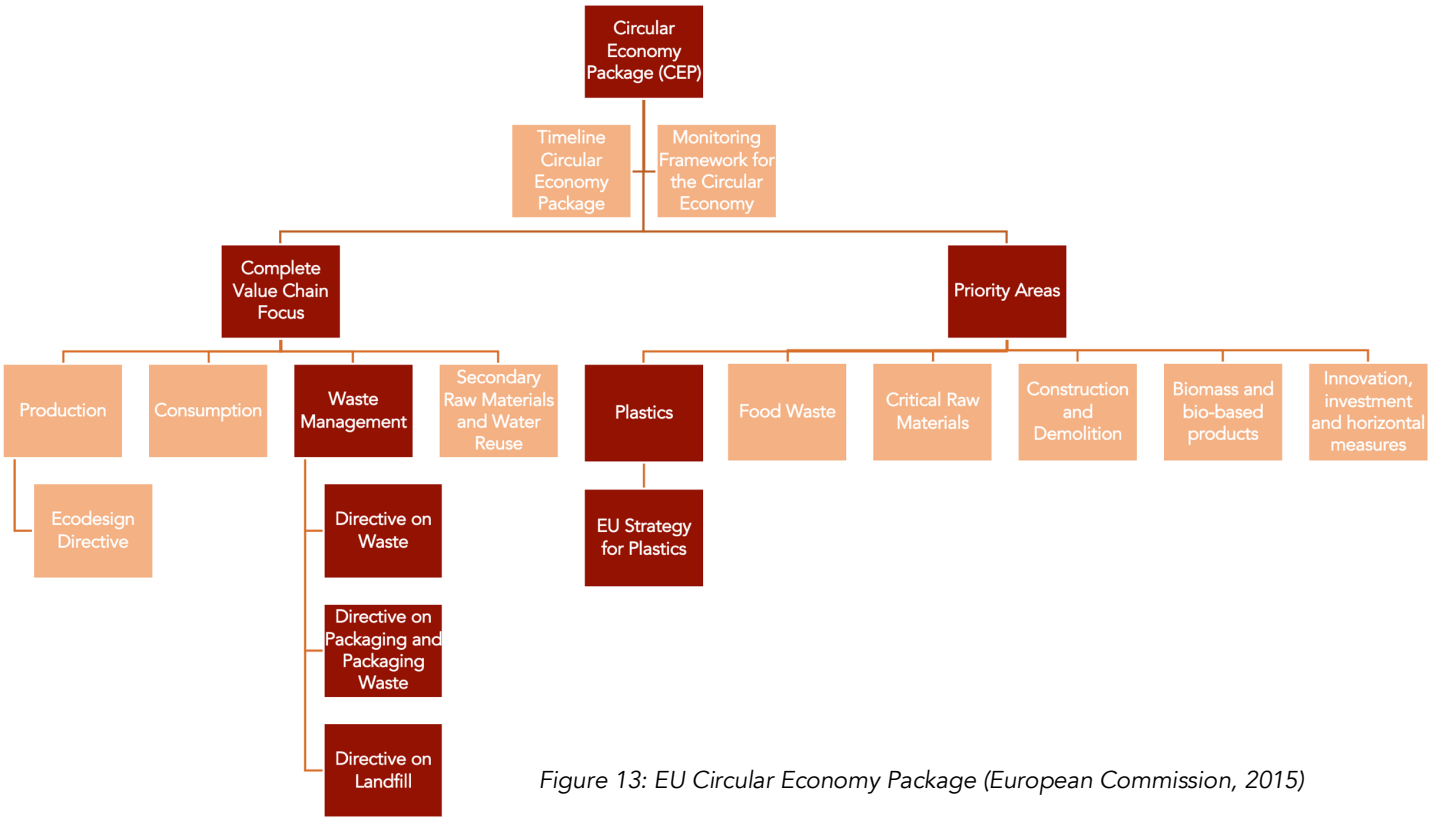


Figure 13: EU Circular Economy Package (European Commission, 2015)

4.1.2.4.2 Directive on Waste

The Directive on Waste, first introduced in 2008, defined basic concepts and definitions with regards to waste and waste management as well as introducing regulations regarding safe waste management (European Commission, 2016b; European Union, 2008) However, what is of greatest impact for the recycling industry is the fact that the Directive was revised in 2018 (European Union, 2018). The revision of the Directive resulted in municipal waste recycling targets (through which post-consumer plastic packaging is collected): a minimum of 55% of municipal waste should be recycled by 2025, a minimum of 60% by 2030 and a minimum of 65% by 2035 (European Union, 2018). Furthermore, minimum requirements for the earlier established Extended Producer Responsibility schemes should be set as currently the impact of the EPR schemes differ greatly between Member States (European Union, 2018).

4.1.2.4.3 Directive on Packaging and Packaging Waste

As the case with the Directive on Waste, the Directive on Packaging and Packaging Waste was also revised in 2018. In this revision recycling targets were set for multiple materials. For plastic these targets are a minimum of 50%, in weight, plastic packaging should be recycled by 2025 and a minimum of 55% in 2030 (European Union, 2018). Furthermore, the Directive on Packaging and Packaging waste sets requirements for placing packaging on the market: weight and volume of the packaging should be reduced, the content of hazardous substances in packaging should be reduced and one should aim to design packaging that is reusable and recoverable. Furthermore, the improved EPR scheme requirements also falls under this Directive. Additionally, Member States should increase the share of reusable packaging through for example implementing Deposit-Return Schemes, setting of targets, using economic incentives, or establishing a minimum of reusable packaging placed on the market. Furthermore, Member States should make sure that sufficient systems are in place for return and collection of used packaging and packaging waste as well as setting up reuse, recover and recycling systems (European Union, 2018). Furthermore, the European Commission will look into marking systems for packaging that indicate the type of packaging materials in order to facilitate identification, which will improve sorting (European Union, 2018).

4.1.2.4.4 Directive on Landfill

As part of the EU CEP, the Directive on Landfill was also revised. While largely inapplicable to mechanical recycling diffusion, it states that the EU will aim to do the following: "phasing out landfilling by 2025 for recyclable waste (including plastics, paper, metals, glass and bio-waste) in non-hazardous waste landfills, corresponding to a maximum landfilling rate of 25%" (European Commission, 2016a). This will most probably boost the demand for mechanical recycling.

4.1.2.4.5 EU Strategy for Plastics

As part of the EU CEP, the EU Strategy for Plastics was developed. As this concerns a strategy rather than a Directive, regulations proposed in the Strategy may not be directly implemented but there is an intention to do so. The proposed measures include improving the economics and quality of plastic recycling; this is done through, for example, setting eco-design measures regarding the recyclability of plastic products, boosting recycled content through campaigns and a quicker authorisation of using recycled content in food-contact materials. Furthermore, a European Ecolabel was developed in order to create an incentive for using recycled plastics by setting certain sustainable packaging standards necessary to receive this Ecolabel on products. Additionally, the separation and collection of waste is to be improved by, for example, issuing new guidelines on separate collection and sorting of waste (European Commission, 2018a).

Additionally, the EU Plastics Strategy focusses on curbing plastic waste and littering. Part of this is the aforementioned single-use ban which prohibits the ten most polluting plastic products[10] found in the ocean (European Commission, 2018d). Industry experts state that this is a good start to tackle the plastic pollution issue but more of a systemic change is necessary, such as focussing on increasing the performance of the waste infrastructure, in order to make an actual lasting impact.

> *"For example, the trend around single-use plastics it's great, but there really needs to be a systematic change rather than just this; and this is happening but it costs time and money"*
>
> - Expert 6

Furthermore, the EU will aim to stimulate investment and innovation towards circular solutions, which may be of positive impact on the mechanical recycling industry and additionally harness global action, focussing on regions outside the EU (European Commission, 2018a).

4.1.2.4.6 Plastic & Waste Legislation Changes in the Netherlands

The Netherlands has both an EPR scheme (Table 4) as well as a Deposit Return Scheme (Table 5) in place. In an EPR scheme, producers placing plastic packaging onto the market pay a fee to a national waste management organisation that in turn pay the local municipalities to employ waste collection infrastructures. The EPR fees charged to plastic producers in the Netherlands can be found in Table 4 below (Afvalfonds Verpakkingen, n.d., b).

[10] 1) Food containers and cups for beverages; 2) cotton bud sticks; 3) cutlery, plates, stirrers, straws; 4) balloons & sticks for balloons; 5) packets & wrappers; 6) beverage bottles & beverage caps and lids; 7) tobacco product filters; 8) wet wipes & sanitary towels; 9) lightweight plastic carrier bags; 10) fishing gear (European Commission, 2018d)

Table 4: EPR Fees the Netherlands (Afvalfonds Verpakkingen, n.d., b)

Plastic Material	2019 Fee €/kg excl. tax	'16 '17 '18 Fee €/kg excl. tax
Plastic *(regular fee)*	0,6400	0,6400
Plastic *(discount fee[11])*	0,3800	n.a.
Biodegradable plastic	0,6400	0,0200
Drinking cartons	0,3800	0,1800
Bottles *(deposit-scheme)*	0,0200	0,0200

In a DRS system, consumers that handed in plastic items, most commonly plastic bottles, are compensated with a fee for each item, the goal being to stimulate consumers to engage in waste collection and thus in turn increasing the plastic waste collection rates as well as the PCPP mechanical recycling performance. The Dutch DRS compensation amounts for this are presented Table 5 (Bergsma et al., 2019).

Table 5: DRS Payments The Netherlands (Bergsma et al., 2019)

Plastic Bottle	Recycling Payment (One-Way)	Reuse Payment (Refillable)
0,25L	-	-
0,5L	-	-
0,75L	€0,25	-
1L	€0,25	-
1,25L	€0,25	-
1,5L	€0,25	-

Additionally, the Dutch government has implemented several new plastic and waste regulations. In 2016, giving plastic carrier bags away for free was banned (Rijksoverheid, n.d. a). Furthermore, the Netherlands set packaging recycling targets for 2019, this is 49% for

[11] This discount fee is applied to plastic packaging that has increased recyclability (Afvalfonds Verpakkingen, n.d.)

plastic packaging (Rijksoverheid, n.d. b), something that was already achieved in 2017 (AfvalFonds Verpakkingen, n.d. a).

Additionally, in February 2019 the Dutch Secretary of State for Infrastructure and Water Management, along with 75 industry players, signed the Plastic Pact NL, which states that by 2025 all single-use plastics placed on the market by plastic-utilising companies, such as F&A companies, should be re-usable if possible and, if not, they should be 100% recyclable. Furthermore, all plastic-utilising companies should not use more plastic than necessary by for example re-using, reduction of use, or using alternative materials, resulting in a 20% decrease (weight) compared to 2017 use. All plastic-producing companies should furthermore create enough sorting and recycling capacity in the Netherlands in order to recycle 70% (weight) of all single-use plastics and packaging in Dutch waste. Finally, all single-use plastics and packaging placed on the market by plastic-utilising companies should include a as high as possible level of recycled (weight) plastics, with an average of at least 35% per company. Bio-based plastics should be used as much as possible and primary fossil fuel use should be minimised (Ministerie van Infrastructuur en Waterstaat, 2019).

4.1.2.4.7 Plastics & Waste Legislation Changes in the UK

Currently, the UK does have an EPR scheme but does not have a Deposit Return Scheme (DRS) in place. However, the UK is set to face multiple changes to its waste legislation, as consultations for multiple plans are ongoing, and implementing a DRS is included in these plans (Department for Environment, F. & R. A., 2019). EPR fees for plastic packaging placed on the UK market are presented in Table 6 below (PRO Europe, 2019)

Table 6: EPR Fees the UK (PRO Europe, 2019)

Plastic Material	2019 Fee Estimation *£/ton*
Plastic	30,30 – 46,80[12]

In addition to assessing the possibility of implementing a DRS system in the UK, the government has announced launching consultations on several other waste legislations including increased EPR fees, implementing a tax on plastic packaging that does not meet a minimum 30% recycled content (Department for Environment, Food & Rural Affairs, 2019). Furthermore, the UK is set to improve its currently underperforming waste collection infrastructure through the aforementioned possible implementation of DRS fees, possible increase of the EPR fees as well as possible taxes for plastic packaging (Addison, 2019).

[12] A range is presented as they vary across the year and PRO Europe (2019) predicted the average to fall within this range at the end of 2019. £30,30-46,80 = €33,81-52,22 using the exchange rate of £1 = €1,12, adapted on the 14th of July 2019.

4.1.2.5 Networks

The above-stated actors operate in networks through several mechanisms.

Firstly, network creation is done independently through value chain collaboration, throughout the value chain as presented in Figure 9. Interviewees highlighted the fact that there is increasing value chain collaboration in the innovation system, even across actors not directly involved, in order to increase the efficiency of PCPP mechanical recycling.

Secondly, the most networks are formed through industry associations as well as commitments and initiatives and the projects that are fostered out of these, both at EU and national (UK and Dutch) level.

At EU level, industry associations operating are as aforementioned, PRE and PlasticsEurope. Apart from the previously stated knowledge creation and exchange these associations foster the collaboration between recyclers and plastics producers and additionally act as a representative for all of its members in, for example, discussions with governmental organisations or large packaging utilisers (e.g. Coca-Cola, Unilever) in order to give the plastic, or plastic recycling industry, a stronger voice in these discussions. Thus, these industry associations in turn result in networks both between different PCPP mechanical recyclers as well as between PCPP mechanical recyclers and other actors in the innovation system, such as packaging producers and packaging utilisers or government. Furthermore, the aforementioned Ellen MacArthur Foundation, apart from creating and sharing knowledge, aids in collaborations between all those involved in the 'Plastics Economy', thus resulting in collaborations between PCPP mechanical recyclers as well as F&A companies, or packaging utilisers, and packaging producers. The key characteristic of these networks, whether created through industry associations or through initiatives and commitments, are that they increasingly take into account, according to the interviewees, all actors within the PCPP mechanical recycling value chain.

At UK level, industry associations such as the British Plastics Federation and The Recycling Association, aid in the formation of networks, similarly to those at EU level, by creating networks both between PCPP mechanical recyclers as well as between PCPP mechanical recyclers and other actors in the innovation system through engaging in discussions representing all of its members.

Regarding initiatives and commitments in the UK, WRAP UK has established a UK Plastic Pact that has set several targets, and a road map, to increasing sustainability of plastics and plastic packaging in the UK by 2025. Several system actors such as F&A companies, retailers, packaging companies, and PCPP mechanical recyclers have signed up and have thus engaged in a broad network integrating all aspects of the value chain as presented in Figure 9.

Analysing the networks in the Netherlands, one sees that these industry association-driven networks are also created here, through associations such as Plastics Recyclers Europe NL, KIDV and NRK.

Regarding initiatives and commitments in the Netherlands, the previously discussed Plastic Pact NL, has caused a strong increase in network creation in the Netherlands as it engages several system actors, ranging from PCPP mechanical recyclers to F&A companies and packaging producers in attaining national recycling and recyclability targets.

Table 7 below displays an overview of the actors and networks discussed above.

Table 7: Actors and Networks in the PCPP Mechanical Recycling Innovation System

Structural Component	Europe (Global Included)	The UK	The Netherlands
Actors: Knowledge and Educational Institutes	1. Initiatives or projects that focus both on knowledge creation as well as exchange, e.g. *CEFLEX, Ellen MacArthur Foundation.*	1. Industry associations involved in both knowledge creation and exchange, e.g. *WRAP UK, PlasticsEurope UK.* 2. Engaged in research on technological innovations, e.g. *University of Portsmouth.*	*1.* Industry associations are largely the stimulator for knowledge development and exchange, e.g. *NRK and NRK Recycling, 'Kennisinstituut Duurzaam Verpakken' (KIDV), PlasticsEurope NL.* 2. Universities, engaged in knowledge creation on request of recyclers or F&A companies, e.g. *TU Eindhoven, Utrecht University.*
Actors: Industry	1. EU/Global Recyclers, e.g. *CeDo recycling.* 2. EU/Global Waste Management Companies, e.g. *Veolia, Suez, Renewi.*	1. UK recyclers, e.g. *RPC bpi group, Recycled Plastic UK.* 2. UK Waste Management Companies, e.g. *BIFFA Waste Services.*	1. NL Recyclers, e.g. *Morssinkhof, 4PET Recycling, KRAS Recycling.* 2. NL Waste Management Companies, e.g. *Attero, AVR.*
Actors: Market	1. EU/Global Packaging	1. UK packaging companies, e.g.	1. NL packaging companies, e.g.

	companies, e.g. *AveryDennison.* 2. EU/Global F&A companies, e.g. *Unilever, Danone, Nestlé, Coca-Cola.*	*M&H Plastics (RPC bpi group).* 2. UK F&A companies, e.g. *Bakkavör.*	*Oerlemans Packaging.* 2. NL F&A companies, e.g. *AholdDelhaize.*
Actors: Government bodies and Supportive Organisations	1. EU Government 2. Ellen MacArthur Foundation	1. UK Government a. Innovate UK. 2. UK Waste Management, EPR organisation	1. NL Government a. Plastic Pact NL 2. NL Waste Management, EPR organisation
Networks	Most interactions between actors happen 1. Through industry associations, e.g. *Plastics Recyclers Europe (PRE), PlasticsEurope.* 2. Or through initiatives and commitments, e.g. *The Ellen MacArthur Foundation Global Commitment.* Key to interaction through initiatives and commitments is the interaction of the complete value chain (F&A, packaging producers, recyclers, government, institutions, etc.).	Most interactions between actors happen through 1. Industry associations, e.g. *The British Plastics Federation (BPF), The Recycling Association.* 2. Or through initiatives, commitments and projects, e.g. *the UK Plastic Pact by WRAP UK* (including both F&A as well as recyclers). Industry associations concern networks mainly between industry actors (recyclers, waste management companies). Initiatives foster value chain collaboration and thus a broader network creation.	Most interactions between actors happen through 1. Industry associations, e.g. *Plastics Recyclers Europe NL.* 2. Or through initiatives set up by such associations, e.g. knowledge development by e.g. *KIDV, NRK.* 3. Also through commitments, e.g. *Plastic Pact NL* (both F&A as well as PCPP mechanical recyclers and government).

Summary Section 4.1: TIS Step 1: Structure

→ Analyses of trends in technological innovations revealed several trends; chemical recycling, a competitor of PCPP mechanical recycling, that will however not form a great threat. Additionally trends in the use of enzymes or additives in treating multi-polymer packaging, innovations focussed on increasing sortation amongst consumers, such as through chips and labels, and finally design-for-recyclability, making the PCPP waste more efficient to recycle.

→ Regarding relevant actors; knowledge and educational institutes concern mainly industry associations, at national levels additionally Universities. Industry actors are visualised in Figure 9, main utilisers of the PCPP mechanical recycling technology being the recyclers and waste management companies. Market actors that stimulate demand are packaging companies and packaging utilising companies (including F&A), demand is largely driven by regulations on these market actors. Governmental bodies and supportive organisations include both national and EU governments, in which many changes have recently occurred (e.g. recycling targets by the EU, the Dutch Plastic Pact, the possible DRS system in the UK).

→ Networks in the innovation system are being formed largely through industry associations as well as through initiatives and commitments. The former mainly creates networks between PCPP mechanical recyclers, the latter causes networks between the entire PCPP mechanical recycling value chain (including F&A companies).

4.2 TIS Step 2: Phase of Development

While the technology of mechanical recycling of general plastic has been around for a long time, and it could be stated that this has reached market saturation, it was stated by multiple interviewees in both the UK and the Netherlands that mechanical recycling of specifically post-consumer plastic packaging is quite a new technology that started only recently in comparison to other types of plastic recycling as well as in comparison to recycling of other types of post-consumer packaging (e.g. glass or paper).

> *"If you look back, you'll see that the recycling industry for post-consumer plastics is quite young, I think … that this has been starting in the Netherlands since 2010"*
>
> **- Recycler 3**

Furthermore, it became clear that the PCPP mechanical recycling technology is in the acceleration phase as it is being commercially applied, yet it will continue to experience growth in the years to come due to the current regulatory as well as societal influences leading to increasing attention for recyclable packaging or using recycled content.

> *"This [increasing regulatory and societal pressure] means that recycling facilities see a lot of opportunities because there is an increasing demand for recycled content. So, we see that as an opportunity"*
>
> **- Recycler 4**

Due to the differences in infrastructure performance, and thus feedstock availability. One can conclude that the Netherlands is further ahead in the acceleration phase in comparison to the UK.

> *"If we look at England, the infrastructure is very scattered, the waste management is not very good"*
>
> **- Recycler 4**

After analysis of all 17 interviews, the phase of development of both the UK and the Netherlands have been placed in the 'acceleration' phase as visualised in Figure 14 below. It should be noted that both countries have only recently transitioned into the phase and neither are close to market saturation. PCPP mechanical recycling in the Netherlands is, however, further developed than in the UK.

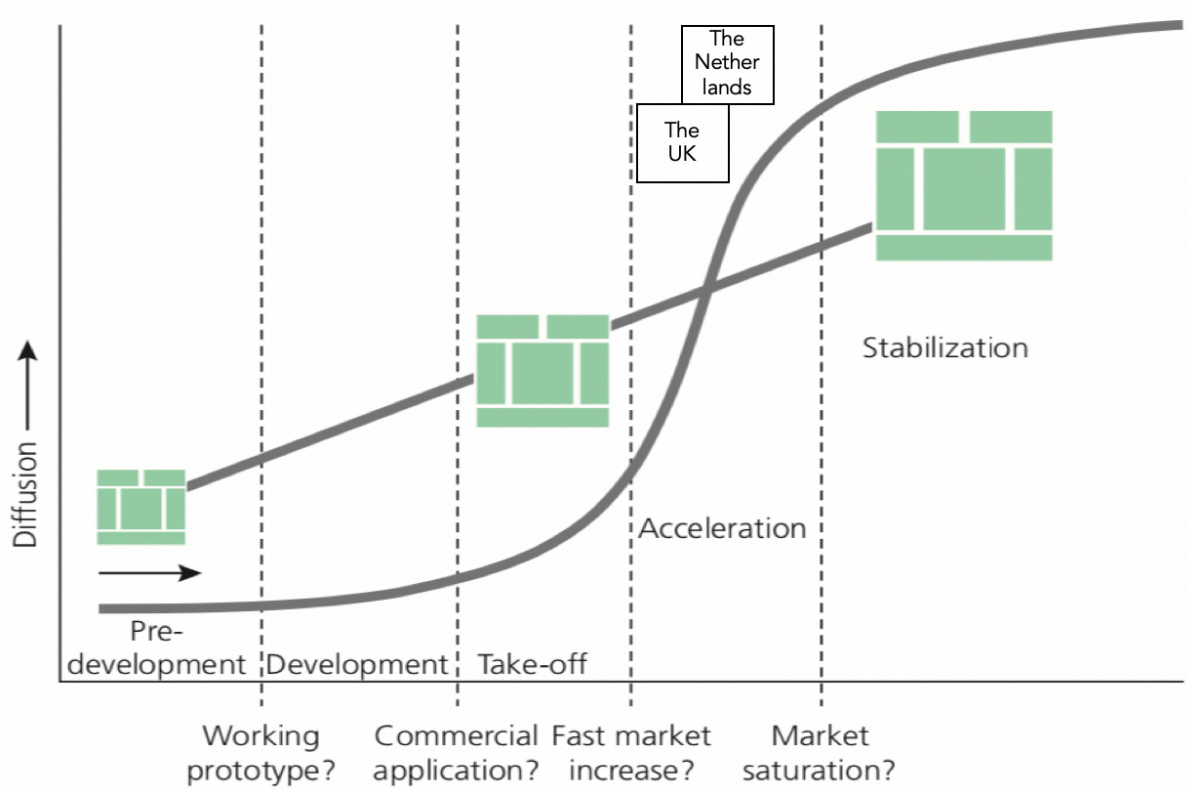


Figure 14: Phase of Development the UK and the Netherlands

Summary Section 4.2: TIS Step 2: Phase of Development

→ The PCPP mechanical recycling industry is quite young. Due to growing societal and regulatory pressures, this technology is currently in the acceleration phase.

→ While both in the acceleration phase, the Netherlands is further ahead in the development than the UK. While the waste infrastructures in both countries need improvements, the UK displays a poorer waste infrastructure and this is the main cause for the difference in development.

4.3 TIS Step 3: System Functions

4.3.1 F1: Entrepreneurial experimentation and production

When asking about innovation efforts being taken by recycling companies, exact specifications on the types of innovations being undertaken were kept confidential. Companies did however disclose in which parts of the mechanical recycling process (e.g. washing, sorting) innovations were being done. From this, it became clear that innovations currently lie on supporting technologies that aid in increasing the efficiency and the quality of the output of the mechanical recycling technology. One of such supporting technologies concerns that of washing, several recyclers disclosed:

> *"The cleaning is the first issue, no one wants this is in a product, that is where we get the most questions for, so we're developing a lot on this, without needing a lot of energy or dangerous chemicals"*
>
> - Recycler 5

As aforementioned, one of the issues of PCPP mechanical recycling is the fact that PCPP is often built-up of multiple polymers. Multiple recyclers stated to focus their innovation efforts on the use of certain additives that make these different polymers compatible during the recycling process, this 'compatibilisation' aids in the separation of these polymers in order to make a cleaner recycled product.

> *"There are also tests being done with compatibilising additives that can separate these types of plastics. However, many of these additives can only separate two types of plastics while some plastics may contain up to 8 different layers of plastics. Ravago is currently running tests with this"*
>
> *- Recycler 1*

Furthermore, some recyclers are focussed on innovating packaging that is easier to recycle in order to share these innovations with F&A companies, packaging producers, or produce it themselves.

> *"Making the packaging more recyclable. In the past some packaging contained material that prohibited the packaging from being able to be recycled. Our innovation activities are looking at making packaging more efficient, recycling and making it more recyclable. So that's broadly what we do within the group"*
>
> - Recycler 4

Furthermore, interviewees stated that there is a lot of innovation happening in the industry, many of these new technologies focus on improving the performance of mechanical recycling. However, a large part of these technologies are still in the first research phase and thus the innovation within the industry definitely has room for improvement.

"What I think is that because the EU has set very ambitious targets, in order to reach these, we really need to make big steps in the usage of recycled content. If you ask the whole chain, both in quality and quantity, it needs to be improved. So, we really have to specifically innovate in order to make sure this will improve"

- Recycler 5

When asked whether they thought there was enough innovation ongoing in the system, and whether there were enough actors engaging in this, F&A companies seemed to be the most positive, both in their interview statements as well as looking at the final given score to this system function (3,67 out of 5 compared to 3 out of 5 by the other interviewees). The recyclers and experts, while not necessarily, gave a more nuanced score and this was also reflected in the interviewees, where they stated that while there is increasing innovation going on due to the growing legislative and social pressures on the industry to increase recycling rates, the current level of innovation is not yet sufficient in actually targeting the issues that are limiting the further diffusion of the PCPP mechanical recycling technology. No clear distinctions regarding entrepreneurial experimentation and production were found between the Netherlands and the UK.

4.3.2 F2: Knowledge development

The mechanical recycling of post-consumer waste, as aforementioned, is quite a young industry, this is namely also due to the fact that recycling of post-consumer plastics faces many technological challenges such as contaminated waste, that remains to have a smell or discolouration after recycling. Knowledge development should thus continue to focus on improving the quality of the recycled material by targeting this contamination issue.

"We do have to be honest though that the recycling industry has leaps to make in quality of material. If you're a producer now you're used to virgin materials, and when from the recycling industry we say: 'Look we have something that's similar to this but the quality might differ a bit per time and the colour might be a bit different and there can be a small smell attached to it' this doesn't make it easy. So, we have a lot of leaps to make regarding quality"

- Recycler 3

Furthermore, another difficulty of PCPP mechanical recycling is that of recycling poorly designed packaging that did not take into account recyclability during the production. For example, packaging that consists of multiple layers of plastics merged together is difficult to separate and, thus, recycle. According to interviewees, more knowledge development should be done in the field of 'design-for-recyclability' in order to develop easier to recycle PCPP.

"Also, the re-development and re-design of packaging. And we try to stimulate this through for example working groups and projects, and this is something that is currently ongoing and that I wish

would go faster but I'm really dependent on the capacity of the members, and their willingness to participate. And many members you do see are focussed on their own business issues"

- Expert 2

Comparing the opinion of the different interviewees amongst each other reveals that, regarding the level of knowledge development present in the system, the F&A companies were the most negative (giving an overall score of 2,67 out of 5). PCPP mechanical recyclers and industry experts were slightly more positive in their rating of the level of knowledge development in the system (3 out of 5 by experts and 3,33 out of 5 by PCPP mechanical recyclers).

This difference in opinion on the sufficiency of knowledge development may be explained by the aforementioned fact that much knowledge development takes place in plastic and plastic recycling industry associations. Many of the industry experts were involved in such industry associations, and the interviewed PCPP mechanical recyclers are often a member of such associations. As F&A companies are not directly involved in this, they may not get a full insight into the level of knowledge development actually present in the innovation system. While knowledge development is also done through initiatives and commitments such as the New Plastics Economy Commitment, where F&A companies are involved, they may only get partial insight into all the ongoing developments, hence explaining their more negative view on the topic.

When comparing the level of knowledge development in the UK and the Netherlands, as well as at EU-level, the conclusions of the interviewees suggest that the most knowledge development is being done at a European level. However, in the Netherlands, there are additional knowledge development activities ongoing within the national industry associations that seem to be less present in the UK. This is concluded from comparing the UK-based PCPP mechanical recyclers to that of the Netherlands-based PCPP mechanical recyclers. The ones in the Netherlands seem to be engaged in both European projects and initiatives as well as national ones, while the UK ones seem to be engaged merely with EU-level projects.

4.3.3 F3: Knowledge exchange

When asked if there is sufficient sharing of knowledge regarding mechanical recycling technology development, or technologies that support the diffusion of mechanical recycling (e.g. design-for-recyclability of packaging, which makes the recycling process more efficient), interviewees state that there was some lag in the sharing of the knowledge, but that the recent regulatory and societal pressure has spurred an increase in this. Main topics covered when exchanging knowledge focusses on 'design-for-recyclability' as well as possibilities in recycled content use, or other innovations. This knowledge exchange is often executed through projects, initiatives, or industry associations.

"The design for recyclability is done within PRE or Petcore, where they're working on the guideline. Even in our case we have developed internal tools on what is existing there. And we're more than happy to share with the rest of the industry, we've organised some meetings to share. In the end there's a conversation on what recyclable means and CEFLEX is an example to find solutions for flexibles [solutions to recycle flexible packaging]. So collaboration is happening, it's probably not happening as fast as we'd like, but again everyone is realising change is necessary [and thus working hard on it]"

– F&A Employee 2

Furthermore, F&A companies are very active in engaging in knowledge sharing, in which they are largely the party aiming to receive input of knowledge from, for example, recycling companies on what the possibilities are in attaining their set targets.

"Currently, the need for information and knowledge is from these large brand-owners because there's a lot of lack in knowledge about what is possible and what is not possible [...] We have a lot of contacts with the Unilevers, the Procter & Gambles, Nestle and clubs like that. But then it indeed concerns focal points such as design for recycling, we are not a supplier for them, there are a lot of links in between us, so there are discussions about what is good and what is less good. So, if you want to become more sustainable and want to transfer your packaging, it should match to the need of the recyclers. So, we have contact with them about what goes well, about some things that might not work, what could be an alternative, etc."

- Recycler 3

While knowledge sharing is thus quite active within the system, some specific knowledge sharing is, by multiple interviewees, stated to remain limited when focussed on technological innovations. This is due to the fact that many of the collaborating businesses are competitors of each other. These companies have to protect their Intellectual Property (hereon: IP), and this sometimes results in limited knowledge exchange:

"I've seen with one of the projects of the Ellen MacArthur New Plastics Economy… the project, it started of as everyone being very keen to make a change and participate. And then when it comes to IP people don't want to disclose, people don't want to get to joint agreements. So, it's still that the project failed because people don't want to be sharing IP or give information to someone else. So, I would say that the project failed because of all these IP sharing issues. It's a shame for the process of these projects."

- Recycler 4

Regarding the sufficiency of level of knowledge exchange within the innovation system, the interviewees were quite split. The F&A companies were very positive, as they stated that they generally experienced the interaction with the PCPP mechanical recyclers, and other system actors such as packaging companies, as very fruitful and positive. This was also reflected in their rating, giving the system function of knowledge exchange a 3,83 out of 5. The industry experts were scattered in their rating, awarding an average of 2,33 out of 5, of which one of

the interviewees awarded a 5. Statements by industry experts reflected this scattered opinion, as they stated that there is a lot of useful knowledge exchange ongoing, and the amount of knowledge exchange is increasing, yet knowledge exchange also seems to be limited by the focus on discussions rather than solutions and by rigid IP protection by companies. Interview statements by recyclers on the knowledge exchange system function were similarly scattered as the industry expert interviewees, stating the same positive and negative aspects of current knowledge exchange activities in the PCPP mechanical recycling innovation system.

4.3.4 F4: Guidance of the search

As aforementioned, the adaptations of the EU legislations have acted as one of the stimuli for the changes currently occurring in the mechanical recycling industry. Therefore, the majority of the interviewees was positive and stated that they believed the changes will definitely be effective in scaling up mechanical recycling. However, during the interviews it became apparent that the changing legislations are also acting as a guideline in how this transition should take place.

"These discussions have been strongly ongoing since the regulations that were introduced by Brussels last year, the clients, being packaging companies or retailers, and one more than the other, have, because of this, started to think about the sustainability of their packaging, for example looking at the recyclability. So, people are thinking about this"

- Expert 2

As aforementioned, the UK is lagging behind in its pathway towards reaching the EU recycling targets and this was reflected in the interviews. Interviewees did, however, also highlight the aforementioned future changes planned for the British waste infrastructure.

"There is currently consultation in the UK going on about the Plastic Pact, for example regarding recycled content in packaging"

- Recycler 4

Regarding Dutch legislation, the majority of the interviewees were pleased regarding the fact that Dutch legislation is ahead of the EU schedule and shows additional efforts such as the Dutch Plastic Pact. However, the main flaws in the Dutch legislation concern the scattered waste infrastructure that, in the opinion of many, should be homogenised as it causes confusion amongst consumers as well as a large variance in feedstock that recyclers can thus not be prepared for.

"[…] and then I would be pro, in the Netherlands, to have one kind of collection system in place, and now there is all these different types, and all the municipalities are responsible for it which is good because you should have this responsibility at such a low level but it does mean that you have

different types of collection systems per municipality, which can be confusing"

- Expert 2

The scattered waste infrastructure in the UK and the Netherlands will be further elaborated on in section 4.4.

A legislation-related issue that often arose during discussion on technological limitations concerns food safety regulations. Strict food safety regulations in both the Netherlands and the UK limit the use of recycled content in food-contact materials and thus limit the increase of demand for recycled material. In the view of several interviewees, food regulation is a limiting factor in the diffusion of mechanical recycling.

"The only one that we are currently using for food-grade application is PET, you have some food-grade for PE and PP in the US, but they are only FDA [U.S. Food and Drug Administration] approved, not in Europe. So, it's only PET, and we really believe that with mechanical recycling the other ones will be difficult to create food-grade"

– F&A Employee 2

When comparing categories of interviews, the results for this system function are very consistent across all categories. Most interviewees were generally quite positive on government and changing regulations, except for two experts, in which their critique concerned mainly the scattered waste infrastructure present, others did not blame this directly on regulations. In general, all interviewee categories agreed that legislation, and recent changes in regulation, have a positive impact on the diffusion of the PCPP mechanical recycling technology.

The main critique, displayed by all categories of interviewees, was that while legislation has a very positive impact on the innovation system, the governmental bodies should be careful not to implement legislations to hasty without considering the environmental impact of the suggested alternative materials. For example, if one were to eliminate a certain type of plastic product and replace it with all-glass, the CO2 footprint of this product will drastically increase as it would require more transport and more production energy. While not having a negative impact on the PCPP mechanical recycling, this was mentioned so often that it was important to note this consideration.

While no distinction was visible between the UK and Dutch interviewees in this system function, one of the UK recyclers did state that the announced changes of the UK government were very necessary, but he was positive about these being implemented.

4.3.5 F5: Market formation

In discussing demand, the results coming from the interviews were very mixed. On the one hand, the increasing societal and regulatory pressure on the plastics industry seemed to have created a strong increase in demand for recycled material.

"Yes, well I just want to say that in 2014 I didn't find it that clear yet; there was interest but it was quite small and we did speak to some brands but namely in 2017, 2018 we saw an acceleration, I would even maybe say since 2018, you also see this in the prices. You see in the prices of recycled material, namely of course of that of mechanically recycled as that's what's on the market, you see that this has increased with 30-40%, because of the huge demand, and in the first half of 2017 this was definitely not the case, there were really low prices. So, I would say this is happening in the last 1-2 years."

– Expert 6

On the other hand, some interviewees also stated that due to customers and marketeers of brand-owners rejecting the use of recycled material in packaging (due to the fact that it may have a slight smell or discolouration), demand for recycled materials is currently still quite limited. In addition, some interviewees stated that Food & Agribusiness companies ask for such high-quality recycled material that it is currently not possible to deliver/achieve and, thus, demand for the current quality of recycled material stays low.

"But then you realise that this whole market is based on virgin raw materials, with the main advantage being that it's consistent with certain specifications and build-up of material that are consistent. And this is not the case when it's recycled, of course it's not a mono-material anymore. The feedstock you get is mixed, so the consistency is difficult to guarantee. So, you have to see where your market is for this. So, sometimes this virgin market creates issues; there is a lot of issues to overcome."

- Recycler 3

Finally, a competing technology for mechanical recycling, chemical recycling, was a much-discussed topic during the interviews when talking about technological limitations or innovations. However, while the majority of the interviewees stated that chemical recycling will increase in the future, none of the interviewees stated that it will diminish mechanical recycling. Rather, in all interviews in which the topic of chemical recycling arose, interviewees stated that mechanical and chemical recycling will complement each other and, thus, the increase of chemical recycling (which will take 5 to 10 years), is not expected to diminish the diffusion of mechanical recycling.

"Just chemical recycling is not viable. I know that lots of companies are doing pilot studies on chemical recycling, big oil companies are looking at it (big polymer manufacturers), but the technology is still not 'there' it will be at least another 10 years before it comes into large production […]. So, you put everything in mechanical recycling and what you can't mechanically recycle, you chemically recycle the rest."

- Recycler 4

Negativity on market formation seemed to be shared across all interviewee categories, while recyclers seem the most positive about a possible future increase demand, for which they largely thank new legislations as well as increasing consumer pressure on plastic. Some recyclers stated the current lagging to be due to resistance to the use of recycled content. This latter statement is reflected in the statements by the experts as well. While agreeing with this statement on resistance, most F&A interviewees were additionally of the opinion that technological limitations were the cause of a lacking recycled content demand, as high-quality recycled content was not yet possible for food-contact products.

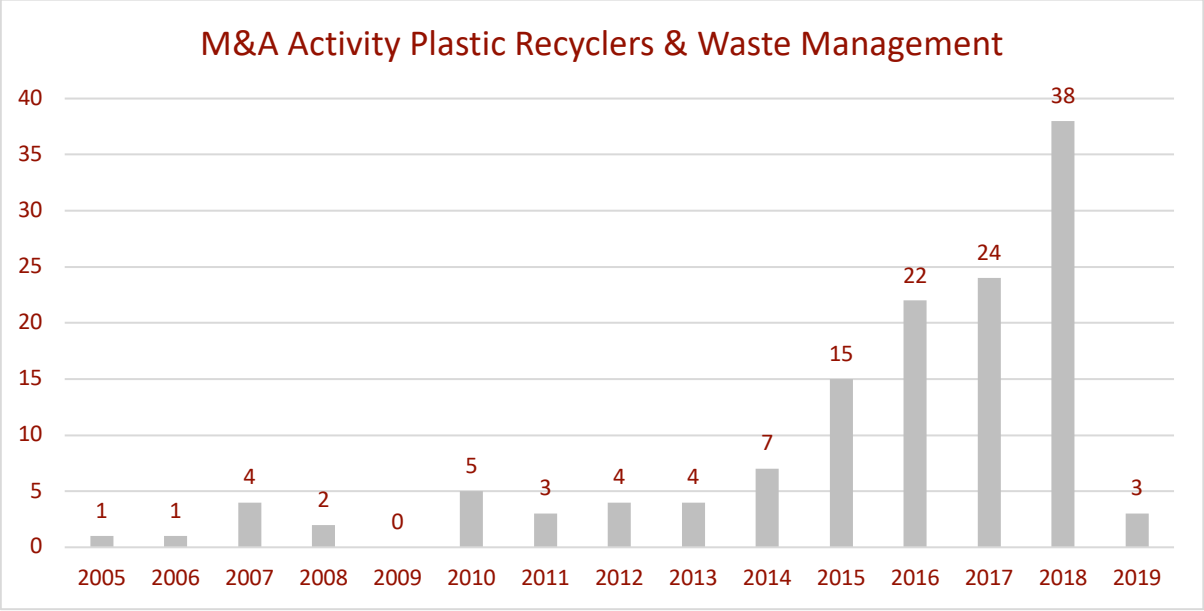
All in all, the main critique, shared by all the interviewees was that the scattered waste infrastructure (different type of collection systems in every municipality or region) caused the imbalance between available feedstock and demand. However, one industry expert interviewee displayed a nuanced view on this, as he said that this was indeed a barrier to increased PCPP mechanical recycling technology diffusion, but that this scattered-nature is, to some extent, necessary as one cannot have the same collection system in regions with vast differences (e.g. big cities with little space for collection bins are forced to have different collection systems than towns with a lot of space for collection bins).

This scattered infrastructure applies to both the UK and the Netherlands and was touched upon in all interviews.

4.3.6 F6: Resource Mobilisation

As it can be seen from Figure 15 below, the annual number of (M&A) activities has increased significantly in the past few years. The growth started in 2014 but took off in 2015, the year of publication of the EU Circular Economy Package.

Figure 15: EU M&A Activity Plastic Recyclers & Waste Management Companies 2005 - March 2019



In addition to the increase of M&A deals, a change in the nature of the deals occurred. Until 2016 deals concerned mainly market consolidation. From 2017 onwards, there is a trend of an increased amount of companies not operating within the recycling industry, or 'external companies' acquiring recyclers or waste managers. Examples of this include an increasing amount of private investors as well as the introduction of F&A companies amongst the buying companies.

Data specific for the Netherlands or the UK was not available as the majority of the companies involved operate at an EU-wide scale. While these data may not offer a direct insight into the M&A activity in the Netherlands and the UK, it gives a strong indication of the general M&A trend present in the EU.

This M&A activity gives an insight into the financial resources present in the system, as an increasing amount of mergers and acquisitions represents an increase in capital present in the industry and in turn an increasing diffusion of the PCPP mechanical recycling technology. However, financial resources are not the main source of diffusion for mechanical recycling. An important technical resource for mechanical recycling is the presence of a well-functioning waste-management system, as this provides the feedstock for the technology to operate. When asked, virtually all interviewees stated that the inefficient waste infrastructures are a barrier to mechanical recycling diffusion. Inefficiency is mainly caused by a 'scattered waste management', caused by the fact that waste collection systems differ greatly both between and within municipalities. It is often unclear amongst consumers what can or cannot be collected and how it should be separated, due to these vast local differences. Furthermore, the accessibility to waste collection points is said to be very low. This scattered waste management results in a lower feedstock for recycling than would be possible with an improved system.

"But the issue with waste is that it's decentralised, the thing with oil is that you can get it a lot easier compared to how easy you can get plastic waste. So logistically there is quite a challenge. In my opinion, the Netherlands can play a guiding role in this challenge"

– Expert 6

Furthermore, the collection aspect of the waste infrastructure was not the only issue. The fact that waste if poorly sorted leads to a contaminated feedstock of plastic packaging waste, resulting in a lower quality recycled material.

F&A employee interviewees were most negative regarding the level of resource mobilisation in the innovation system, some of which stating that governmental bodies should enable more financing of the national waste infrastructures. This opinion may be influenced by the fact that a large contribution to waste management finance is currently through the EPR fee system, to which F&A companies largely contribute. A majority of the F&A interviewees

stated that in order to scale up and improve the waste management infrastructures, more finance in addition to the EPR fees is necessary.

Industry expert interviewees were generally more positive, some of which stated that financial resources will not be an issue in increasing PCPP mechanical recycling diffusion, the main issues lies with the lack of willingness of consumers to engage with recycling and recycled content products.

No distinction between UK and Dutch interviewees were seen in this system function.

4.3.7 F7: Counteract Resistance to Change

In the interviews, very little resistance to change within companies (be them recyclers or F&A companies) became apparent. What is more, apart from the aforementioned resistance to share knowledge within industry projects, it seemed companies in general have faced very little resistance in this transition.

"No, I don't think so, I think for the large part no. I think the technical people and the people within public affairs and sustainability saw it coming and understand why, so when it comes you want to adapt. But, of course, when it comes you have to ask how the rest of the business adapts? Is it a surprise for the board or the marketeers? If you don't manage that well, they might be surprised on some new ideas, but I really don't recognise within [F&A Company 4]"

– F&A Employee 4

However, the main barrier regarding resistance concerns the consumers. Several interviewees stated that the acceptance of recycled content within plastic packaging by consumers will form a barrier for the increased demand for recycled material and thus for the diffusion of mechanical recycling.

"Another issue is also smell in the recycled material, and the market should accept this, same for that the colours would not be the same. The market expects the recycled material to be a look-alike of the virgin material and they want it at cheaper, which is not feasible. They want virgin-looking material, no smell, good properties, they want it at good availability and they want it cheap, this is not feasible."

- Expert 4

All interviewees shared the opinion on there to be very little resistance within the innovation system from the perspective of internal resistance. F&A companies, for example, stated that their employees were very willing, and even pressuring, to increase PCPP mechanical recycling involvement. This was reflected in the positivity of both the industry experts and PCPP mechanical recyclers. The main issue of resistance, according to interviewees, lies with the consumers and their acceptance of the use of recycled content in packaging.

No distinction is to be seen between the UK and the Netherlands in the interview results. However, it was stated that UK citizens are not as familiar with recycling of plastics

and thus one can state that UK consumers are having more difficulties than Dutch citizens, while both remain an issue.

4.3.8 F8: External Firm Influence (Food, Beverage & Agribusiness Companies)

A sample of 63 Food, Beverage & Retail companies previously analysed by the Rabobank on their packaging recyclability and recycled content targets gives a first insight into the influence of F&A companies in improving the performance PCPP mechanical recycling.

Of the 19 food companies included in the sample, 55% had stated targets concerning recyclability of packaging, this compared to 62% of the beverage companies (sample of 19) and 79% of the retailers (sample of 24). Furthermore, some food and beverage companies and retailers have set targets committing to the use of recycled content in packaging.

However, it is of importance to gain insight into the nature of these targets in order to determine the level of commitment taken by these F&A companies, and thus to conclude that these targets will indeed lead to actions and influence on the mechanical recycling diffusion. Table 8 below shows the percentage of companies having set targets or commitments at different degrees, illustrating percentages of concrete targets, showing signs of intent or having existing commitments in place.

Table 8: Packaging Recyclability & Recycled Content Targets by F&A Companies

Company Sample	Packaging Recyclability Targets	Concrete Targets	Showed Signs of Intent	Existing Commitments	Recycled Content Targets	Concrete Targets	Showed Signs of Intent	Existing Commitments
Food	55%	42%	13%	-	58%	54%	4%	8%
Beverage	62%	33%	8%	21%	50%	38%	4%	8%
Retail	79%	63%	8%	8%	54%	21%	8%	25%

The percentages stated in the table above are reflected in the interviews; interviewees state that a large part of the F&A companies are aware of or are taking actions regarding recyclability or use of recycled content, and many state that the F&A industry is actually having a stimulating impact on the diffusion of mechanical recycling.

"And the brands, even though they're the biggest polluters, are definitely the parties that stimulate innovation the most in order to make sure that solutions are actually found."

– Expert 6

This impact is translated into a number of different activities, ranging in magnitude of impact. Firstly, F&A companies offer financial investments through, for example, investing with recyclers or other parties in the mechanical recycling value chain. Additionally, the majority of actions taken by F&A companies concerns collaboration with parties in the PCPP mechanical recycling value chain. Collaborations between F&A companies and the PCPP

mechanical recycling system largely concern exchanging knowledge on improving the design of packaging in order to make it more recyclable ('design-for-recyclability'). Easier to recycle packaging increases the efficiency of PCPP mechanical recycling and thus improves the performance of the technology. Collaborations can also entail working on improving the waste infrastructure, and thus improving the quality of the feedstock used in mechanical recycling.

"I think where we have a common battle is the design, I think we need to design our products to give them a maximum of chances to be recycled at the end. And I think that there is an understanding there, we are working on this."

– F&A Employee 3

However, the role of F&A companies is also criticised in certain aspects. Firstly, as aforementioned the marketeers of the large F&A companies are sometimes hesitant in using recycled content in packaging. If they do decide to use it, the quality demand is so high that the actual recycled material that they buy is quite little.

"Well I don't actually even know if it's the consumer, we often experience that it's the marketeers that are worried that the consumer won't accept it while I think in reality this won't be that bad"

- Recycler 5

Opinions on the performance of F&A companies in the innovation system differed slightly across interviewee categories. Recyclers were in general very positive, which stands in stark contrast to several of the voiced critiques by recyclers (e.g. too high quality demand of recycler material, afraid to use recycled content because of difficulties presented by consumer acceptance), recyclers were in general very positive about F&A companies on increasing the diffusion of the PCPP mechanical recycling technology when specifically asked to elaborate on the role of F&A companies, whereby the aforementioned critiques were merely stated as points of improvement. The experts in general stated that F&A companies are well on the way but there is still much room for improvement. F&A companies all rated their own, and their competitor's interaction with the PCPP mechanical recycling innovation system with a nuanced 3. They said there is an ongoing increase in activities involving PCPP mechanical recyclers, and these activities in general have a positive impact, but there is still room for improvement.

As all but one of the F&A companies operated at both UK and NL level (one of them did not operate at UK level). There is no distinction to be made between the UK and the Dutch innovation systems on this. However, as aforementioned, the Netherlands has more platforms stimulating value chain collaboration on PCPP mechanical recycling than the UK.

4.3.8.1 F&A Companies' Dynamic Capabilities and their Impact on PCPP Mechanical Recycling Performance

From the above results, it has become very clear that F&A companies are indeed influencing the diffusion of the PCPP mechanical recycling technology. However, as aforementioned, one should be able to distinguish the level of impact of these companies. The interviews highlighted, firstly, that the level of F&A activity within the PCPP mechanical recycling system has recently started to increase. Some interviews highlighted that the awareness amongst F&A companies regarding the necessity of increased recycled content use and recyclability of packaging came quite late.

> *"I get the feeling that they [F&A Companies] think about it better more and more, they start to realise more that they're putting something on the market that should be reused. In the past, it just concerned that it looked good and was light, transportable, oh and also there's sustainability which we'll check in the end. And now more and more they're starting to realise that we should start with how we design the packaging, how do we get it back, how can we reuse it"*
>
> – Expert 3

Furthermore, while F&A companies are currently very strongly engaging with the PCPP mechanical recycling technology and increasing its diffusion, actions remain largely of the 'sensing' or 'seizing' nature, the first two phases of the Dynamic Capabilities framework. Other than a few bottles made of 100% recycled rPET (making up only part of the company in question's portfolio), which can also be grouped as a 'seizing' activity as it concerns a strategy, there were no actions that displayed a sense of cultural and embedded transformation regarding the consistent interaction with the PCPP mechanical recycling system. Most activities currently being undertaken concern the aforementioned knowledge sharing activities, which can be deemed as 'sensing'. Additionally, all interviewed F&A companies have set targets regarding recyclable packaging or recycled content, but none of the interviewed F&A companies have yet fully employed this or have structural, long-term, investments or internally-led innovation projects that directly influence the PCPP mechanical recycling technology diffusion.

All in all, regarding the influence of F&A companies on the PCPP mechanical recycling industry, one can conclude that this influence is rapidly increasing but is currently not making a long-lasting impact as it merely concerns knowledge-sharing and target-setting activities. However, in the pursuit of these targets, companies will transition to 'transforming' capabilities, for example, through the consistent use of recycled PCPP materials. Thus, while F&A companies are currently strongly impacting the PCPP mechanical recycling technology in the long-term, their targets are predicted to transition these companies to ones that embed the interaction with the PCPP mechanical recycling industry in their company culture and thus impact it in the long-term.

4.3.9 System Function Fulfilment

Figure 16 below presents the average of the grades given by the interviewees to each of the 8 system functions. The grades given strongly reflect the conclusions drawn from the above system function analyses. There were not sufficient responses from interviewees on the grading scheme in order to make a differentiation of grades between the UK and the Netherlands on the grading scheme, unless stated otherwise below.

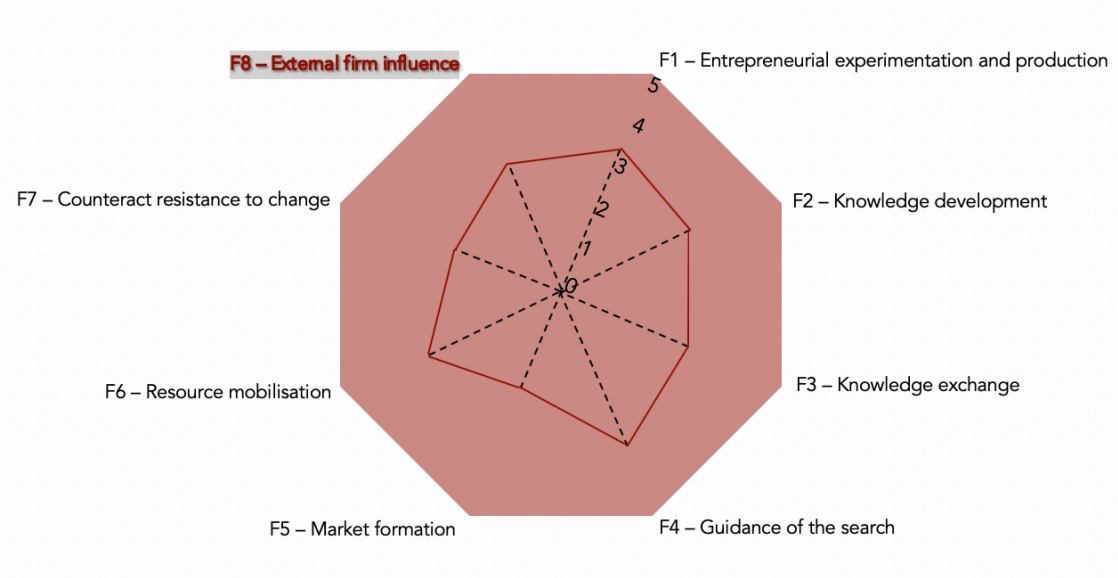


Figure 16: System Function Fulfilment Results

Firstly, strong improvements are to be made in the market formation system function (which received an average of 2,22 out of 5), where interviewees stated the main issues to be the availability of feedstock due to a faulty waste infrastructure system limiting the collection rates of recyclable plastic. Additionally, the demand side of the market formation is lacking due to the fact that oil prices are low, thus making higher-quality plastics currently more affordable and thus more favourable for producers. Interestingly, the UK recycler rated the market formation system function with a 2 out of 5 while the two Dutch recyclers rated this system function with an average of 3 out of 5, this is a slight difference but does reflect the earlier statements on the poor state of the British waste management system.

Secondly, the counteracting resistance to change system function performed poorly (2,44 out of 5). This seemed surprising as, as aforementioned, interviewees stated that resistance within PCPP mechanical recyclers, F&A, or other companies within the value chain, was low. When asked to elaborate on their score, all companies stated that resistance within companies was indeed very limited, and the vast majority of the employees did not show signs of resistance. The reason for the low score concerned the resistance of consumers, as they are hesitant to use packaging that contains recycled material due to discoloration or different odour characteristics. At least two of the F&A companies had conducted research into the reactions of their consumers on this, and due to the negative results they may currently be hesitant in using recycled material in their packaging Additionally, while the

consumer puts a lot of pressure on sustainable packaging, this is not reflected in their buying behaviour.

"While consumers have a lot of critique on our packaging, this is not reflected in their behaviour at the shelves [buying behaviour], they do not seem to go for more sustainable packaging when choosing their products"

– F&A Employee 6

The strongest performing system functions are that of guidance of the search (3,56 out of 5), as interviewees were largely of the opinion that EU regulations are a very strong factor in increasing the performance of PCPP mechanical recycling. Furthermore, the system function of entrepreneurial experimentation and production performed well (3,22 out of 5), this was reflected in the fact that multiple interviewees stated there are many ongoing innovation efforts within the PCPP mechanical recycling innovation system.

Summary Section 4.3: System Functions

- → F1 Entrepreneurial Experimentation & Production: interviewees stated there to be a lot of useful innovation to be ongoing currently, but in order to make an actual impact on the PCPP mechanical recycling innovation system it will have to drastically improve
- → F2 Knowledge Development: a lot of knowledge development regarding solving technological limitations of the PCPP mechanical recycling technology, this should increase to make more impact. Focus should lie on eliminating waste contaminations and making packaging recyclable.
- → F3 Knowledge Exchange: recent increase in regulatory and societal pressure has spurred a growth in knowledge exchange, most exchanged through project, initiatives and industry associations. Sometimes limited by IP protection.
- → F4 Guidance of the Search: influence of legislation is generally regarded as having a very positive impact on the PCPP mechanical recycling innovation system.
- → F5 Market Formation: regarded as quite negative by all interviewees, main focus of critique was on the scattered waste infrastructure causing a lack of quality feedstock, and the unwillingness of consumers limiting the demand for recycled content.
- → F6 Resource Mobilisation: strong increase in M&A activity visualises the increase in financial resources in the innovation system, this is reflected in statements by interviewees. Some F&A companies state the necessity of more state finance for the waste infrastructure system.
- → F7 Counteract Resistance to Change: resistance within companies in the innovation system is very low, resistance by consumers against the use of recycled content and engaging in recycling is a barrier.
- → F8 External Firm Influence: role of F&A companies generally interpreted as positive, quite strong, and increasing.
- → Interviewees that filled out the grading scheme, rated the system functions of market formation and counteracting resistance to change as the most poorly performing system functions. Guidance of the search and entrepreneurial experimentation & production performed were rated most positively.

4.4 TIS Step 4: System Failures

All in all, the interviews highlighted a number of key issues limiting the faster diffusion of mechanical recycling in both the Netherlands and the UK:

- EU Legislation: while in general EU legislation is received positively, some aspects act as a barrier to further diffusion. The fact that the EU has set no hard targets for the use of recycled content is seen as very negative, adding this aspect to the regulations is predicted to significantly increase demand for recycled material.

"So currently, the EU does have goals for collection and recycling, which is positive, but not for effort yet. So, if the EU wants to do something good, they should put rules on this recycled content aspect, as this will cause the demand to increase. Now, a lot of recycled material is bought on the basis of price as sometimes it's cheaper, which means it's interesting for consumers to use. But when the producers have certain regulations to stick to regarding recycled content, this demand will be less price-driven, and will offer more possibilities on the basis of material characteristics. I do expect this to happen, I think from 2020 or 2021 onwards. This would create an enormous boost of recycling"

- Recycler 3

- National Legislations: while legislation is generally regarded as having a positive influence, the main barrier that causes the differences in the phase of development and performance of the PCPP mechanical recycling innovation systems between the UK and the Netherlands concerns national legislations. The differences in national legislation concerns both those legislations that motivate the use of recyclable materials or recycled content as well as national legislations that set to improve the national waste infrastructure. While both categories of legislations receive criticism in the Netherlands as well, the UK is lagging behind in both aspects more severely. This can serve as an explanation for the vast difference in recycling rates, and thus for the difference in PCPP mechanical recycling technology diffusion between both countries.
- National Waste Infrastructures: improvements should be made, in both countries, on the accessibility of waste collection for consumers, the quality of plastic packaging waste provided to the recyclers and the awareness of consumers on how to sort plastics in order to prevent mixed waste streams as much as possible. These faults in the waste infrastructure cause recyclers to receive variable, as well as often poor, quality of feedstock, thus negatively impacting the quality of the output. The availability of high-quality feedstock is currently very low. These factors apply both to the UK and the Netherlands. However, the UK's waste infrastructure can be considered to be performing the poorest due to the fact that there is currently no DRS system in place and a less broad EPR scheme than the Netherlands. According to Recycler 4, a British recycler, improving these will partially lift the barrier to mechanical recycling diffusion in the UK.
- Consumers: while partially deemed as a stimulant to the diffusion of mechanical recycling due to the earlier stated increasing societal pressure, can in some cases also

be considered as a barrier to diffusion. In the UK especially, consumers are unaware of the necessity of collection of plastic packaging waste. In the Netherlands this awareness is increasingly there but still has a lot of room for improvement. Additionally, many misunderstandings regarding plastics cause a negative pressure to be put onto the plastics, and thus on the plastics recycling industry, a factor that could possibly form a barrier. Furthermore, the acceptance of increasing prices or changes in packaging due to the use of recycled content is an issue that may form a barrier in the future, in both the UK and the Netherlands.

- Technical limitations: currently, mechanical recycling technology still has some technical barriers to overcome, namely the issue of waste contamination negatively impacting the quality of the feedstock and thus output. Issues in sorting, and thus mixed feedstock leading to contaminated output are also still forming a barrier currently. Lastly, there are many issues concerning difficult to recycle plastic packaging of which some mechanical recycling currently can process well.
- In order to facilitate the diminishing of the above-stated technical limitations, more innovation as well as more knowledge sharing across the value chain is necessary. While both British and Dutch recyclers and experts state this is increasingly happening, they also state that there is still room for improvement.
- Chemical recycling may form a barrier to the diffusion of mechanical recycling. However, all experts and recyclers which were asked on the relation between the two stated that they will have to operate at similar scales and the lift-off of chemical recycling will only be in approximately 5-10 years. Chemical recycling thus should not be considered as a large barrier to the diffusion of mechanical recycling.
- Currently, the demand for recycled material may also be a barrier to diffusion. Largely, the current demand concerns high-quality recycled material, of which there is very little available. Furthermore, the current low oil prices have caused a decrease in the demand for recycled material as producers tend to go for the cheapest option, which is currently virgin rather than recycled material.
- The influence of the F&A industry is generally considered a very stimulating one of the diffusion of mechanical recycling. However, more could still be done on value chain collaboration, namely in knowledge sharing and innovation on design-for-recyclability. Furthermore, if the F&A industry were to focus more on recycled content, this diffusion of mechanical recycling will increase even further.

Summary Section 4.4: TIS Step 4: System Failures

→ EU legislation generally received positively, national legislations should improve in regard to homogenising the waste infrastructure. Further need for recycled content regulations was voiced.
→ In accordance to this, a large barrier are the scattered national waste infrastructures, this is considered to be the main barrier causing the difference in recycling rates between the UK and the Netherlands.
→ Consumers and their limited willingness to cooperate in sortation as well as their limited acceptance of recycled content use are considered a strong barrier in the innovation system.
→ Technical limitations in PCPP mechanical recycling such as treatment of contaminations or multi-layer plastics are considered a barrier, more innovation and knowledge development regarding these issues are necessary.
→ Chemical recycling may form a slight barrier, but not significant.
→ Lacking demand for recycled content is considered a barrier in the innovation system. This is, apart from consumers, also impacted by the, current, low oil price, offering producers a cheaper product that is of higher quality than recycled plastics.
→ The role of F&A companies is very positive, more value chain collaboration on knowledge exchange is, however, necessary.

5. Discussion

5.1 Theoretical Implications

This research aimed at analysing the performance of the PCPP mechanical recycling systems in the UK and the Netherlands. The comparison of a laggard versus a frontrunner case aimed to uncover the barriers and opportunities within the system that affect the performance of the technology. By using the TIS framework, this research took diffusion of the PCPP mechanical recycling technology as a standard for performance and through analysing the seven system functions of the TIS uncovered the present barriers and opportunities in the UK, the Netherlands, and in many instances Europe when a comparison was not applicable or possible. Additionally, this research aimed at analysing how strongly the F&A industry impacts the diffusion of the PCPP mechanical recycling technology. In order to include this analysis into the theoretical framework, the Dynamic Capabilities Framework was utilised. By analysing the types of actions F&A company employees stated in the interviews it was possible to conclude that the majority of the companies still focus on the 'sensing' and 'seizing' capabilities as a reaction to the changing environment around them (in this case the PCPP mechanical recycling system), this led the research to make conclusions on the level of impact, namely that it is currently significant but has potential to increase and have an even stronger influence on the diffusion of the PCPP mechanical recycling technology.

The TIS framework as it is now did not offer a layer of analysis that differentiated between different types of impacts on the innovation system by external firms. For example, there was no distinction made on short-term, long-term or embedded efforts made by external companies, all of which have a different level of impact on the innovation system. Short-term actions by external firms, for example, make less of a change to the innovation than companies that have long-term actions, or actions that are consistent due to embeddedness in the company. By integrating the Dynamic Capabilities Framework, this research managed to analyse the reactions of F&A firms, the external firms, to the changing environment of the PCPP mechanical recycling system and make this necessary distinction in type of influence by the external firm on the innovations system. By distinguishing the types of reactions, namely sensing, seizing or, transforming, it was able to conclude the current level of impact by the F&A firms and the potential for more, or stronger, influence on the innovation system in the future.

Regarding previous findings of similar studies by (Hestin et al., 2017; Hopewell et al, 2009), this research found supporting outcomes through uncovering the need for recyclable packaging as well as identifying the same fluctuations in quality and quantity of PCPP waste available for mechanical recycling (Hestin et al., 2017) and the necessity for increasing collection rates (Hopewell et al., 2009). However, this research did not reflect the earlier found barrier of high landfilling rates or high export rates. While this issue is most definitely present (European Commission, 2018a), this may not have been highlighted as an issue due to the

recent legislation changes regarding landfilling (European Commission, 2016a) and the recent ban by China on their import of plastic waste (McNaughton & Nowakowski, 2019).

Additionally, this research contributed to existing literature by identifying several barriers and opportunities in the innovation system not identified in the aforementioned researches. This includes, amongst others, the need for increasing knowledge exchange, the role of F&A companies on the diffusion of PCPP mechanical recycling, or the stimulating impact of increasing financial resources in the innovation system. These additional findings were uncovered as analysis was done by comparing a laggard and a frontrunner. This highlights additional barriers and opportunities present in the PCPP mechanical recycling innovation system that may not have been able to be highlighted in analyses at European level. Furthermore, through conducting a TIS analysis, and additionally incorporating the Dynamic Capabilities framework, this research analysed a broader spectrum of factors involved than previous studies, putting an additional analytical focus on aspects such as legislation or knowledge exchange and incorporating additional actors into the analysis such as industry associations and government bodies.

5.2 Practical Implications

5.2.1 PCPP Mechanical Recycling and F&A Industry

This research uncovered multiple barriers present within both the PCPP mechanical recycling innovation system as well as barriers originating from the F&A industry. These findings have significant practical implications as they can be applied to the development of new strategies and plans within both these industries. While both the PCPP mechanical recycling industry as well as the F&A industry have multiple points of improvement to work on, the main recommendation concerns that of increased value chain collaboration, as this facilitates a more efficient PCPP mechanical recycling system. Value chain collaboration should focus on the following points of improvement:

- Increased knowledge sharing and collaborative innovation in order to eliminate the current limitations (e.g. sorting, washing) present in the PCPP mechanical recycling technology.
- Related to this is knowledge sharing on designing recyclable packaging, as this is done in another part of the chain than the recyclers, collaboration is key in making packaging more recyclable, and thus making PCPP mechanical recycling more efficient.
- Collaboration, or individual efforts, should be done on increasing the awareness of consumers, both on the positive aspects of plastic (such as preventing of food-waste) as well as on the need for correct sortation and collection of PCPP waste.

5.2.2 Implications for Government and Policy-Makers

Additionally, findings of this research contribute necessary knowledge to policy-makers, which can be utilised in the development of the necessary regulatory changes. In general, legislation was considered as a very stimulating factor to the increasing diffusion of PCPP mechanical recycling. Points of improvement, however, concerned that of increasing demand for recycled content as well as the quality of the waste infrastructure.

Firstly, this can be done through implementing regulations on the use of recycled content in order to stimulate this demand and thus stimulate the need for plastic recycling. A recent example of such a regulation was in France, where 'penalties' will be incorporated into the pricing of packaging that does not contain recycled content, therefore making packaging with recycled content cheaper, and thus more favourable, for the consumer ('Our Foreign Staff' The Telegraph, 2018).

Secondly, stimulating the demand for recycled content can be done through increasing the price of raw materials used for plastic production, increasing this price will make the use of recycled products more favourable and increase the demand.

Additionally, the focus should remain on improving the quality of the waste, especially waste collection, infrastructure present in both the Netherlands and the UK. The main critique concerned the scattered nature of the waste infrastructure, a focus on homogenisation of the waste infrastructure, both at national and EU level, could significantly improve the performance of PCPP mechanical recycling.

5.3 Research Limitations

While this research did lead to a number of relevant results, it is important to note several research limitations, these being limitations within the theoretical framework as well as within the research strategies themselves.

5.3.1 Theoretical Framework Limitations

Firstly, the TIS framework was used to analyse the diffusion of the PCPP mechanical recycling technology. As defined earlier in the paper, the PCPP mechanical recycling technology consists of multiple phases. By utilising the TIS, these phases were grouped into one technology rather than analysed separately. This was, however, accounted for in system function 2, knowledge development, where a differentiation was made in the interviews regarding innovation on different aspects of the PCPP mechanical recycling technology (e.g. a focus on sorting or washing), thereby making sufficient differentiation in the structural analysis of technology.

Secondly, while it was necessary to include an additional layer for analysing the level of impact that F&A companies are having, the dynamic capabilities framework was useful but not perfect. This is due to the fact that the framework in itself, while it analyses a firm's reaction to the changing environment, does not focus on the impact of this reaction back on

the environment. This is something that can be indirectly concluded but is not embedded in the theoretical framework itself.

5.3.2 Desk Research Limitations

Some research limitations occurred during the desk research phase. Firstly, the geographical focus of the M&A data presented in section 4.3.6 was that of Europe, rather than specifically focussing on the UK and the Netherlands. This was necessary due to the fact that the vast majority of the M&A deals concerned companies that operate at EU- or global-level and it would have resulted in incomplete data to remove these M&A deals from the analysis. However, as the majority of the companies involved in the deals also operated in the UK or the Netherlands, or both, the conclusions regarding the resource mobilisation drawn from the M&A activity analysis can be applied to both the Netherlands as well as the UK. In addition to this limitation applying to the M&A analysis, this EU-wide focus was applied to multiple areas of the research as well. Results were largely focussed on an EU-wide analysis with a focus on the UK or the Netherlands. While this may lead one to conclude that an incomplete comparison was made, this structure was necessary as during the research it became clear there is continuous market consolidation across Europe regarding the PCPP mechanical recycling technology and its relevant actors.

Secondly, the sustainable packaging F&A targets data utilised for data triangulation represents merely a sample of 63 companies and there was no control over this data collection as it was done prior to this research by Rabobank. However, the conclusions drawn from the target analysis were strongly reflected in the targets mentioned by the F&A interviewees, who stated that targets were, in addition to focussing on collection, mainly focussed on recyclability of packaging and use of recycled content. The sample analysis by Rabobank can thus be deemed as relevant data.

5.3.2 Interview Limitations

Originally, the research aimed to interview 8-10 recycling companies and 8-10 F&A companies, thus 16-20 interviews in total. As 5 recycler interviews and 6 F&A interviews were conducted, this total amount of 8-10 per category was not reached. However, as aforementioned, a third interviewee category was established during the process of searching for interviewees which included 6 interviewees, thus reaching a total of 17 interviewees. As these 6 'Industry Experts' offered insight into both the PCPP mechanical recycling technology diffusion as well as the influence of F&A companies on this diffusion, it can be stated that a sufficient amount of interviews was conducted. Furthermore, theoretical saturation, the moment that all aspects of the innovation system were sufficiently discussed and no new information arose from interviews, occurred quickly amongst all interviewee categories[13] and thus the amount of interviewees per category can be deemed sufficient.

[13] Theoretical saturation occurred after 3 out of 5 recycler interviews, after 3 out of 6 expert interviews and after 4 out of 6 F&A interviews.

Another limitation regarding interviewee amounts was that only 9 out of 17 interviewees filled out the grading scheme of the system functions, limiting the ability to sufficiently compare both interviewee categories as well as possible differences in grading between the UK and the Netherlands.

Additionally, one cannot dismiss the influence of researcher bias during the interview and coding processes. Firstly, the interviewee selection may be more focussed on the Netherlands due to the fact that it was largely established through personal networks as well as through the Rabobank, a Dutch bank. However, this was compensated for due to the large amount of interviewees having a European perspective on the issues. Furthermore, there is always a risk of interviewer bias, in this case this risk was limited due to the fact that the topics set in the interview guides were based on previous desk-research. Finally, while coding consisted of multiple phases, thus diminishing the risk of researcher bias, future research in this topic could decrease the impact of this limitation by including a second coder.

5.4 Recommendations for Future Research

Several future research recommendations can be made, both at European and non-European level.

At European level, future research could focus on more detailed aspects such as the role of consumers or the role of the municipality, as this was only broadly discussed in interviews. Furthermore, more non-Western European countries can be analysed in order to create a more reliable overview of the entire European PCPP mechanical recycling system.

However, the most important research recommendation concerns that of non-European analysis. As, while there are still many improvements to be made in the Dutch and British, or European, PCPP mechanical recycling systems, the main cause of the current global plastic waste issue is originating from lower-developed regions. Cultural differences mean that this research is most definitely not applicable to low-developed regions such as Sub-Saharan Africa, Latin America, or Asian regions, research into improving PCPP mechanical recycling in these regions will offer another strong contribution to tackling the global plastic waste challenge.

Summary Section 5: Discussion

- → By comparing the innovation systems of a laggard and a frontrunner, this research was able to uncover several barriers and opportunities involved in the diffusion of the PCPP mechanical recycling technology.
- → This research contributed to existing theory through extending the TIS framework with the Dynamic Capabilities Framework, this research was able to integrate an additional layer of analysis regarding the external influence of F&A firms.
- → This research contributed to existing literature by utilising the TIS and Dynamic Capabilities Frameworks, offering a broader insight into the PCPP mechanical recycling innovation system than previous research.
- → This research was of practical relevance as it offered both PCPP mechanical recyclers, F&A companies as well as government bodies and policy-makers insights into the current barriers limiting the diffusion of the PCPP mechanical recycling technology, this section highlighted several recommendation based on these identified barriers.
- → Limitations of the research included: limitations of the Dynamic Capabilities Framework in highlighting the impact of the external company on the system, some findings being presented at European rather than national level and a shortage of interviewees for the previously established interviewee categories.
- → Recommendations for future research regard an increasing focus on the role of the consumer or the municipalities on the innovations system. As well as researching the barriers and limitations of other global regions.

6. Conclusion

The current faulty PCPP mechanical recycling systems combined with the societal and regulatory pressures regarding sustainability and recycling being placed on the plastic packaging industry ask for increased recycling rates of PCPP. As mechanical recycling of PCPP is currently the mainstream technology to recycle, the performance, or diffusion, of this technology should increase. Furthermore, due to the large contribution of F&A to plastic packaging, it is beneficial to analyse their current impact on PCPP mechanical recycling technology diffusion. This resulted in the research question of this research to be:

What causes the differences between the Dutch and British mechanical post-consumer plastic packaging recycling performance and how do F&A companies impact the performance of this technology?

By utilising a theoretical framework combining the TIS framework, analysing the state of technology diffusion, and the dynamic capabilities framework, analysing the reaction of F&A firms to the environment, the research question was answered. Firstly, desk research was conducted at the Rabobank RaboResearch department. This was combined with 17 interviews with recyclers and waste management companies, industry experts, and F&A company employees. These research phases were placed in the theoretical framework in order to establish the current state of the Dutch and British PCPP mechanical recycling systems. As it was pre-established that the Dutch system is a frontrunner and the British system was a laggard, this comparison allowed the identification of a number of barriers and opportunities present in moving towards a higher technology diffusion. Furthermore, this research uncovered the role of F&A companies in this diffusion and how this role can be improved.

The main outcomes of the research were that the waste infrastructure remains the biggest barrier to higher PCPP mechanical recycling technology diffusion rates. While improvement is definitely also necessary in the Netherlands, the waste management, and thus recycling infrastructures present in the UK are currently performing so poorly that this difference in infrastructure is one of the main barriers causing the difference in PCPP mechanical recycling performance between the two countries.

Another main outcome is that legislation is in general perceived as very stimulating for the diffusion rates and is thus an opportunity in the technology innovation system. However, strict food-safety regulations are a barrier as these often limit the use of recycled content in new food-contact products and, thus, the demand for certain recycled products.

Furthermore, the role of consumers is strong both as an opportunity as well as a barrier. Firstly, consumers have been putting strong pressure on the plastics industry, driving the demand for recycled products up. However, once consumers have to commit to the use

of recycled content in the packaging they purchase, or the increased prices that accompany this, their enthusiasm is lacking, thus limiting further demand growth as many companies, including F&A companies become fearful to use recycled content in their packaging. Additionally, it was often mentioned that consumers do not want to take part in the crucial waste sortation processes that is necessary to provide sufficient and high-quality feedstock for the mechanical recycling process.

Another outcome was that an increased value chain collaboration is necessary, especially increased knowledge sharing across the chain. More specifically, interviewees noted this knowledge sharing should focus on exchanging knowledge on increasing recyclability of packaging in order to make the PCPP mechanical recycling process more efficient.

Lastly, the impact of F&A companies on the PCPP mechanical recycling technology diffusion is in general very positive and becoming increasingly powerful. However, the majority of actions are currently focussed on aiming to improve knowledge sharing or making more recyclable packaging, it is necessary to focus on more long-term actions, such as the use of recycled content, which will drive up the demand and thus diffusion of the PCPP mechanical recycling technology.

These conclusions, and the aforementioned practical implications, contribute to a wider societal relevance, aiding in the development of one of the solutions, recycling of plastics, necessary in combatting the ever-increasing plastic waste issue. The insights gained regarding what currently are barriers, and what are opportunities for the diffusion of PCPP mechanical recycling in the UK and the Netherlands can be mirrored onto the PCPP mechanical recycling systems present in Europe in order to increase overall plastic recycling rates. Additionally, the large contribution of PCPP to global plastic waste means that the mechanical recycling of this group of plastics in specific is important to tackle.

All in all, this research thus contributed insights for both the PCPP mechanical recycling as well as the F&A industries, and additionally the policy-makers at both national and EU levels, into what is necessary to increase the diffusion of the PCPP mechanical recycling technology in Europe, an important step in tackling the global plastic waste challenge.

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Appendices

Appendix I: Interview Guide Waste Management Companies, Recyclers and Industry Experts

Interview guide structure

Topic

- *Open question*
    - *Leading questions that could aid the discussion*

Company and professional background

- How is COMPANY engaged in the recycling business?
    - E.g. focus on sorting or focus on recycling?
- What is INTERVIEWEE role in the company?

The Recycling Process

- What is your production capacity per year?
- What does your feedstock consist of?
    - E.g. is this *post consumer waste or food packaging*? Is this purely previously sorted *PET products*? Or do you recycle multiple sectors?
    - Do you buy feedstock from certain waste managers or do you get paid to recycle?
    - How stringent are you standards for feedstock? Do you look for high quality feedstock to create high quality materials or do 'downcycle' and recycle whatever feedstock is offered?
- From where do you get your feedstock?
    - E.g. is this through municipal collection, through buying from larger waste management companies or through collaboration with companies/producers?
- Do you have current collaborations with the food, agriculture or beverage industry and if yes, what does this collaboration entail? **(F8)**
    - E.g. does this focus on collection schemes, or on collaboration for improving design for recyclability?
- What kind of regrind/end products do you create?
    - E.g. *In addition to PET*, what other polymers do you recycle?

Technologies

- What specific technologies do you use for you recycling phases?
    - E.g. do you use water or chemicals to clean?
- What are some rising technologies that you think have a high potential?
    - E.g. what is your opinion on chemical recycling?

- What are the biggest opportunities that lie in the field of *PET/post consumer waste* recycling?
- What are currently the biggest struggles you face in recycling *PET/post consumer waste*?
    - Is contaminated plastics harder than multi-layer plastics? What are some solutions you have for these issues? What are some developing technologies that you think will aid in solving these issues in the future?
- What are innovation efforts that you as a company are taking in solving these recycling issues? **(F1)**
- Are you involved in industry-wide initiatives or actions that stimulate innovation within your company or within the industry? **(F2 + F3)**
- What is your opinion on the division of mechanical versus chemical recycling in the *PET recycling industry*?
    - While chemical recycling is not yet employed at such a large scale as mechanical, do you think this will grow fast or do you think mechanical recycling will remain the norm?
- If one were to introduce a new *PET/post-consumer waste* recycling technology, what are some of the issues one would face in the implementation of this technology? **(F7)**
    - Would this be purely financial, technical or would you also face issues with regards to difficulty to implement amongst stakeholders and workers?
    - Does the recycling industry have a rigid attitude towards new recycling technologies or is it highly innovative?

<u>Impact of Legislation</u>

- What is your opinion on the new EU legislations in place regarding plastics, waste and recycling? (The EU Waste Directive, the EU Packaging Waste Directive, the upcoming Single Use Ban, the EPR schemes, the DRS schemes?)
- How will the new EU legislations impact your way of business?
- How will the new EU legislations impact the *PET/post consumer waste recycling* sector in specific?
- How is the industry adapting to the recent and upcoming legislations both at EU and national levels?
    - E.g. member of EU-wide associations?

<u>Societal Influences on the Recycling Industry</u>

- What are some of the major influences of societal pressures that you have experienced on your company?
    - E.g. the rising hate against plastics?
    - Good for business or bad for business?
- Are you undertaking any efforts in combating these negative ideas on plastic?

- Does the rising pressures for recycled content make it more difficult to find qualitative feedstock for your recycling processes?
    - Has these legislations caused any financial issues within the industry? What are some of the challenges that the industry is facing especially regarding the many pressures it is facing (e.g. shortage of workers of finance) **(F5 + F6).**
- Furthermore, are there any recycling industry-wide assocations that involve multiple companies in analysing and assessing trends present in the industry and what is necessary to adapt to this? **(F4)**

Appendix II: Interview Guide Food & Agribusiness Companies

Interview guide structure

Topic

- *Open question*
    - *Leading questions that could aid the discussion*

Interviewee

- What is INTERVIEWEE role in the company?
- How is the department of INTERVIEWEE involved in packaging and sustainability?
- How long has this department been in place in its current form in COMPANY?

The Company & Packaging

- What kind of plastics does the packaging of COMPANY contain?
- What is the production capacity of packaging per year?
- Does the company produce its own plastic packaging or does it have external companies for this?
    - Who are these external companies?
    - How is the collaboration with these external companies?
    - Does COMPANY own packaging producers or regularly invest in these?
- Does the packaging of COMPANY contain recycled content?

Recycling/Packaging Sustainability Targets Company

- What are COMPANY's targets concerning plastic packaging sustainability?
    - Do these targets contain recycled content or recycling targets?
    - E.g. recycled content, collaborations with recyclers, bio-based packaging?
- When were these targets set?
- What caused these targets to be set?
- How many departments/workers are focussed on the completion of these targets?
- How feasible do you consider these targets to be?
- Are you working on new targets for after the completion of these targets?

Short-Term Actions

- Are you undertaking any actions regarding consumer awareness of your packaging?
- Are you undertaking any actions regarding the awareness of your workers regarding packaging sustainability?
- Are you undertaking actions regarding the battling of the plastic soup or are you purely focussed on longer-term actions?

Long-Term Actions

- What are some internal projects running within COMPANY focussed on attaining these sustainable packaging/recycling targets?
    - Was it difficult to implement this project within the COMPANY?
        - E.g. due to internal resistance?
    - How long has this/have these project(s) been running?
    - How many people are on this/these project(s)?
- What is/are the status of these project(s) and efforts?
    - E.g. do you have a closed-loop packaging process or are you only undertaking small circularity efforts?
- Investments
    - Have you made investments or are working on investments stimulating plastic packaging waste collection?
    - Have you made investments or are working on investments stimulating plastic packaging waste recycling?
- Do you have your own recycling line or have you recently invested in one?
- Do you have a collection scheme in place to get back packaging you have placed on the market?
- Have you recently invested in new recycling or sustainable packaging innovations? Or are you working on sustainable packaging and recycling innovations yourself?
    - Mechanical vs chemical recycling?
    - Enzymes
- Venturing Arms
    - Do you have a venturing arm in place that also focussed on sustainable packaging solutions or recycling?

Collaborations with (Recycling) Industry

- Do you have any current collaborations with the following working on packaging sustainability?
    - Recyclers
    - Government
    - NGOs
    - Collectors
    - Research Institutes
    - Other (food, agribusiness and beverage) companies
- What do these collaborations entail and how long have they been in place?
    - Do they focus on collaborative innovation?
    - Do they focus on knowledge exchange?
- With what parties do you collaborate on 'design for recyclability'

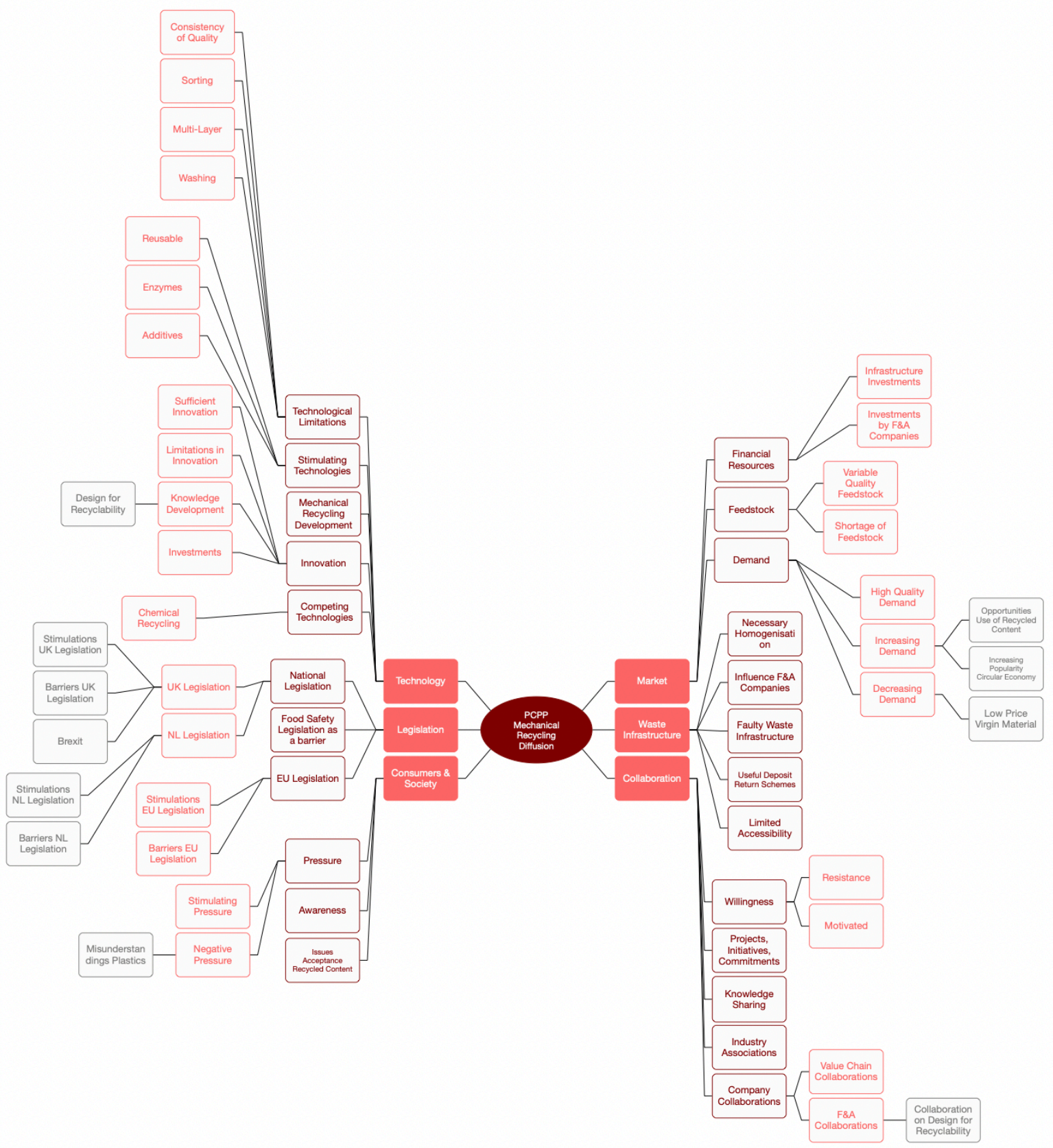
The Role of Consumers & Legislation

- What do you experience from the recent 'plastic hate' that has arisen in society?
    - Do you notice it often?
    - In what way has it affected the COMPANY business?
- What are the issues you have been facing using sustainable packaging or packaging with recycled content regarding consumers?
    - E.g. use of 'grey' plastic due to recycling?
- Comparing societal pressure with legislator pressure, which was more key in COMPANY setting these targets?
- Additionally, what is your opinion on the legislative changes happening regarding plastic and waste?
    - Effective or not?
    - Difficult to adapt to?

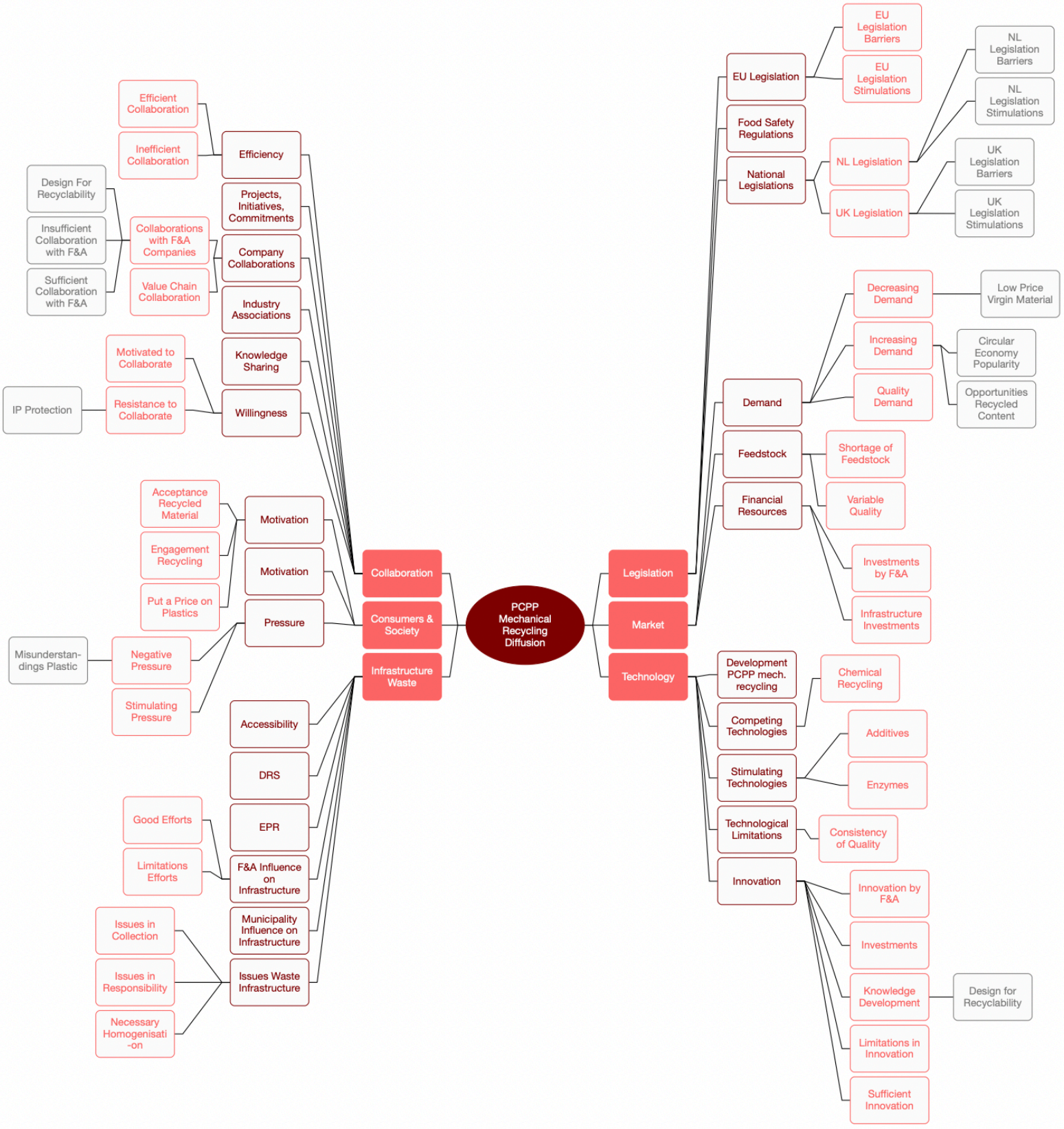
The Packaging & Recycling Industry

- What is necessary to improve…
    - The recycling of food, beverage & agribusiness recycling rates
    - The collaborations between food, beverage & agribusiness companies with the recycling industry
    - The motivation of consumers to recycle
- What is the role of industry associations in the transition towards sustainable packaging/packaging with recycled content?
    - Is this purely a 'discussion' oriented entity or does it stimulate collaboration and innovation?
- Are there enough (financial) resources in place in order to develop the market for packaging with recycled content/recycling?
- Do you see recycling and packaging with recycled content as a viable business case in the long-term?
- Any further social, technical or legislative changes that you think would speed up the packaging sustainability process?

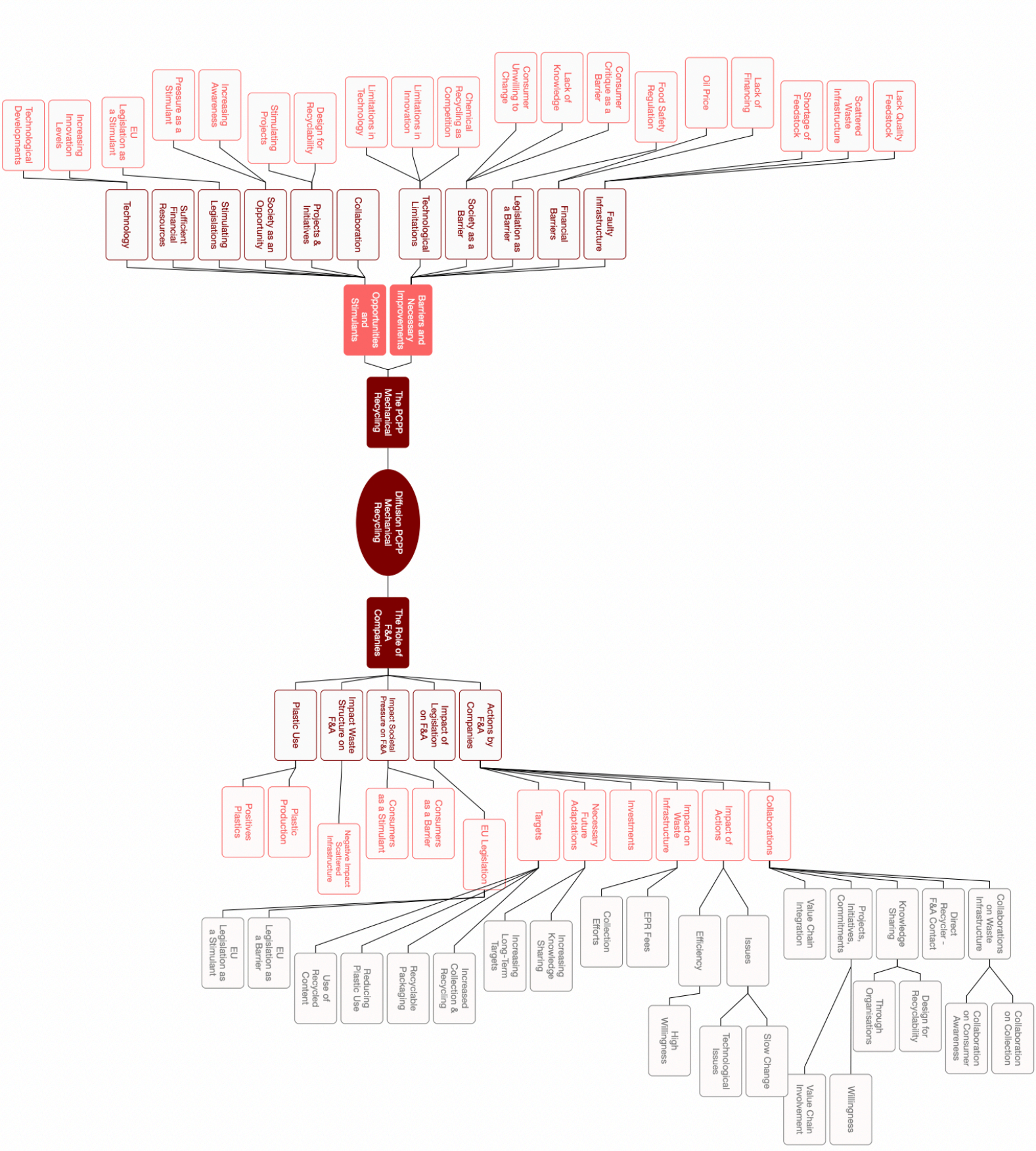
Appendix III: Coding Framework Recycler Interviews



Appendix IV: Coding Framework Industry Expert Interviews



Appendix V: Coding Framework F&A Interviews



Appendix VI: Grading Scheme System Functions for Interviewees

Universiteit Utrecht

Maaike Blom
m.i.blom@students.uu.nl
maaike.blom@rabobank.com
+31614121811

Rating Scheme System Functions

Interviewee Name:
Company Name:

On a scale of 1-5 (1 being very weak, 5 being very strong), how would you rate the fulfilment of the following 'system functions' regarding the recycling industry? Some indicative questions are stated below the system function that can assist in the rating process.

F1: Entrepreneurial experimentation and production
Your Rating: .....

- Are there sufficient actors (recyclers, waste management and food & beverage companies) involved in the innovation efforts for recycling/recycled content?
- Is there in your opinion sufficient innovation regarding plastic packaging recycling?
- Is there sufficient experimentation and production by actors to aid innovation or is it not sufficient and therefore forming a barrier for further innovation?

F2: Knowledge development
Your Rating: .....

- Is there enough knowledge development regarding recycling of post-consumer packaging waste in Europe?
- Is there enough knowledge development regarding recycling of post-consumer packaging waste happening within academia?
- Is there enough knowledge development regarding recycling of post-consumer packaging waste happening within the food, beverage & agribusiness industry?
- Is there enough knowledge development regarding recycling of post-consumer packaging waste happening within the waste management industry?
- Is the quality of knowledge development sufficient?
- Is more knowledge development necessary or is it currently sufficient?
- If there is a lack of knowledge development, would you say this limits innovation in recycling?

F3: Knowledge exchange
Your Rating: .....

- Is there enough knowledge exchange between science and industry?
- Is there enough knowledge exchange between consumers and industry?
- Is there enough international knowledge exchange?
- Is the knowledge exchange within Europe sufficient?

F4: Guidance of the search
Your Rating: .....

- Is there a clear vision within the food & beverage and recycling industries on how the increase of recycling rates and use of recycled content should further develop?
- Are the expectations high regarding the technological developments within recycling of plastic packaging waste?
- Are the policy goals within the industry regarding recycling clear?
- Are the visions and expectations of food & beverage companies in line with those of recyclers and waste management companies?
- In case of a lack of shared vision, does it limit the technological innovation within recycling technologies?

F5: Market formation
Your Rating: .....

- Is the current feedstock of waste necessary for recycling sufficient?
- Is the market size of recyclates limiting the development of the recycling/recycled content market or limiting food & beverage companies in using recycled materials/engaging in recycling practices?
- Is there enough demand for recycled plastic?

F6: Resource mobilisation
Your Rating: .....

- Are there sufficient human resources for increasing plastic packaging recycling rates? If not, does it limit technological development in recycling?
- Are there sufficient financial resources for increasing plastic packaging recycling rates? If not, does it limit technological development in recycling?
- How strong are the physical constraints limiting technological development?
- Is the physical infrastructure in place sufficient to aid technological development?

F7: Counteract resistance to change
Your Rating: .....

- Is there, within your firm, a lot of resistance regarding recycling or sustainable packaging projects?
- Is the length of such project(s) sufficient in order to create a long-lasting change?
- Does resistance towards recycling and recyclates by consumers limit the technological development of recycling technologies or the increase of recycling rates within Europe?

F8: External firm influence (food, beverage & agribusiness companies)
Your Rating: .....

- Is the amount of investments by food & beverage firms sufficient to aid the technological development of the plastic packaging recycling industry? If not, does this form a barrier for further technological development?
- Are there sufficient long-term projects regarding plastic packaging recycling initiated within food & beverage firms? If not, does this form a barrier for further technological development?
- Is the collaboration of food & beverage firms with recyclers and waste management companies successful? If not, does this form a barrier for further technological development?
- Can food & beverage firms instil a long-lasting development of plastic packaging recycling through projects, investments or venturing arms? If not, does this form a barrier for further technological development?