Insights in the market of recycled plastic, with practical value chain research

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by

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Executive Summary

The European Union (EU) landfilled and incinerated 600 million tons of waste in 2013, which could have been recycled and returned as raw material to the economy. Resource efficiency can regain this value and bring economic, environmental and social benefits. The EU has therefore adapted the Circular Economy Package with targets to stimulate the transition to a circular economy. These targets include reusing and recycling 55% of plastic packaging waste by 2025. Member states act to achieve those targets with subsidies and funding schemes. This enables entrepreneurs to enter the market of recycled plastic with innovations to gain Schumpeterian rent.

However, only approximately 50% of starting companies are still operating after 4 years. It is crucial to increase the success rate of turning new technologies into innovations in order to reach the recycling targets. These innovations must generate Schumpeterian rent to stimulate entrepreneurs to innovate continuously. Which will accelerate reaching the recycling targets and furthermore bring economic growth. Market exploration and orientation strategies can aid entrepreneurs to gain insight in the recycled plastic market. Globalized value chain research is a commonly used method, but not suitable to address the recycling industry as it is not globalized but restricted by country borders and local governance. The success rate of innovation results in a low return on investment from EU subsidies and limiting resource efficiency. Creating insight in the plastic recycling industry will increase the survival chance and Schumpeterian rent for entrepreneurs, enabling growth of the market and increased use of recycled plastic.

Value chain research methodology was used, according to a handbook written by Kaplinsky & Morris from 2001, which refers to and uses globalized value chain research methodology. For the recycling industry a specific selection was made from elements mentioned in the handbook. This enabled the execution of value chain research for the not globalized recycling industry. The interview questions and topics were made based on the required data for the selected elements. This thesis focussed on the biggest market segment of post-consumer plastic packaging waste in the Netherlands. In total 149 compounders, recyclers and converters were included in a database for a selection, fifty-five companies were selected on quantity processed material from high to low and contacted through email with a follow-up call. Of which seven companies participated, which resulted in qualitative data that gives insight into the industry and enabled answering the research question.

What is required from the value chain of the plastic recycling industry to increase the use of recycled post-consumer PPW?

Converters must be able to get access to regranulate with stable MFI and crystallization time characteristics in higher quantities. Compounders can initiate this with joint design projects with branding companies thereby highlighting the possibilities of their regranulate. The optimization of the product and process for their regranulate lowers the switching costs for the converter and can bring rent opportunities. It furthermore showed to increase the sales of regranulate. The

compounder requests higher quantities of mono streams recycled plastic from the recycler to comply with demand for regranulate to be used for high volume consumer goods. Recyclers however, upgrade their processes to maximize output for the Dutch 'Raamovereenkomst', which includes a mix stream next to the mono streams. This mix stream cannot be used by the compounders to make regranulate for the converters. The recyclers claim that they can technically increase the mono streams at the expense of the mix stream, although this leads to lower profits for them. A change is therefore required in the Dutch 'Raamovereenkomst' to optimize for mono stream output. However, the mix stream is currently used for end of life plastic products. This makes it possible to recycle 90% of the plastic waste instead of 70% with only mono streams as output. The removal of the mix stream from the Dutch 'Raamovereenkomst' therefore has positive and negative consequences. Further research is required regarding the compensation of the mix stream under the Dutch 'Raamovereenkomst'.

A limiting factor in this research is the low response rate of companies contacted for interviews. Apparently, the selected companies receive up to one request a day to participate in a study. This makes them hesitant to participate. Another factor is that governments in different countries have different legislation and rules, and not all might be visible. This makes it difficult to compare value chain characteristics, thereby limiting the results of value chain research of the plastic recycling industry throughout the EU.

Contents

1. Introduction

The European Union (EU) generated a total of 2.5 billion tons household and industrial waste in 2013, of which 1.6 billion tons was landfilled or incinerated (European Commission, 2015b). It is estimated that 37.5% of that discarded waste could have been recycled or reused for the production of new products. This would improve resource efficiency and benefit the EU economy. In order to stimulate recycling, the European Commission (EC) has constructed the Circular Economy Package to bring economic, environmental and social benefits. A new proposal for a directive (amending Directive 94/62/EC), on packaging and packaging waste published December 2015, is part of this agreement and includes targets towards the reduction and reuse of plastic waste (European Commission, 2015b). The EU and member states individually developed subsidies and funding schemes to achieve these targets, for example an industry agreement for packaging in the Netherlands (Ministerie van Infrastructuur en Milieu, Verpakkende bedrijfsleven, & VNG, 2013). These kinds of subsidies enable entrepreneurs to enter the market of recycled and reused materials with new technologies. For instance in recycling plastic, where new technologies can accomplish a higher grade of purity in recycled plastic, thereby increasing its value (PlasticsEurope, 2015). However, recycling plastic is not new and a market already exists. It is difficult for entrepreneurs to choose a point of entry for their innovation, as insight in the recycled plastic market is not available. This thesis will therefore apply value chain research to gain insight in the market of plastic recycling industry. Thereby increasing the chance for the entrepreneur of gaining a return on his investment and ultimately growth of the recycled plastic market. The structure of this thesis is given in the figure below.

1. **Introduction**
2. **Research**
3. **Methodology**
4. **Kaplinsky's value chain research**
5. **Results**
6. **Conclusion**
7. **Discussion**
8. **Epilogue**

Figure 1, structure of the thesis

1.1. Context

Resource efficiency is important in governmental legislation as it brings economic, environmental and social benefits (European Commission, 2015a). An essential part of resource efficiency is closing the loop in a circular economy by turning waste into a resource. The European Commission estimated that approximately 600 million tons of currently incinerated or landfilled waste could have been recycled or reused. Here lies an opportunity to improve resource efficiency, which can lead to sustainable growth, job creation, reduced greenhouse gasses and a better environment (European Commission, 2015b).

The European commission adopted the ambitious Circular Economy Package in December 2015 to stimulate the transition towards a circular economy (European Commission, 2016). This agreement includes a revised legislative proposal on waste, with targets for the reduction of waste and a long-term path for waste management and recycling. The key targets are: recycling 75% of packaging waste by 2030; A ban on landfilling of separately collected waste and a maximum of 10% of municipal waste by 2030; Economic incentives to put greener products on the market and support recovery and recycling schemes (European Commission, 2016).

A proposal from December 2015 for a directive (amending Directive 94/62/EC) sets a 65% target by weight for all packaging waste to be reused and recycled in 2025 and 75% by 2030 (European Commission, 2015b). More specific: 55% of plastic, from this packaging waste, must be reused and recycled by 2025. The proposal focuses on packaging waste as it is the biggest waste category within municipal waste (Eurostat, 2017). The EU member states therefore must act to achieve these targets. The Netherlands for example, created the so called 'Raamovereenkomst' for packaging. This agreement was setup in collaboration with the packaging industry, municipalities and national government. The key element of this agreement is a fund, filled by packaging producers who pay by production volume (Ministerie van Infrastructuur en Milieu et al., 2013). The fund subsidises recycling, making the recycling of packaging waste profitable. This leads to growth and investments in the recycling industry. The idea is that the recycling industry can innovate, which should lead to higher margins. This should be enough to gradually eliminate the contribution by the funds, which is set to decrease every year. The 'Raamovereenkomst' will be explained further as part of the research results.

Innovation in the recycling industry is needed as current technologies are not able to extract high grades of purity required for the reuse of plastic in high-end products. This is caused by the complex content of the waste stream. They are polluted with other materials, such as foams, rubber, other plastics, etc. (Bonifazi, Damiani, Serranti, Bakker, & Rem, 2009). New technologies should increase the purity, and thereby increasing the value of the plastic waste stream. Making the plastic waste industry more attractive for entrepreneurs, enabling innovation and increasing competition for the virgin plastic producers. Who are plastic producers that make new plastic from oil.

The EU is stimulating the development of innovations and new technologies that can overcome current challenges with the initiative: Innovation Union. Part of this initiative is the EU Research and Innovation programme Horizon 2020, a financial instrument with nearly €80 billion of funding available over a 7 year period, from 2014 to 2020 (European Commission, 2013b). Its predecessor, FP7 (7th Framework Programme for Research and Technological Development), had a total budget of €50 billion (European Communities, 2007). W2Plastics was one of the projects within FP7 that focused on the recycling of plastic waste (Di Maio, 2014). It achieved to research, develop, build and test a Magnetic Density Separation (MDS) pilot plant, that could recover more than 90% of high-grade plastics. This is one example of a newly developed technology, made possible by EU funding, that can help the EU reach its recycling targets.

Turning new technologies like the MDS machine into a sustainable business requires a transformation of the technology into an innovation. Schilling (2005) defines technological innovation as: *"The act of introducing a new device, method, or material for application to commercial or practical objectives"* (p. 1). Schilling includes the terminology 'introducing' and 'commercial objectives' in his definition. This underlines that introducing new technology and achieving commercial objectives is important before a technology can be named an innovation. An example of a commercial objective is making enough profit on new technology to continue the development of other new technologies. This kind of profit can be called 'Economic rent' or 'rent'. Economic rent is profit that derives from a difference in productivity and from barriers to entry, which are created by scarcity (Kaplinsky, 1998). In other words: economic rent is profit that comes from being better than your competition. Scarcity for your product or preventing competition access to your rent source can be obtained by creating barriers of entry. Sloman (2005) defines barriers to entry as obstacles that make it difficult to enter a given market. Thereby sustaining sources of rent, thus remaining profitable.

1.2. Schumpeterian rent

Schumpeter describes innovation as new combinations of new or existing knowledge, resources, equipment, and other factors (Schumpeter, 1961). In his theory he describes that the entrepreneur plays a unique role in carrying out this new combination. Entrepreneurial surplus is the return on the new combination and is created when the price of the product following the introduction of the new combination is higher than the cost of the innovation (Kaplinsky, 1998). This surplus is only temporary, the rate of profit will return to the equilibrium that existed before, when the competition copies the new combination. This entrepreneurial surplus stimulates the entrepreneur to continuously search for new combination, therefore innovate.

The entrepreneurial surplus is a form of economic rent. Economic rent that comes from innovation which results in a form of super profit is known as Schumpeterian rent (Schumpeter, 1961). This super profit enables and stimulates entrepreneurs to innovate continuously, which brings economic growth. This growth is what the EU tries to accomplish with the directives on recycling and subsidized innovation. It is therefore important to make a distinction between Schumpeterian rent in this thesis compared to just rent or profit to focus on growth and 'super profit' for entrepreneurs.

1.3. Problem description

The success rate of turning technology into a self-sustaining business is low. Eurostat's Business Demography by Size Class statistics states that the EU-28 reported approximately 2.58 million births of new enterprises in 2014 of which approximately 1.75 million survived until 2016 (Eurostat, 2016a). This 67.9% survival rate after 2 years decreases below 60% when the firm shows innovativeness (Hyytinen, Pajarinen, & Rouvinen, 2015). Increasing this success rate would improve the return on EU funding and help to achieve its recycling targets. However, the traditional market of waste disposal tries to create barriers for entering the market by limiting publicly available knowledge (Innovatie Zuid, 2009). The market is therefore non-transparent. Market exploration strategies (Jaworski & Kohli, 1993; Schilling, 2005) and market orientation (Urban & Hippel, 1988; Zhou et al., 2005) can increase the transparency of the recycling market. Several market analyses strategies that incorporate exploration and orientation were previously described (Porter, 1985). Around 1990s the process of globalization started, which resulted in international integration of economic activities. This derived from advances in infrastructure, telecommunications and the rise of the internet (Al-Rodhan & Stoudmann, 2006). A new approach for market analyses was warranted; the so called 'globalized value chain research'. Unfortunately, globalized value chain research tools that are commonly used today are not suitable to address the recycling industry, because it is restricted by country borders and local governance. The non-transparent market and currently available value chain research tools impair recycling initiatives and prevent turning recycling technology into an innovation. This results in a low return on investment from the EU subsidies on recycling and limits economic growth. This thesis will therefore create insight in the plastic recycling industry with non-globalized value chain research, thereby increasing the survival chance and Schumpeterian rent for new recycling initiatives.

Recent non-globalized value chain research tools are not available in the literature, because of the focus on globalization. It might therefore be necessary to slightly deviate from these recent tools to compensate for the expected mismatch of globalized parts of the tool, which might not be present in the plastic recycling industry. Thereby using the new insights from recent literature compared to the old tools before 1990s. The conclusion will reflect if this was necessary after the execution of the value chain research and see if a scientific addition to the current literature was needed within the scope of this thesis.

1.4. Scope

The EU categorises waste in different streams and has identified recycling the plastic waste stream as a priority in their circular economy strategy (European Commission, 2018). The potential of recycling plastic waste is big, because more than 70% of annually generated consumer plastic waste was not recycled. This thesis will therefore focus on post-consumer plastic recycling. Post-consumer plastic waste is mixed plastic waste from end of life products. In contrast to post-industrial plastic waste which is created with the industrial production of products. The content of post-industrial waste is known and therefore does not require separation. This thesis will furthermore focus on the segment plastic packaging waste (PPW), which is the biggest market segment within post-consumer plastic waste, almost 40%, as shown in Figure 2. Figure 3 shows the applied scope as described above. A geographical focus area for this research will be selected after the research question and objective in the following chapter. To summarize chapter 1, this thesis will focus on increasing Schumpeterian rent within the post-consumer PPW recycling value chain.

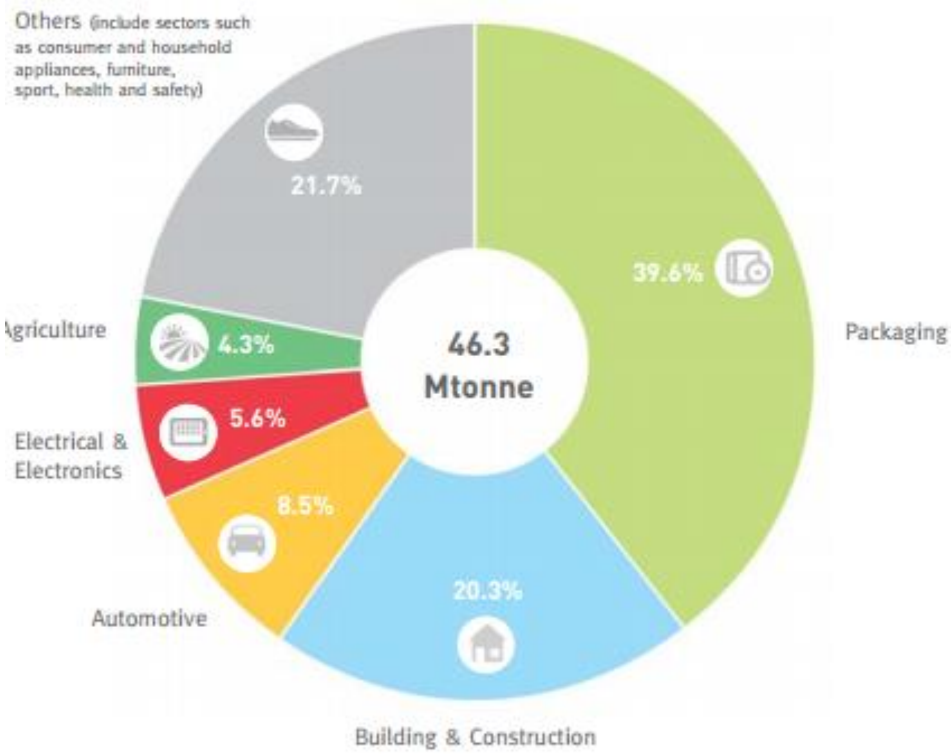

Figure 2, European plastics demand by segment 2013 (PlasticsEurope, 2015)

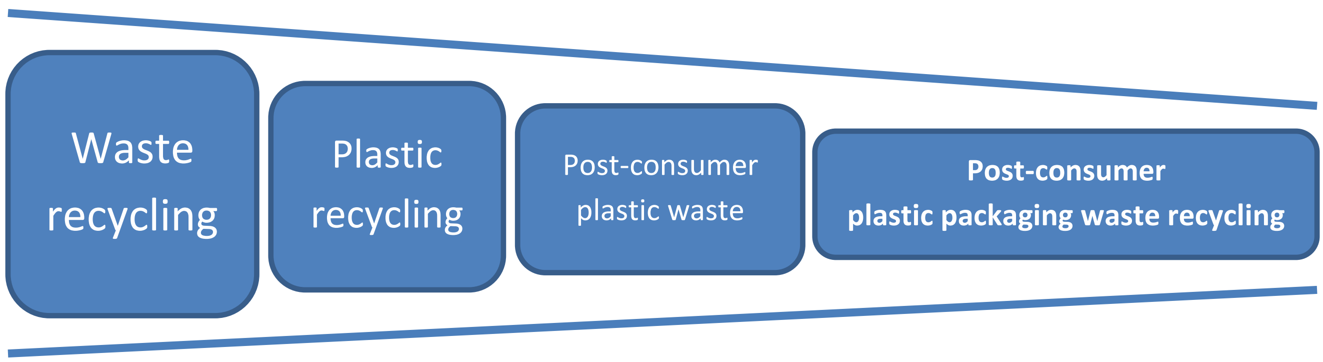

Figure 3, subject scope funnel

2. Research

2.1. Research question

Increasing Schumpeterian rent and the survival chance for new recycling initiatives within the post-consumer PPW recycling value chain can be achieved by creating insight in the market. Currently available globalized value chain research tools are not suitable for the plastic recycling industry, as described in the previous chapter. Different methods for value chain research will therefore be analysed in the next chapter, where a suitable method will be selected and applied to the plastic recycling industry. The following research question aims to bring focus to that value chain research.

What is required from the value chain of the plastic recycling industry to increase the use of recycled post-consumer PPW?

The answer to this question will identify what currently limits the growth of the plastic recycling industry. These challenges or opportunities create insight into that industry and will increase the survival chance and Schumpeterian rent for new recycling initiatives. The following sub-questions are steps towards the answer of the main research question above:

1. ***What is the most influential activity in the recycled post-consumer PPW value chain?***
   The most influential activity will most likely determine rules to participate and for entering the market. It is therefore important to identify the most influential activity of the value chain and analyse its characteristics and relationships with other linkages in the value chain.

2. ***What is the required quality of plastic waste for the production of recycled plastic?***
   A definition of quality or a description of the required quality for recycling seems to be unavailable in literature. It is important to identify the quality definition for further interpretation of information about the value chain and its challenges.

3. ***What influence has plastic quality on the use of recycled plastic within the value chain?***
   Compounders make plastic, which probably gives them influence on plastic quality. Evaluating the quality requirements of their input and output materials will therefore give challenges and opportunities surrounding plastic quality.

4. ***What is the influence of governance on the use of recycled plastic?***
   Governance affects the value chain and its challenges and opportunities. It is therefore important to map what sets of rules exist and to analyse its influence.

5. ***What is the influence of innovation on the use of recycled plastic?***
   Innovations within the value chain of the plastic recycling industry can change the rent distribution and therefore have influence on the linkages in the value chain. It is therefore important to analyse the influence of innovation.

6. ***In what segment of the value chain could the case company generate Schumpeterian rent on its innovation?***
   Paragraph 2.4. will introduce the case company which provides a starting point for this value chain research. The director of this company indicated that the answers to a couple of questions, as described in paragraph 2.4., would yield useful information for him. These questions are combined in this sub-question.

2.2. Objective

The objective is to create insight in the plastic recycling industry, thereby increasing the survival chance and Schumpeterian rent for new recycling initiatives. This objective will be achieved by executing value chain research, in which the different product stages and companies will be identified through a literature study. The value chain influencers will be analysed and interviewed to create insight. A starting point for the value chain research was found through the Resource and Recycling department of the Delft University of Technology. This starting point is a new recycling initiative that is looking for their market entry point and therefore requires market insight. This company will be introduced later in this chapter.

This thesis furthermore serves as an example on how value chain research is applied for other entrepreneurs within the recycling industry. It will do so by selecting elements that can be researched with value chain analysis. These other entrepreneurs can repeat that process for their market niche. Chapter 7 will discuss how to repeat a value chain research after this thesis concluded its research.

2.3. Geographical scope

This paragraph will select a geographical scope to make it possible to achieve the objective within a practical timeframe. The first boundary for the scope is the EU, because the case company operates inside the EU and is based in the Netherlands. The case company will be introduced in the next paragraph. A selection from EU countries will be made to narrow down the scope. This will be done based on market size, because the case company adds most value with high volume applications. From Eurostat, the statistics of four size indicators of plastic packaging waste in the EU from 2014 are collected and displayed in table 1:

- *Turnover:* the turnover from the manufacturing of plastic packing goods in millions of euros (Eurostat, 2016b).
- *Waste generated:* the total plastic packaging waste generated by economic activities and households in kilo ton (Eurostat, 2016b).
- *Recovery:* any operation were waste is serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function (Eurostat, 2014a).
- *Recycling*: any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes (Eurostat, 2014b).

The EU-27 refers to the EU in the period between 2007 and 2013, when it comprised of 27 countries. Table 1 furthermore shows the indicator percentage of the EU-27 market and is displayed in the same order as in the Eurostat data explorer. Only five countries are displayed in the table, the four biggest countries by waste in kiloton and the Netherlands since the case company is located here.

Table 1, Plastic packaging turnover and PPW, recovery and recycling 2014 (Eurostat, 2017)

Packaging	Turnover (M€)	%	Waste (kt)	%	Recovery (kt)	%	Recycling (kt)	%
Germany	9,375	19%	2,946	19%	2,941	27%	1,479	24%
France	7,354	15%	2,062	13%	1,320	12%	520	9%
Italy	8,317	17%	2,082	14%	1,642	15%	790	13%
Netherlands	-	-	474	3%	464	4%	236	4%
UK	5,032	10%	2,220	14%	1,068	10%	842	14%
Sum:	30,079	60%	9,784	64%	7,435	69%	3,867	64%
EU-27	49,793	100%	15,353	100%	10,829	100%	6,067	100%

These five countries recycle 64% of the total recycled waste in the EU-27. It is therefore likely that a first customer for the case company comes from these countries, because of their processing volume. This thesis will therefore focus on these five countries.

Table 1 furthermore shows a difference in recovery rate per country. Germany and Netherlands recover almost 100%, where the United Kingdom (UK) only recovers 48% of their packaging waste. The UK and France, with 64% recovered packaging waste, are below the EU 2030 recovery target of 75%. The UK is not following with legislation, there is no landfill ban for example, which explains the lower recovery rate (Recycling Waste World, 2014). This is important for the case company as these countries will have an incentive to fund new recovery and recycling installations to achieve the EU 2030 target.

2.4. Case company

Prof. Dr. Ir. P.C. Rem and his research group Resource and Recycling at the Delft University of Technology focus on new technologies for recycling waste and are driven by the wish to see more entrepreneurs succeed in his field. They conducted multiple studies, which indicate the importance of technological advances in waste recycling (Bonifazi et al., 2009; Rem, 2012). One of their inventions is the Magnetic Density Separation (MDS) technology (Bakker, Rem, & Fraunholcz, 2009).

Urban Mining Delft was a spin-off company that was established in 2012 to develop and market that patented MDS technology (Urban Mining Corp, 2019). The MDS machine can separate plastics based on density by influencing magnetic fluid with a magnetic field, thereby enabling accurate segregation of many different sorts of plastics in a continuous process. Details about the technology can be found in Appendix A - MDS technology. In 2014 a new partnership was established, creating the new Urban Mining Corp (UMC) which will continue to transform the MDS technology into an innovation, thus monetizing the business potential. The MDS technology was being tested for plastics in 2016. The separation of plastics has a great business potential, due to its technical advantages and the increasing market of recycled plastics (PlasticsEurope, 2015). The MDS machine characteristic of delivering a constant flow of high-quality plastics makes it a promising new technology for the recycling industry.

Jaap Vandehoek, director of UMC, indicated that the answers to the following questions would yield useful information for him:

- How and where can we place ourselves in the value chain of plastics?
- What is a good entry point in the value chain?
- Is there a niche market that could provide our first entry?
- Who or what is of influential importance in the value chain?

These questions are combined in sub-question 6 of the research question in paragraph 2.1 as:
In what segment of the value chain could the case company optimize its Schumpeterian rent on its innovation?
The answers for the four questions above will be incorporated into the answer of the research question.

2.5. Plastics and EU

Plastics are chains of polymers and polymers are chains of molecules. The raw materials for plastic production are natural organic products such as cellulose, coal, natural gas, salt and crude oil. New plastics made of these raw materials are called virgin plastics. Crude oil is the most commonly used raw material for plastics. The most common applied plastic grades are polypropylene (PP) and polyethylene (PE), 48.5% of the total market (PlasticsEurope, 2015). PE for example, can be subcategorized in high density (PE-HD) and low density (PE-LD). PE-HD or HDPE is such a subcategory commonly used for the hard plastic caps on bottles. Multiple plastic categories have subcategories, which create hundreds of plastic grades with their own characteristics. These sorts of plastics can be further specialized depending its application by adding additives to the mixture. Some examples are:

- Fillers, reduce the plastic fraction to reduce material costs.
- Fire retardants, increase the fire resistance.
- Plasticizers, increases the flexibility.
- Colorants, add colour.

This enormous variety of different sorts of plastics makes the plastic industry and therefore the recycling of plastic a complex business.

Figure 4, European plastics production in million ton (PlasticsEurope, 2015)

In 2013, the European plastics industry employed over 1.45 million people and realized a turnover of 320 billion euro in sales. Global production experienced continuous growth and rose to 299 million tons. China is the leading plastic producer with 24.8% of the world's total production, Europe ranks second with 20%. However, the European production stagnated in 2013 as the world production grew with 3.8% (Figure 4). Mind that Germany accounts for 25.4% of the EU plastic demand, and almost 64.5% together with Italy, France, UK and Spain. Packaging is the biggest market segment with 39.6% of the total demand of 46.3 million ton plastics. The EU set an ambitious goal of zero plastics to landfill before 2020. Nine countries already reacted by banning plastics on landfills, which created an enormous stimulant to recover and recycle plastics (PlasticsEurope, 2015).

Recycling is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes (Eurostat, 2014b). There are two plastic waste streams (OECD Environment Directorate, 2010):

- Post-industrial or pre-consumer plastic waste, generated during converting or manufacturing processes, 22% of total waste stream in 2007.
- Post-consumer plastic waste is generated by end-of-life products, 78% of total waste stream in 2007.

Figure 5, Treatment of post-consumer plastic waste in 2012 (PlasticsEurope, 2015)

99% of the post-industrial waste stream was recovered, thereof 80% was recycled. This is possible because the composition of the waste stream is not mixed and its content is known. The Post-consumer waste stream is mixed, unknown and complex (OECD Environment Directorate, 2010). The EU member states recovered 62% of the post-consumer plastics waste (Figure 5); 25.2 million tons in 2012 (PlasticsEurope, 2015). The EU further characterizes waste recovery in two categories:

- *Energy recovery*: the use of waste as a fuel to generate energy, 9 million ton.
- *Recycling*: the process of reprocessing into products or raw materials, 6.6 million ton.

There are two types of recycling: chemical and mechanical recycling. Chemical or feedstock recycling is the chemical breakdown of the polymers into their constituent monomers so it can be reused in refineries. Reprocessing plastic waste by melting, shredding or granulation is called mechanical recycling (European Commission DG ENV, 2011). Shredding plastics results in flakes which can be separated, melted and granulated. The resulting granules (Figure 6) from these processes are referred to as regranulate or recyclate and indicated with a non-capital letter 'r' before the plastic name: rPE.


Figure 6, Granulate (GearedforGreen, 2019)

Regranulate plastics are often used for other products than their previous application, with lower or other quality requirements. These recycle processes are being referred to as downcycling. Closed loop recycling is when the regranulate is moulded back into the same product. This happens rarely as there is always some contamination of the mixture (Hopewell, Dvorak, & Kosior, 2009). The Society of the Plastics Industry (SPI) developed resin identification codes (Figure 7) in 1988 to allow efficient separation of different polymer types for recycling.

Figure 7, Resin identification codes (NatureWorks, 2008)

Figure 8, Simplified PPW recycling value chain

A simplified value chain of PPW recycling is displayed in Figure 8. First the plastic waste is collected. Then the plastics are separated with different techniques and pressed into a bale (Figure 9). The plastic waste is shredded to small flakes to improve subsequent transportation. Sometimes the flakes are washed between the different steps to remove any contaminations. The plastic is than transformed into granules by a compounder, forming the regranulate to become usable for converters that make plastic products. The compounders can influence the material specifications for the converters by adding additives during the compounding process. More extensive information on what plastics are and their life cycle can be found in Appendix B - Plastic 101.

Figure 9, separated HDPE plastic pressed in bale (Recycling Industry News, 2017)

2.6. Macro impact of new recycling technologies

The biggest value can be achieved by recycling the plastic back to an usable product (Innovatie Zuid, 2009). Increasing the recycling rate and usability of the recycled plastic is therefore a real opportunity. New technologies can grasp this opportunity and have the following impact in the EU (PlasticsEurope, 2015)(European Commission, 2018):

- Reaching zero plastics on landfills in 2020
- Increase the success rate of new entrants in the recycling industry
- Reduce subsidized collection of plastic waste
- Reduce the dependency on oil exporting countries
- Bring social benefits with multiplier effects to the EU economy

In 2008, the EU parliament introduced a five-step waste hierarchy to its waste legislation, the so called Directive 2008/98/EC (known in the Netherlands as the Ladder van Lansink):
Waste prevention, reuse, recycling, recovery and ultimately safe disposal.
Recycling and reuse can be improved with new technologies and innovations. That is why the EU is stimulating waste innovations with policies and funds (European Commission, 2013a).

New companies, or new entrants, using new technologies often fail in business execution (Hyytinen et al., 2015). An important part of the execution is the selection and right approach towards a market. A value chain research is needed to determine the best entry point into the market. In this thesis, the concepts that can be investigated in the value chain will be evaluated, specifically for the European plastic industry. The selected concepts, or elements of the value chain research, can also be used by other new initiatives to research their value chain within the recycling industry. This will improve the decision making process for the right approach.

The collection of plastics needs to be subsidized by the governments in the EU in order to be cost neutral, meaning that the collected plastic has a negative value (Rem, 2012). Recycling this stream of recovered plastics creates a material that has a positive value, meaning that it can be sold. The MDS technology can deliver a higher quality plastic for lower process costs (Merrifield, 2013). This will result in a higher value of the plastic and ultimately in a positive value of post-consumer plastics waste prior to collection.

The European Commission has published the memo: "Reducing the EU's dependency on raw materials: European Innovation Partnership launched" (European Commission, 2013a). Part of this strategy is to recycle more waste to recover the raw material. They have funded multiple research initiatives that are looking for new technologies that can achieve this. The MDS technology is a result of the W2Plastics consortium, one of those research initiatives. The import of raw materials can be reduced by recovering them from waste. This will lead to a reduction of dependency on raw materials, especially from political unstable countries. If the MDS technology can help to recover plastics, the import of virgin plastic or oil for its production can be reduced.

Innovation in the plastic industry furthermore brings social benefits and has a multiplier effect on the economy (PlasticsEurope, 2015). The plastic industry generates about 26.3 billion euro for public finance and welfare and created 1.4 million jobs in 2013 (Eurostat, 2017). Research showed that a 10% increase in the value added of the plastics sector could lead to a 4.4% increase in the value added to the overall EU manufacturing sector. PlasticsEurope found that for every job created, almost 3 jobs are created in the wider economy at a national level for Italy (PlasticsEurope, 2015).

To conclude, the macro impact of plastic waste recycling in the EU has potential to bring social and economic benefits. As mentioned in paragraph 2.3., some countries only recover 50% of the packaging waste, indicating there is an opportunity for improvement. UMC can increase the value of recycled plastics, thereby making recovery profitable. This will help with in reaching the zero plastics on landfills in 2020 goal, to reduce subsidized collection of plastic waste and to reduce the dependency on oil or virgin plastic exporting countries.

3. Methodology

Insight into the plastic recycling industry needs to be created to answer the research question. Market analyses can create this insight. This chapter will therefore select the methodology that will be used to execute a market analysis, which will fulfil the objective and answer the research question.

3.1. Research methodology

Around 1990s the globalized value chain research was introduced and applied for performing market analysis. Currently used value chain research methods therefore focus on globalized value chains that integrate international economic activities and operate globally. These value chain research methods differ in different elements to be researched, were elements are topics like governance or rent distribution. The recycling industry has barriers of entry resulting in limited international integration. For example, local government rules (country, province or municipality level government) and export limitations (Innovatie Zuid, 2009). Value chain research for the plastic recycling industry based on pre-selected value chain research elements by other methods is therefore not possible. However, the creation of a new element selection provides the opportunity to tailor value chain research for the recycling industry.

Multiple manuals that sum up elements for value chain research are evaluated by Bolwig et al. in an attempt to convert value chain analysis into action-orientated research. They describe some manuals as fairly sophisticated analytical tools that summarize different elements that can be researched (Bolwig, Ponte, Du Toit, Riisgaard, & Halberg, 2008). Bolwig et al. make a distinction between essentially analytical tools (Ferrand, Gibson, & Scott, 2004; Kaplinsky & Morris, 2000; van den Berg, 2004) and action-oriented ones (Bernet, Thiele, & Zschocke, 2006; Faida, 2006; Roduner, 2007). They criticize these manuals for subscribing to *“a cooperative, mutually beneficial framework, where power relations are underplayed to the benefit of win-win managerial solutions and ‘partnerships’”* (p. 46). Three papers are excluded from this criticism (McCormick & Schmitz, 2001; Schmitz, 2005; Vermeulen, Woodhill, Proctor, & Delnoye, 2008). Of which the last manual, prepared by Vermeulen et al., is praised for its recognition for the existence of conflict of interests and power inequalities in value chains. However, Bolwig et al. questions if the proposed method of ‘multi-stakeholder processes’ to improve participation for weak actors is sufficient for value chains with unequal power relations.

For this thesis one of those manuals from Bolwig et al. will be selected to review the elements for the recycling industry. It is important that the selected manual covers views on local value chains and include analysis on Small and Medium Enterprises (SMEs) as actors in the recycling industry are SMEs that act locally (Innovatie Zuid, 2009). Governance by individual countries or municipalities makes the industry not globalized and must therefore also be covered by elements in the manual. It is furthermore important to analyse any other barriers to entry to discover challenges or opportunities that can further increase the use of recycled post-consumer PPW. Innovation must also be covered as multiple studies indicate the importance of technological advances in waste recycling (Bonifazi et al., 2009; Rem, 2012).

The handbook prepared by Kaplinsky & Morris on doing value chain research is very comprehensive (Kaplinsky & Morris, 2000). They define value chain analysis as: *"Value chain analysis plots the flow of goods and services up and down the chain, and between different chains"* (p.25). These flows of goods and services can be mapped to increase the understanding of the value chain. They furthermore cover innovation, barrier to entry and governance topics as is required for this thesis. This handbook will therefore be used to select the elements that are going be analysed during value chain research. Kaplinsky & Morris advise to use the manual prepared by McCormick and Schmitz for more detail on SMEs (McCormick & Schmitz, 2001). The element selection and preparation of the value chain research will be done in chapter 4. Kaplinsky's value chain research.

3.2. Research strategy

This thesis will use parts of the framework from Kaplinsky and Morris to do a value chain research. They use an industry characterization tool to gain initial insights into a value chain, which enables them to select elements to be analysed specifically for that industry. Their handbook provides strategies to find data on those elements, which will be used to construct an interview strategy.

The first step of the results chapter will be an initial visual map of the value chain. This will be used to create understanding during market segmentation. Next step is to introduce the interviewees and describe the geographical distribution. The selected elements will be researched with the data retrieved from the interviews.

The conclusion will give the answer to the research question. The discussion will continue on the main research question with advices on improvements for the plastic recycling industry. This will be followed by an advice for UMC and for entrepreneurs on how to repeat this research within their own market niche. Combining the information above gives Figure 10, Schematic representation of the thesis:

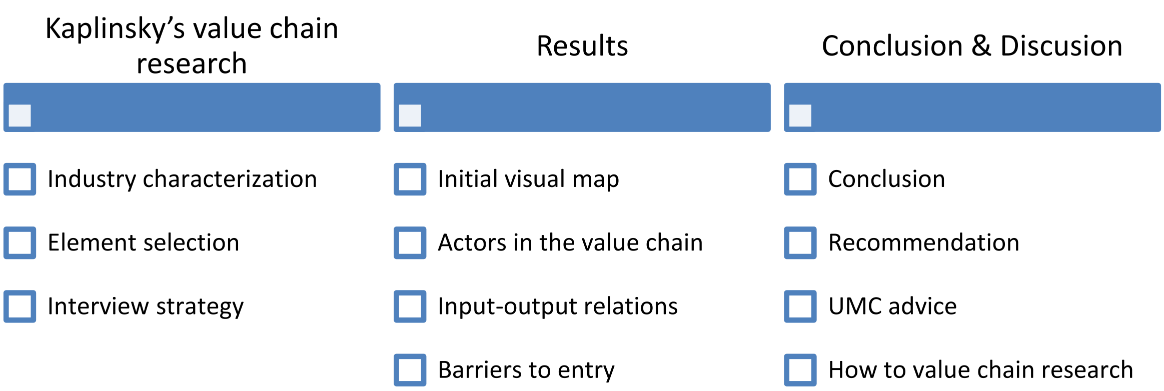

Figure 10, Schematic representation of the thesis

3.3. Data collection method

The research material for the introduction came from a literature study. News pages and informational papers describing the plastic recycling industry will be utilized for the characterization of the industry, as well as PlasticsEurope and other governing bodies. Annual reports and Eurostat statistics database will be used to make an estimation about who the influencers are. The information needed for the value chain research will be retrieved through semi-structured interviews with those influencers, as this information is not available publicly. The results of this thesis will consist of qualitative data and when possible supported with quantitative data.

Selecting the elements for a value chain research will be done by analysing the Kaplinsky & Morris handbook. The industry characterization will be done according to a list of characteristics named in that handbook. The handbook furthermore advises on where and how to acquire data about the actors in the value chain needed to research the elements. Some of the data can only be retrieved by asking experts or actors from the value chain. The interview questions will therefore be prepared according to the needed data at the end of chapter 4 in the interview strategy paragraph.

There are multiple associations for plastic manufacturers that have lists of their members and or affiliated companies that will be used to search for actors in the value chain, for example PlasticsEurope (PlasticsEurope, 2019). By looking at key financial indicators and published production numbers the influencers can be identified for the interviews. These interviews will be semi-structured interviews, which will be explained in the interview strategy in chapter 4.3.

4. Kaplinsky's value chain research

Kaplinsky and Morris had the intention to cover as many elements of value chain analysis as possible in their handbook. They urge the user to make a selection which is relevant for their research. Insight in the Industry is needed to make this selection, which they advise to do by characterizing the industry.

4.1. Industry characterization

Kaplinsky uses a framework by Gereffi to create an initial insight into the industry, which is needed to make a selection of the elements for the value chain research. This insight is created by investigating if the value chain is a producer-driven or buyer-driven commodity chain according to that framework of Gereffi (Gereffi, 1999). He defines a commodity chain as an economic chain of activities involved in design, production and marketing of a product (Gereffi & Korzeniewicz, 1994). Two types of commodity chains can be distinguished:

- *Producer-driven commodity chains* have manufacturers that coordinate the production network, the backward and forward linkages (Gereffi, 1999). Examples are capital- and technology-intensive industries such as automobiles, aircraft, computer and semiconductors.
- *Buyer-driven commodity chains* are characterized by large retailers, marketers and branded manufacturers that set up decentralized production networks in exporting countries, typically low wage countries. Most companies design and/or market branded products, but do not make them (Gereffi, 1999).

The main features of producer-driven and buyer-driven commodity chains are highlighted in Table 2. These features will be discussed for further understanding of the post-consumer PPW industry in the EU.

Table 2, Producer- and buyer-driven chains compared (Gereffi, 1999)

	Producer-Driven Commodity Chains	Buyer-Driven Commodity Chains
Drivers of Global Commodity Chains	Industrial Capital	Commercial Capital
Core Competencies	R&D; Production	Design; Marketing
Barriers to Entry	Economies of Scale	Economies of Scope
Economic Sectors	Consumer Durables Intermediate Goods Capital Goods	Consumer Non-durables
Typical Industries	Automobiles; Computers; Aircraft	Apparel; Footwear; Toys
Ownership of Manufacturing Firms	Transnational Firms	Local Firms
Main Network Links	Investment-based	Trade-based
Predominant Network Structure	Vertical	Horizontal

Drivers of Global Commodity Chains

There are two different drivers for the producer-driven and buyer-driven commodity chains: industrial capital and commercial capital (Gereffi, 1999). It can be argued that both concepts apply to the PPW chain. The capital circulating in the PPW chain is driven by what the buyer wants to pay for the product (Plasticker, 2014). The PPW is sold in two ways, through contracts with a constant flow and per available quantity. The constant flow contracts can be obtained by winning tenders, mostly offered by municipalities who do the collecting of waste (Innovatie Zuid, 2009). The price is determined by the lowest and best bidder. The quantities are sold per big-bag and are traded on online marketplaces or through direct contact. The industrial capital needed for the production could also be argued to be the real driver behind the PPW chain. Because the product cannot be created without the investment in machinery for the recycling process (Neidel & Jakobsen, 2013).

Core Competences

The price of virgin plastics is based on the price of crude oil, as it is the raw material for plastics and provides the energy needed for production (Innovatie Zuid, 2009). The regranulate, the end product of the commodity chain in this case, is currently used as a cost reducing replacement of virgin plastic. It is therefore bound to the price of virgin plastic. That is the reason why the price of regranulate fluctuates with the price of crude oil. Nobody in the chain has influence on this fluctuation. Another factor of the price is the quality of the regranulate (Neidel & Jakobsen, 2013). This can be influenced by the recycling process and controlling the waste input. The core competences of the post-consumer PPW commodity chain are therefore controlling the waste input, trading and controlling the quality of the output through the recycling process without creating high recycling costs. This can be done by the core competences *trading, R&D, technology and production.*

Barriers to Entry

"Economy of scale is when increasing the scale of production leads to a lower cost per unit output" (Sloman, 2005, p. 95). This is applicable for the PPW chain, because the biggest costs are the investments in the recycling street machinery. This will not increase if more material is processed. Meaning that the cost per ton output of plastics reduces, which increases the margin. The recycler could use this to lower the prices in the market, making it harder for competitors to enter the market and forming a barrier to entry. "*Economy of scope* is when increasing the range of products produced by a firm reduces the cost of producing each one" (Sloman, 2005, p. 97).This is not true for the PPW chain, different sorts of plastics require different machinery for recycling (Neidel & Jakobsen, 2013). The barrier of entry for the post-consumer PPW commodity chain could therefore be created by *economy of scale*.

Economic Sectors

Economic sectors can be separated, as can be seen in Table 2, between producer- and buyer-driven commodity chains: consumer durables, intermediate goods and capital goods for producer-driven chains and consumer non-durables for buyer-driven chains (Gereffi, 1999). The regranulate is an *intermediate good*, thus a product which is used as input for the production of other goods (Sloman, 2005). Therefore, the PPW chain is a producer-driven chain analysed from this feature.

Ownership of Manufacturing Firms

The manufacturing firms in this feature are the companies that process the waste and own the recycling machinery. They are mostly located close to the source of the waste, because of regulations and costs surrounding the logistics of waste (Hopewell et al., 2009; Innovatie Zuid, 2009). The gross of the companies in the chain operate locally, which is located in the buyer-driven column of Table 2. The PPW chain is therefore a buyer-driven commodity chain according to this feature.

Main Network Links

With enough time and money, everybody can buy the required machinery, get the permits and start processing waste. Acquiring a constant waste stream cannot be done by everyone. This requires knowledge and a network in the waste industry (Innovatie Zuid, 2009). The commodity chain is therefore *trade-based* and can be perceived buyer-driven from this viewpoint.

Predominant Network Structure

A trend to integrate vertically in the industry, by adding other recycling activities, is observed by the Dutch Federation of rubber and plastics industry. Companies in this federation recycle glass, wood, plastics and metals (Federatie Nederlandse Rubber– en Kunststofindustrie, 2014). This is different for post-consumer PPW companies. They tend to integrate horizontally by making products with the regranulate from the recycling process, or start collecting plastic waste and thereby controlling the quality of the waste input stream (Innovatie Zuid, 2009). The predominant network structure in this commodity chain is therefore *horizontal*, thereby characterizing this industry as buyer-driven.

Conclusion: Producer-Driven or Buyer-Driven?

Kaplinsky states in his handbook for value chain research, that the Gereffi framework is useful for helping to formulate research questions. It should however not be used to formulate a proven research conclusion, because the distinction between producer- and buyer-driven is not binary. This also seems to be the case with the PPW industry. The post-consumer PPW commodity chain has both producer- and buyer-driven characteristics. Table 3 gives the results from the analysis of the features from the Gereffi framework. The key characteristics are:

- Commercial capital driven, because of the pricing is based on trading.
- Industrial capital driven, because of the required investments in the recycling machines.
- Core competencies are trading and controlling the recycling process: R&D, technology and production.
- The economy of scale concept applies: producing more regranulate lowers costs, which results in a competitive advantage creating a barrier to entry.
- The chain produces intermediate goods.
- Firms operate locally and are geographically dispersed, due to logistic legislation and costs.
- Network and knowledge of the market is important, because the main network links are trade-based.
- Most firms integrate horizontal in the chain to increase margin and increase synergy.

Table 3, Post-consumer PPW commodity chain characterization

Features:	Characteristics:	Buyer / Producer Driven:
Drivers of Global Commodity Chains	Industrial / Commercial Capital	-
Core Competencies	Trading; R&D; Technology; Production	Producer-driven
Barriers to Entry	Economies of Scale	Producer-driven
Economic Sectors	Intermediate good	Producer-driven
Ownership of Manufacturing Firms	Local Firms	Buyer-driven
Main Network Links	Trade-Based	Buyer-driven
Predominant Network Structure	Horizontal	Buyer-driven

The Gereffi framework improved our insight into the characteristics of the value chain. This knowledge can now be used to select the elements of value chain research in the next paragraph.

4.2. Element selection

Kaplinsky & Morris (2001) describe multiple elements that can be used to research a value chain. For example, the element governance could have a tremendous impact on the value chain with regulations and required permits. The elements are selected for the value chain research of the post-consumer PPW recycling industry using the previously determined characteristics. Kaplinsky & Morris refer in their handbook to the manual prepared by McCormick and Schmitz (2001) that focuses more on the role of SMEs in the value chain. Both papers are therefore used for extracting elements for the selection. The following relevant elements are selected and will be discussed:

- Mapping value chains
- Market segments and Critical Success Factors
- Producers accessing final markets
- Barriers to entry and rent
- Governance
- Upgrading

Mapping Value Chains

An initial value chain map increases understanding of the industry during the research (McCormick & Schmitz, 2001). This map can be created by constructing a tree of input-output relationships with accounting identities (Kaplinsky & Morris, 2000). Sources of data can be annual reports and interviews. However, the companies in this industry tend to be privately owned and are expected to be very protective with their data and relationships. It is therefore expected that little information can be gained from these sources. Components of this element that can be pursued during the interviews are: gross output values, physical flow of goods, destination of sales and number of buyers (Kaplinsky & Morris, 2000). Data about growth or decline of processed material in the past and future will be collected to be able to determine who will be a leading actor in the industry. McCormick and Schmitz (2001) made an action list to make this initial value chain map, in short:

1. Identify main final markets and make a quality distinction (<5 groups).
2. List functions (activities), for example retailing, advertising, shipping, production etc.
3. List participants; obtain rough estimate of number of enterprises involved; list key contacts.
4. Drawing lines between enterprises in the different functions to represent their relationships.

This list will be followed to establish the initial map and analyse the input-output relations. McCormick and Schmitz (2001) furthermore give the advice*: "chain analysis is mainly about relationships; hear both sides of the story"* (p. 38). Which will be done by validating statements between interviewees.

Market segments and Critical Success Factors

After the initial map, a market segmentation overview should be created to further breakout the different branches within the value chain providing a deeper insight (McCormick & Schmitz, 2001). Next step would be to select a market segment to prevent information overload and apply focus, thereby increasing the applicability. Within this market segment the input-output relations will be analysed. The employment rate will not be analysed, because it will not tell anything about the influence of an actor only about the production efficiency. This is different from the method of McCormick & Schmitz. Production capacity and current output will be used instead. This will indicate the size and influence of the individual actors. Four components need to be analysed to understand the value chain dynamics (Kaplinsky & Morris, 2000):

- *Market segmentation*, the PPW chain can be segmented in the different plastic grades. Each segment has its own characteristics: market size and growth.
- *Critical Success Factors (CSFs),* what characteristics are critical for success? Some segments could be driven by quality for a certain plastic, others by quantity.
- *Order-qualifying and order-winning characteristics,* the CSFs can be grouped into order qualifying (characteristics that enable participation in these markets), and order winning (critical factors which lead firms to succeed).
- *Market volatility*, are there characteristics that change over time? This could provide insights in which characteristics could become critical success factors or not.

Kaplinsky & Morris describe that the data for these components can be collected through interviews. Triangulation could form an issue with qualitative perceptions, this can be mitigated by cross-checking the data. In our case the information can be cross checked by asking the supplier and the customer of a certain regranulate or granulate about their CSFs perceptions.

Producers accessing final markets

Producers need a point of entry into markets (Kaplinsky & Morris, 2000), for example compounders who produce regranulate need a buyer. Every point of entry has its own terms; For example, the buyer has reasons to buy regranulate and sets terms for this transaction. Producers will focus on these reasons and terms to win over that buyer. This point of entry and its characteristics affects the capacity and focus on where to upgrade for producers. This makes it relevant to analyse how producers access final markets. Kaplinsky & Morris (2001) have identified six key issues to research:

- *Identification of key buyers,* large firms in key links in the chain which buy in large volumes and/or who set the rules which govern incorporation in final markets.
- *Dynamics of the buying function,* concentration of buyers geographically and in volume influences the power of these buyers in the value chain.
- *CSFs of different buyers,* in most cases the CSFs are defined by the market segments, but often buyers in the same segments will nuance their requirements. Bigger compounders could set their own requirements which change or influence the CSFs in a market segment.
- *Strategic judgments on sources of supply,* buyers may have preferences for specific sources of supply. In our case, a compounder may prefer buying regranulate from a recycler that they

already know, and/or an ex-employee may work there. Identifying those preferences are important to understand the dynamics in the market.

- *Supply chain management policies,* are often linked to the durability of relationships between buyers and suppliers. The development of long-term and high-trust relationships generally requires a smaller number of suppliers, so the number of, and the degree of concentration of key suppliers, are important datasets.
- *Supply chain innovation policies*, buyers may provide inputs to assist their suppliers to innovate.

Barriers to entry and rent

Access to Schumpeterian rent or normal rent is protected with barriers to entry. New sources of rent will emerge with new technologies and the increase of regranulate applications. These new sources of rent need a barrier of entry to be sustainable. The barriers to entry in the plastic recycling industry need to be mapped to facilitate successful market entry. It is therefore important to analyse what form of rent is available or will be created in the near future and how this rent is protected. Below are different forms of economic rent with their related barrier to entry (Kaplinsky & Morris, 2000) that will be analysed during the value chain research:

Technology rents can be created by the owner of a scarce technology. Recyclers or compounders can increase their rents when having access to such a technology where others do not. This is important to analyse as numerous recyclers claim to have special technologies to differentiate from their competition.

Organizational rents can be created when an organisation is more efficient than others. Some recyclers show more professionalism through their website than others. This could indicate a difference in efficiency between organisations and thereby possible different rents.

Relational rents can be created when an organisation has superior relationships with suppliers or customers compared to others. Some companies claim to have superior or exclusive partnerships and publish these partners on their website (RTGE Staff, 2014). This source of rent is therefore important to analyse.

Resource rents can be created when an organisation has access to valuable resources, where other organisations do not or have less access to that resource. Resource rent is closely related to relational rents for the recycling industry as exclusive PPW supplier partnerships result in having exclusive access to PPW resource.

Governance

Value chains imply repetitiveness of linkage interactions (Kaplinsky & Morris, 2000). These interactions are guided by rules or governance. "*Governance ensures that interactions between firms along a value chain exhibit some reflection of organization rather than being simply random*" (Kaplinsky & Morris, 2001, p. 29). These rules or governance are strongly influenced by the regulatory framework for recycling formulated by governments. Governments are therefore important and could be powerful parties in the value chain. The power which any party may have in the chain can be executed in two distinctive ways: forcing other parties to take a particular action or having the capacity to be deaf to the demands of others (Kaplinsky & Morris, 2001). Governments use their power to formulate and enforce new rules, although governments may not be the only party with power in the value chain. The extent of chain power can be analysed by looking at:

- Share of chain sales or size.
- Control over a key technology and distinctive competence.
- Holder of chain "market identity" (for example a dominant brand name).

Rules can also be set by powerful actors internal or external to the value chain. For this research, it is important to look for the rule regime internal to the chain, because the internal actors have the power to change rules. External powerful actors like governments, often need a lot of time to change the rules, they are also harder to influence from the SME point of view. Kaplinsky & Morris (2001) explain to analyse rules set by key links in the chain, which producers need to attain. These rules can for example be quality standards, environmental standards and on-time-delivery requirements.

There is one external set of rules specific important for this thesis, called the Dutch 'Raamovereenkomst' of packaging waste (Ministerie van Infrastructuur en Milieu et al., 2013). This agreement will be analysed to see what the impact is on the value chain.

Upgrading

The capacity to innovate is a key capability to ensure continuous improvement in product and process development. This is needed for meeting new market needs and building a sustainable business. But innovation alone is not enough: "*If the rate of innovation is lower than that of competitors, this may result in declining value added and market shares*" (Kaplinsky & Morris, 2001, p.37). Innovation must therefore be placed in a relative context, how much innovation compared to the competition. This is called upgrading and it distinguishes itself from innovation by recognizing innovation relative to the competition and the resulting source of rent. The data for analysing upgrading must therefore be collected over time. This will be done by asking about future growth, previous growth projects and potential capacity during the interviews.

Upgrading can be researched by examining the firm's capabilities with focus on core competences (Hamel & Prahalad, 1994) and on dynamic capabilities (Teece & Pisano, 1994). Actors will be asked if they have competences or capabilities that:

- Provide value to the final customer.
- Are relative unique.
- Are difficult to copy.
- Facilitate learning through Internal processes.
- Position specific competences in own activities or from reginal innovation system.

The last two are dynamic capabilities which describe the ability to upgrade the activities over time and the first 3 are core competences that describe the current ability to upgrade.

Recycling applications that show cooperation with suppliers and customers in new product development and/or their own internal product development show chain upgrading (Kaplinsky & Morris, 2000). This is one of the four trajectories that can be identified as a form of upgrading. Others are process, product and functional upgrading. Process upgrading increases the efficiency of the internal processes. Product upgrading is improving or introducing new products. Functional upgrading is changing the activities of an actor by outsourcing, integrating or changing processes.

Lastly, having capabilities which are relative unique can be used to create barriers of entry for the competition and are therefore indicators of Schumpeterian rent. Having a capable upgrading process increases the chance of creating Schumpeterian rent. The element upgrading is therefore related to the element barriers to entry and rent.

4.3. Interview strategy

Preventing information overload while executing the value chain research is important to maintain usability of the research (Kaplinsky & Morris, 2000). Their advice is to keep the research question in mind during the interviews and focus on getting the information to answer it:

What is required from the value chain of the plastic recycling industry to increase the use of recycled post-consumer PPW?

The required data for answering the research questions is selected in the previous paragraph. This is summarized in Appendix C - Required data, which was used for the formulation of the interview questions, which can be found in Appendix D - Interview questions. A one-pager is shared with the interviewees with the aim of increasing the response rate, which can be found in Appendix E - Dutch one-pager. The main data collection method will be semi-structured interviews in an informal setting to maximize knowledge transfer by the interviewee. The interviews will not be recorded, because this could limit information sharing by the interviewee. Interviews in the Benelux will be done live and through Skype when further away. The terminology of upgrading and Schumpeterian rent will be replaced by easier to understand concepts of innovation and profit respectively. The triangulation principle will be used to verify statements made by interviewees. That is bringing back a statement as a topic with other interviews. An interview report will be made directly after and will be send to the interviewee to prevent misinterpretations. The retrieved information from the interviews will be anonymized and used in the results chapter on the next page.

5. Results

Seven interviews were conducted with an average time of two hours. The interviewees all showed compassion for creating more transparency in the plastic recycling industry and agreed that it would lower the barrier to entry which can further professionalize the industry. The information from the interviews is displayed in this chapter according to the following value chain research execution steps:

1. Starting with a visualization of an initial map and giving a detailed market segmentation.
2. Listing participants and identifying actor connections.
3. Zooming in on the value chain by describing input-output relations.
4. Identifying barriers of entry and upgrading processes.

The interview notes can be found in Appendix G - Interviews. Every paragraph in this chapter finishes with findings, where the results of the interviews are related to the terminology of the elements as selected in the previous chapter.

5.1. Initial visual map

The simplified value chain for regranulate, is shown below in Figure 11. Plastic that is discarded is collected by municipalities. They sell the collected plastic to recyclers who separate it in different plastic sorts. The recycler sells the separated plastic to compounders who make regranulate, which is used by converters that injection mould plastic products. Branding companies design the products to be moulded and distribute them to the end consumer. UMC, the company that was selected as starting point, separates plastic flakes from collected plastic and sells it to compounders. They therefore fit in the recycling box in the simplified value chain below.

Figure 11, Simplified value chain for regranulate

Market segmentation

A market segmentation diagram was missing in the literature. Figure 12 was therefore created with information from the interviews and retrieved information from the literature used in previous chapters. The market segmentation diagram will now be explained per blue block following the green path (bold in text on next pages). This path will result in the chosen market segment for this value chain research. The referenced companies in the explanation of the diagram will be introduced in the following paragraph. The diagram starts with plastic waste, followed by the first choice for post-consumer waste.

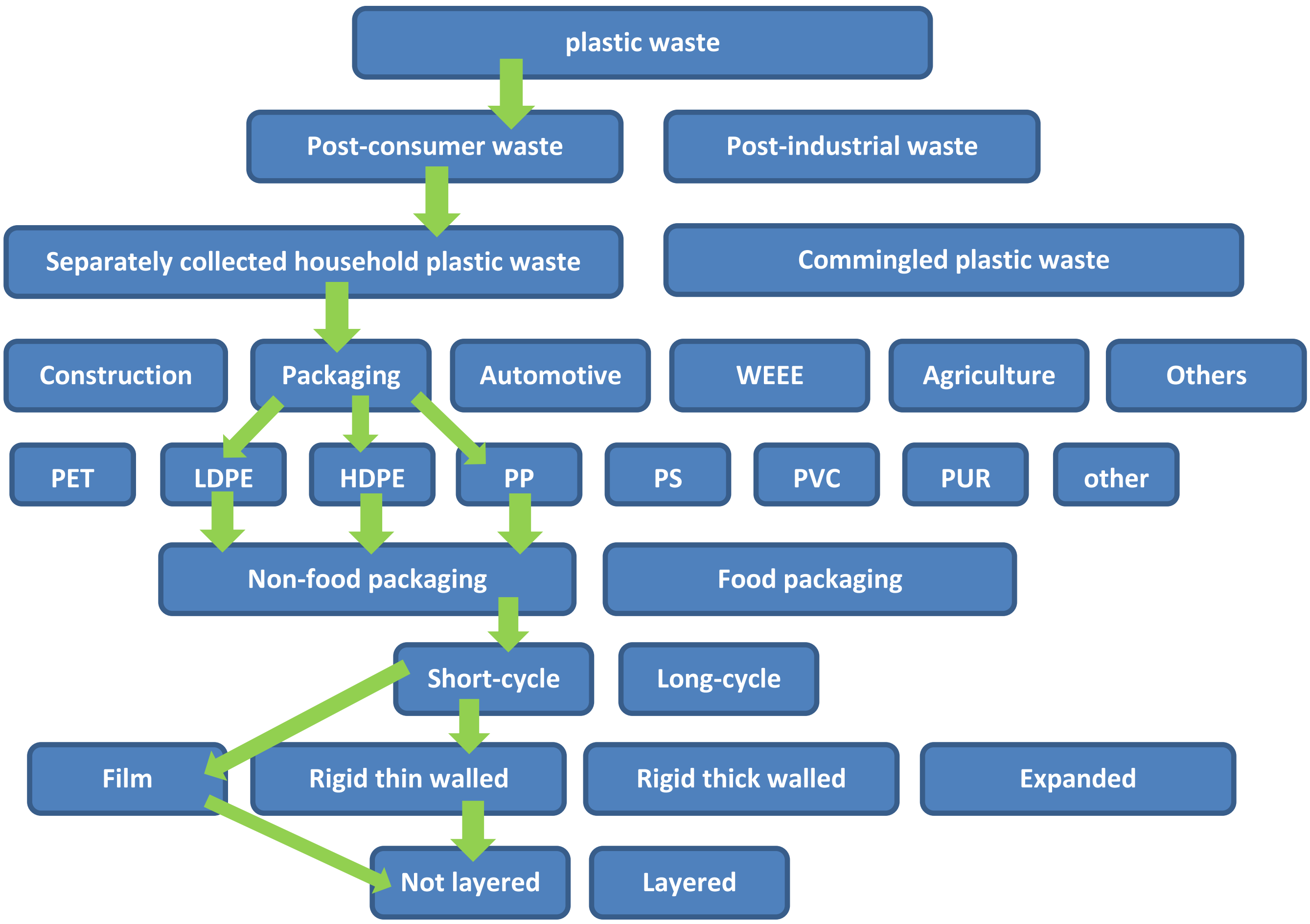

Figure 12, Market segmentation diagram

Post-consumer waste is a continuous waste stream that is relatively stable, apart from seasonal influences when packaging changes temporarily, for example during Christmas. Post-industrial is a batch waste stream, as indicated by interviewee B during the interview:

> *"post-industrial plastic waste is mostly created by batch manufacturing processes. We need a continuous flow of plastic waste to deliver a continuous flow of regranulate. We therefore prefer post-consumer waste".*

Interviewee A and B indicated that **commingled plastic waste** collection, retrieving plastic from commingled household waste stream, gets more contaminated especially the smell gets worse. Interviewee B therefore prefers **separately collected plastic,** which is not mingled with the mixed waste stream. Interviewee D mixes the two types and says that they both have bad and good properties:

> *"The commingled plastic contains less plastic foils but has more contaminations. The foil doesn't dry completely, thereby clogging the machine street and holding sand in the stream. Contaminations like sand, can increase the wear and tear of the machines, especially the shredder in the beginning."*

The next step downwards in the diagram, Figure 12, is **packaging**. This choice is based on its size (40% of total plastic waste as described in the scope of this thesis) and its characteristic to have **short-cycle** plastics. Meaning that new packages return into the waste stream within a short time period, for example food packaging. Interviewee B indicated that long-cycle plastics, for example car bumpers, could contain old types of plastic which have different specifications than currently produced plastics. They furthermore say:

> *"The advantage of short-cycle plastics is, that they are not subjected to long life degradation of the molecule structure. Long-cycle plastics mostly require lengthy development relationships for making a grade that ensures a stable long-life cycle. I have seen 5-year pre-design projects for automotive parts. This is impossible for recycling companies, who cannot guaranty the same product over 5 years."*

Interviewee A also indicated this problem and added that rules and regulations may change in 5 years, which could change the composition of plastics and therefore the regranulate. Some car bumpers, however, contain recycled plastic as a replacement for fillers for cost reduction or marketing purposes. **Non-food packaging** was chosen, because there is an underutilized market for non-food recycled plastic and food-graded recycled plastic is highly dependable on regulation. According to interviewee B:

> *"Making food grade recycled plastic is expensive or legislative impossible in the Netherlands. For example, paint buckets don't have to be food grade or high-quality due to their short live cycle. This will probably be our first application"*

End of life plastic products can easily be made with recycled plastic, for example park benches and underground pipes. But higher-grade plastics, for example thin walled plastic packaging, are not made with recycled plastic on a bigger scale. New technologies and separate collection initiatives enable high-grade applications. The machinery needed to create food grade recycled plastic seems too expensive, not profitable, concluded from the limited number of companies that invest in this. There are however, some companies in the UK who make food-grade plastics with the machines of the company Erema (Welle, 2005).

Recyclers exclude (remove) **expanded plastics**, for example Styrofoam, from the recycling process because it is not profitable to recycle. The expanded plastics consists 98% of air and are therefore expensive to transport. They are also incompatible with most recycling technologies, because they float and easily fly away due to their low weight. The **rigid thick walled** plastics are also less profitable, because they are excluded from subsidy plans which will be explained in the governance paragraph after the introduction of the actors. The last distinction is **not layered** (homogeneous) or layered plastics, for example potato chips bags where plastic is combined with aluminium. This group requires a different recycling process, separating the two small layers, which is currently not done by any of the companies found during this value chain research.

Findings

The initial visual map and market segmentation resulted in a simplified overview of the value chain and a, beforehand non-existing, market segmentation overview. The activities in the value chain were characterized and the case company UMC was placed in the recycler box. The market segmentation yielded insights on the different possible final markets in the value chain. The reasoning behind some of the choices for a final market made by the interviewees showed to give valuable insights. It was surprising to see that some intermediate choices were made different by different interviewees. For example, the choice for commingled plastic waste over separately collected plastic waste, which depends on the internal processing at the recyclers and their knowledge on how to process it. The different choices by the interviewees, like the previous mentioned example, can influence the rent distribution between them in the final market.

5.2. Actors in the value chain

The value chain activities recycling, compounding and converting have actors that specialize in recycled plastic. Actors involved in these activities can give insights in the relationships between those links in the value chain. A database is created with those actors to identify a first compounder to interview. The choice for starting with a compounder was made because the end product of UMC, separated plastic flakes, goes to compounders. They are selected for the database based on the following characteristics:

1. Process recycled material into rPP and/or rPE regranulate, which is the selected market segment from the previous paragraph.
2. Within the geographical area of: The Netherlands, Germany, Italy, France and United Kingdom. The selected geographical area of the scope, which represents 64% of the total EU-27 market based on recycling volume.
3. Use additives or technologies to adjust specifications of their end products. This selection criteria separates the actors who adjust plastic specifications from those who just transform flakes into granules with an extruder.

The indexed companies are retrieved from lists from industry organizations, see Table 4. The assumption is made that bigger companies enlist themselves to these organizations, mining it would therefore yield a database of actors that are relevant to UMC. Articles from plastic news pages, for example Plastic News, PlasticsEurope etc., yielded actors that have something special and therefore worthy to include in the list of companies.

Table 4, Sources for finding companies

Source:	Geographical area:	Link:	Size:
NRK Recycling	Netherlands	http://vkr.nrk.nl/leden/	25
Nedvang	Netherlands	http://www.nedvang.nl/afvalbedrijven/erkende-bedrijven	29
Plastics News	Europe	http://www.plasticsnews.com/article/20110930/FYI/309309!	10
VKR - NRK	Netherlands	http://vkr.nrk.nl/recycling-duplicate/regranulaat/	8
Plastics recycling conference	Europe / UK	http://plasticsrecyclingeurope.com/speakers-plastics-recycli	10
Plasticker compouding list	Europe / Germany	http://plasticker.de/avz/rohstoffe_en.php?typ=bereiche&typ2	44
Material Data Center	all over the world	http://www.materialdatacenter.com/mb/	
EUWID	Europe / Germany	http://www.euwid.com/	
PlasticsEurope	Europe	http://www.plasticseurope.org/plastics-industry/our-membe	60
Eucertplast	Europe	http://www.eucertplast.eu/uploads/downloads/certified-recy	120
Recycling Today		http://www.recyclingtoday.com/	

It total 149 companies are included in the database. With their location indicated in Figure 13, with compounders in blue, recyclers in brown and converters in yellow. The compounders are selected through the previous mentioned criteria. The recyclers and converters in the map are the suppliers, customers or partners of the compounders. Some companies have integrated in the value chain, doing recycling and compounding. If such a company has more focus on the recycling activities, than they would be marked as recycling company in the database. This information was retrieved through their website and in some cases through direct contact.

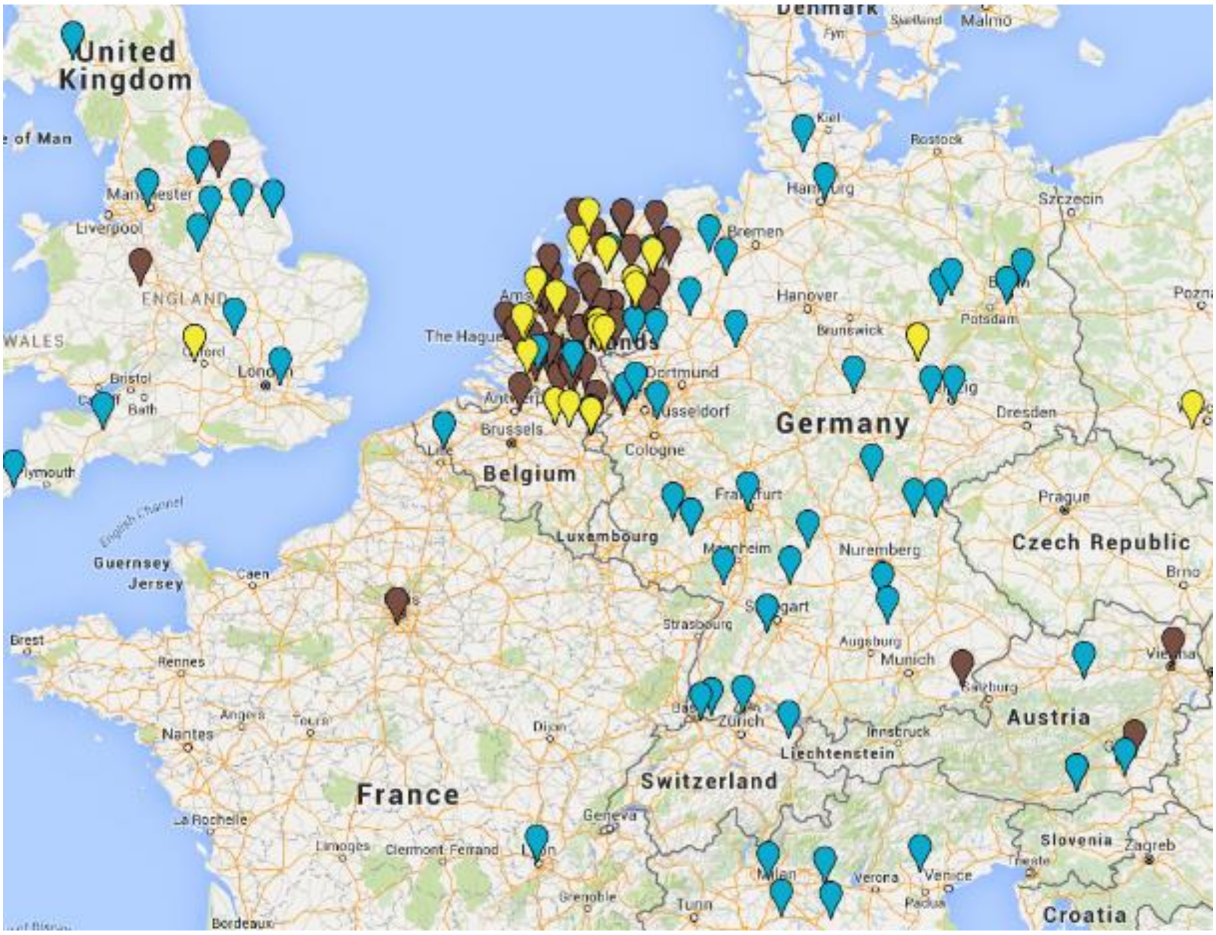

Figure 13, Map of database (compounders in blue, recyclers in brown and converters in yellow)

The sources used for finding these companies only yielded one company in France, the recycling company (brown). The compounder (blue) which can also be seen in France is a production facility from a company in Switzerland. The scarcity of French companies in the database is a result of not using any sources in the French language. It can be concluded that French companies do not enlist themselves with European industry organisations like PlasticsEurope. More companies were found in the Netherlands as compared to other countries which can be explained by the use of three Dutch sources. EUWID has a focus on Germany, although not exclusive. Searching and requesting lists of other countries in the scope were not successful. It must be noted that most of the English and Dutch companies had websites and German companies did not all have a website to search through. This made it impossible to check the criteria for some companies.

It turns out that compounders are in general less fragmented than recyclers or converters, because:

- Recyclers process waste locally due to transport costs and regulations (Innovatie Zuid, 2009).
- Converters specialize in a certain product, which results in high diversity.

Fifty-five companies from the database are contacted through email, selected on quantity processed material from high to low. Sixteen responded, of which seven companies replied not to be interested. The companies that did not reply received a follow-up call or an email, when no phone number was available. None of German companies replied to the email and two answered the phone after follow-up. One disconnected after the word research and the other said that he could not speak English. Two companies from England showed interest in an interview but never followed through after making an appointment for the interview. The yield of contacting recycling companies in the five EU-27 countries resulted in redefining the geographical scope. As only Dutch companies were willing to participate the geographical scope changed to the Netherlands. The Dutch part of the database is displayed in Appendix F - Database overview.

Geographical location and overview

Recyclers (brown)

Recyclers are agglomerated around the sources of PPW near big cities: Amsterdam, Rotterdam, Eindhoven and Arnhem. The collected household plastic is processed at separation plants which is done in only four locations: Rotterdam, Groningen and two in Germany. Other recyclers process plastic that is collected from the post-industrial waste stream and the rigid-thin and thick-walled plastics at the environmental waste parks from the municipalities.

Figure 14, Recyclers in The Netherlands

Compounders (Blue)

Virgin plastic compounders that produce regranulate could not be found within the Netherlands. All compounders in this map are solely making regranulate. There are recyclers who integrate into compounding by making their own regranulate. This is a limited group and have no clear centralized location. Their orientation seems to be towards Germany, probably to also utilize the almost ten times larger market.

Figure 15, Compounders in The Netherlands

Converters (Yellow)

The list of converters is limited. There are a lot of converters that specialize in their own market segment, but don't process regranulate and or do not display that on their website. Bigger branded companies tend to integrate into converting, because the barrier of entry is low and the converters do not do small series which is sometimes required by branded companies. This will be explained in more detail in the chapter Relationship: Compounder - Converter.

Figure 16, Converters in The Netherlands

Overview in numbers

As seen in the scope from Eurostat, 236 kton PPW was collected in The Netherlands. According to one of the recycling interviewees, 120 kton PPW was collected in the Netherlands in 2014, from which 25-30 kton was processed in the installation in Rotterdam. The rest was exported to Germany for processing. A new expansion in Rotterdam will enable the processing of 80 to 100 kton of plastic at the end of 2015. To put the size of the market in perspective: Germany processed 1405 kton in 2014.

Company profiles

The interviewees A to G are anonymized actors in the recycling industry that are interviewed to retrieve data for the value chain research. They are referred to as interviewee in person or as Company with their anonymous alphabetic letter. The paragraphs below will introduce them and give their position in the chain, with input and output products. The unique selling points (USPs) are written down as how the interviewee explained them in the interview. This can result in inconsistent and sometimes unbelievable information.

Company A: Recycling consultant

Input: not applicable - Output: knowledge

USPs: Recycling and plastic knowhow

Capacity per year (intend to grow to): Not applicable (consultancy)

Interviewee A is a sole practitioner that failed on building his own high-tech recycling facility due to lack of funding. During this process, he acquired knowledge regarding recycling machinery and plastic waste stream characteristics. Interviewee A is hired by UMC as a consultant to help with the technological implementation. Interviewee A helped in the beginning of the value chain research to identify if the interview questions were possible to ask.

Company B: compounder & recycler

Input: bales - Output: regranulate

USPs: Hot washing process; Knowledge about polymer; Scale; Extruder knowledge; Extruder supplier connections; Logistical knowhow.

Capacity per year (intend to grow to): 35.000 ton (100.000 ton)

Compounder B is going to buy bales of PP and PE post-consumer plastic from a collector / recycler, who collects the plastic and makes the first separation. They will start production with an output of 35 kton regranulate per year at the end of 2015. The first application is a paint bucket for the German market. 70% of the input mass will be used for the output product. The output material will consist of minimal 90% recycled material. They have the ambition to grow to an output of 100 kton per year. Characteristic for Company B is that they partnered up with Company F, locking-in the supply.

Company C: recycler, compounder & converter

Figure 17, logistic pallet (Van Maren Systems, 2015)

Input: bales - Output: regranulate & pallets

USPs: Bales converted to pallets (for logistics) under the same roof; Control of the recycling, compounding and converting increases quality control.

Capacity per year (intend to grow to): Not disclosed

Company C buys bales of different plastics from the collectors. They claim to sell regranulate on their website, but the director told me they almost transform all their produced plastics into logistical pallets. Those pallets are for the logistics industry as a better alternative to the wooden pallet, not to be confused with an output product from compounders: pellets. Interviewee C also consults the waste collector companies on their sales activities. They facilitate the export to German companies, claiming to facilitate 100% of the waste streams from big recycling systems in Groningen, Friesland and 50% of the stream of Rotterdam. Interviewee C strongly believes in an integrated systems approach of materials, design and processing.

Company D: recycler & compounder

Input: bales - Output: regranulate

USPs: Bale to regranulate under one roof, less logistics; Fully developed end product with one company; 8 years guaranteed input of material with municipalities.

Capacity per year (intend to grow to): 12.500 ton (35.000 ton)

Company D is a listed company to the Amsterdam Stock Exchange, which seems unique. The choice for this financing strategy is outside the scope of this thesis. Company D consists of three companies: polymers, compounding and converter. Interviewee D works at the compounding company, who makes regranulate compounds. They manage to deliver a constant product to their customers from commingled and separately collected plastic waste. They work together with companies that deliver end products to close the loop of recycling. An example of a closed loop are the containers of SSI Schaefer. Company D regrinds the broken containers and upgrades the plastic to the same mechanical properties that is needed to make new containers. Their activities are shredding, washing, drying, separation and compounding. They have the ability to apply hot washing, but they do not do that because it is too expensive.

Company E: converter & brand owner

Input: granules - Output: cups, trays and other storage solutions

USPs: Service orientated; Local production, quick response and delivery upon request.

Capacity per year (intend to grow to): Not disclosed

Company E is a high-end converter, delivering premium branded storage solutions to stores for the consumer market. They also make trays and other storage solutions for corporate clients. Activities are marketing, design and injection moulding. Most of the sales are in the Benelux. They bought a bankrupt converter a couple of years back to produce their own product. They used to design them and source out the production. Taking over a converter created production flexibility, increased service and reaction speed towards their customers. It also enabled the recycling and mostly selling of their own post-industrial plastic waste. They launched a product line made with regranulate material more than 6 years back, but the production yield was to low which decreased the margin on the product. The consumer was not willing to pay extra for products made of regranulate, so the product line was terminated. The production at the converter must continue 24h a day to be profitable. The moulds can only be changed during the day. Production stops when a smaller series of products is done during the night, making them less profitable to make. This caused converters to turndown small series jobs.

Company F: recycler

Input: Separately collected household plastic waste - Output: bales

USPs: They are the only one in NL with this recycling machine; Direct connection with compounder; Collaboration strategy; Knowledge build up with installation.

Capacity per year (intend to grow to): 100.000 ton (200.000 ton)

Company F recycles separately collected household plastic waste in the Netherlands. They achieved to win 80% of the tenders, thereby the ownership of the to be recycled plastic. They are the only company in the Netherlands with an installation that is capable of separation of plastic into bales of individual types of plastic. They started the installation in 2011 and build it for a capacity of 1200 ton per week, currently running at 2000 ton per week. They plan to have the second installation running by the summer of 2015, doubling the installation capacity. The output consists of bales of foils, PP, PE, PET, a mix stream and a rest stream which is incinerated. The mix stream is used for end of life plastic products like park benches. The interviewee is sales manager plastics. He handles the procurement of plastics. Some plastic is processed in the plant and some is resold. He is now focusing on post-industrial circular recycle projects. An example are the trash containers they use, they grind them to flakes when broken and send them back to the supplier who makes new containers from the flakes.

Company G: recycler

Input: Separately collected household plastic waste - Output: bales

USPs: They are the only one in NL with this machine; Direct connection with compounder; Collaboration strategy; Knowledge build up with installation.

Capacity per year (intend to grow to): 30.000 ton (100.000 ton)

Interviewee G works at the same company as interviewee F, but the interviewee G was directly responsible for the installation and thereby the production as plant manager. He focusses on process optimization, which can be achieved by working closely together with the individual machine suppliers to tweak the configuration of the installation. He also must manage audits and monitor quality checks by governing parties who have a strong influence on the value chain.

Table 5, processing capacity per year and the intension to grow to between brackets

Company:	Capacity per year (intend to grow to):
A	Not applicable (consultancy)
B	35.000 ton (100.000 ton)
C	Not disclosed
D	12.500 ton (35.000 ton)
E	Not disclosed
F	100.000 ton (200.000 ton)
G	30.000 ton (100.000 ton)

Governance

There are two influencing factors in the value chain regarding governance: The DSD-standards from the company DerGrünePunkt from Germany (DerGrünePunkt, 2014) and the Dutch 'Raamovereenkomst' from the packaging industry in The Netherlands and its government (Ministerie van Infrastructuur en Milieu et al., 2013). DerGrünePunkt is the trade name for the German company 'Duales System Deutschland GmbH', which makes the abbreviation DSD.

The DSD-standards apply to the quality of bales, as described in the standards D324 for PP and D329 for HDPE (DerGrünePunkt, 2014). These standards are set by the commercial company 'DerGrünePunkt' in Germany, which is the biggest recycling company in Germany. It states, among others, the degree of allowed contamination and the inacceptable materials in the bales. The DSD-standards, also called DKR-standards from 'Deutsche Gesellschaft für Krieslaufwirtschaft und Rohstoffe mbH', are commonly used in the EU plastic recycling industry. For example, company F must comply to the DSD-standards for their customers and the government. The bales are checked randomly for contaminations by their customers. Or the contaminations can be traced back when they detect defects in the regranulate.

The second influencer: the Dutch 'Raamovereenkomst' for packaging materials (Ministerie van Infrastructuur en Milieu et al., 2013). This 'Raamovereenkomst' was setup by the packaging industry, the municipalities and the Dutch government. Its goal is to reduce, reuse, recycle and renew packaging waste. The agreement covers all plastic, metal, paper / carton, wood and glass packaging. The producers of plastic packaging are obligated to put money in a fund per produced product based on weight. This fund is managed by the governmental institution Nedvang and is used to finance the recycling of plastic packaging products. Municipalities receive €656 per processed ton, which they achieve by tendering for plastic waste solutions. Nedvang has made an online platform available named: 'WasteTool' for all involved parties to report the processed material. Nedvang subsequently hires independent companies to perform audits to compare the actual processed material with the input into the WasteTool. For example ILT, Inspectie Leefomgeving en Transport, does administrative audits and a company called "Kiwa" checks if the output complies with the DSD-standards. The included parties of the 'Raamovereenkomst' have set recycling percentage targets that gradually increase every year, see Figure 19. In 2015 a minimum of 45% mono streams PP, PE, PET and foils must be separated from the plastic fraction of the collected PPW to qualify for the compensation.

Jaar	Vergoeding per ton
2015	€ 817
2016	€ 788
2017	€ 756
2018	€ 712
2019	€ 656

Figure 18, Reimbursement per ton (Nedvang, 2014b)

Materiaal	2013	2014	2015	2016	2017	2022
Kunststof	43	44	45	46	47	52
Hout	27	29	31	33	35	45

Figure 19, Recycle targets (Ministerie van Infrastructuur en Milieu et al., 2013)

Findings

149 companies fitted the selection criteria from the eleven sources that were used. Fifty-five companies from the database were contacted through email, which resulted in 7 interviews. For the element mapping the value chain the following data was requested: gross output values, physical flow of goods, destination of sales and number of buyers for determining an industry leader. None of the companies published or share that data. It is therefore not possible to qualitatively determine who is or is going to be the leading actor in the industry. All interviewees gave the impression during the interviews that they were or were going to be the market leader in their segment. This was not validated with other interviewees. Processing capacity was sometimes published on websites or a verbal indication of current flow of goods was given during the interviews. Interviewee F and G are two employees in different parts of the same recycler and gave processing capacity numbers of 30 kton and 100 kton, which shows that those numbers are unreliable. However, those numbers helped to give some idea on who are the key buyers and large firms in the chain for the element producers accessing final markets. Company F or G is the key recycler and company B is going to be the key compounder when they finish their factory based on processed material. Company D is currently a key compounder and showed multiple projects where they work together with other actors to use regranulate. Other companies, apart from company A and E, showed similar collaboration projects where they recycled end-of-life products into regranulate for new products. Another observation was that many of the companies integrate within the value chain through collaboration or buying equipment to add activities of the value chain. The geographical distribution of the actors did not seem to influence the power of their buyer function. Interviewee D explained that their location close to the German border enabled them to serve that market as well. Company B is located in an industrial area where many chemical oriented companies are founded and where many chemical related knowledge is available. Their processing capacity makes that Company B will overtake D, which is related to their buyer relationships which are given in the next chapter.

For the element governance the power to force new rules and having chain power was analysed. The German company DerGrünePunkt forced standards internal to the value chain, for the allowed contamination in bales. The Dutch ‘Raamovereenkomst’ is an external set of rules set by the external actor government of the Netherlands in cooperation with internal actors. Another powerful factor are subsidies, where the rules or requirements for the subsidies determine the order winning requirements for collectors and recyclers. No distinctive competence or key technology was found that enabled an actor to have more power than others and influence the governance in the PPW value chain.

5.3. Input-output relations

Find below the map of the two researched relations between: (1) recyclers and compounders and (2) compounders and converters. The letters represent the anonymized companies, where the x is a placeholder which can be any company. The square icons are recyclers, round icons are compounders and the hexagon icons are converters:

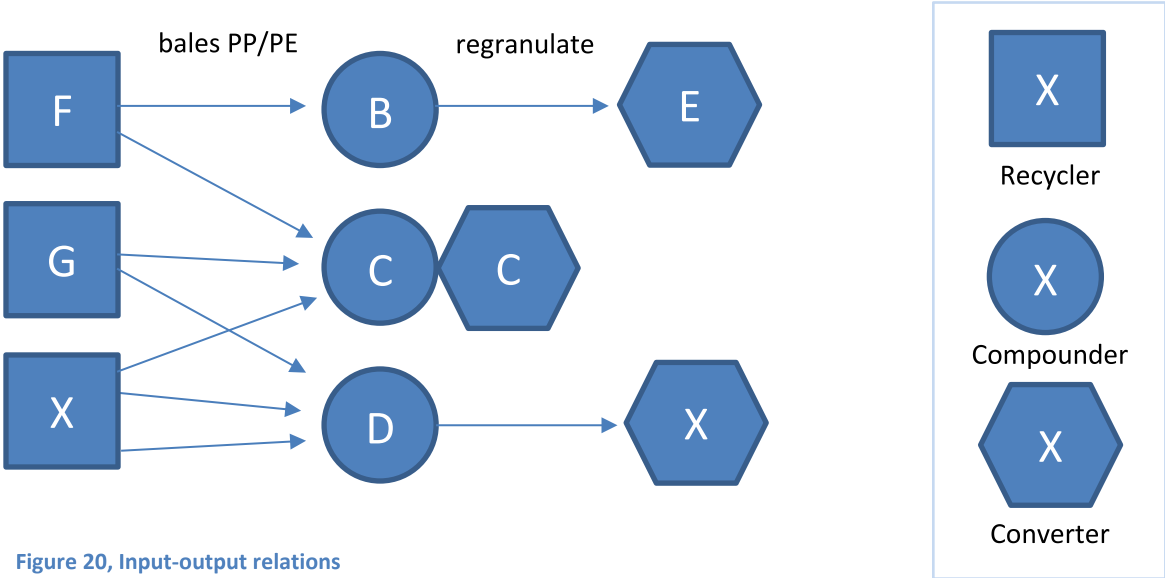

Figure 20, Input-output relations

Key suppliers for bales in the Netherlands are recycling companies F/G, who control 80% of the Dutch market (square icons in Figure 20). However, Dutch PPW bales are not the only input for the compounders (round icons in Figure 20). Rigid thick walled plastics can also be sourced at the municipalities, moreover the German market is not far away with a volume of 1405k ton per year. Converters (hexagon icons in Figure 20) purchase regranulate from the compounders based on specs from the branded companies, were company C and D currently fulfil a key supplier role. Their customers are branded companies, for example Philips, that are willing to pay an equal price compared to virgin plastic, because it will boost the durability perception of the product and/or company. Company B will probably take over the key supplier role of regranulate in the future, regarding the volume they will start to create with their new factory.

According to Eurostat the Netherlands recycled 219k ton PPW in 2012 (Eurostat, 2017), the interviewed companies say around 150k ton for 2015. Eurostat includes all PPW that is transported to Germany, the interviewed companies talked about the processed material in the Netherlands. Company F/ G are the only one in the Netherlands that produce bales from separately collected PPW, producing around 30k ton per year. There is another company in Groningen in the Netherlands that produces bales from commingled PPW, interviewee D claimed to use these bales. Company D produces 12,5k ton regranulate per year and has competition from a couple of other big producers. Company B will be a new entrant with a production capacity of 35k ton per year, which they intent to increase to 100k. This will create a big shift in the market, because they will use the input currently used by their competitors.

The composition of the input bales is different by geographical area and are influenced by seasonal fluctuation. Senior staff can combine the right batches of recycled plastics from different geographical areas and from different points in time to yield a stable output for the extruder of the compounder. They can than upgrade the stable stream with additives towards the properties requested by the branded company and or converter.

Order winning requirements

Compounders set their input requirements for recyclers and/or have to meet requirements from converters. Recyclers use the DSD-standards for their output requirements as these requirements are set by subsidies and use their own quality requirements for input, depending on their capabilities. Order winning requirements for the output of recyclers are set by compounders and are requirements that differentiate recyclers. Important to note for the following paragraphs is that the term ‘quality’ of recycled plastic is different for different actors. The quality requirements from recyclers relate to the contamination level in their input, for example the amount of sand or different unwanted plastics sorts. Compounders and converters often refer to material properties of the plastic, for example Melt Flow Rate (MFR), and its consistency throughout the batch.

Requirements for recyclers

Compounder B is going to ask their suppliers to comply with the DSD-standards for their bales, which is very common in the industry. Company F must comply with two requirement sets: the DSD-standards and the Dutch ‘Raamovereenkomst’ rules. They have one extra requirement for their input that states that they can reject a shipment if the contamination is higher than 30%. This is however impractical, as claimed by the interviewee, because it is operational impossible to control or check the quality of the input. One truck load in the past 3 years was rejected by company F. The content of the truck was burned which was easy to see and smell, probably by an internal fire in the truck. Many of the interviewed people talk about one other unofficial rule: ‘garbage in equals garbage out’. This states that if the input quality is bad than it is very hard or impossible to get a good output.

Requirements compounders - converters

Company E buys their virgin granules form SABIC, one of the big virgin material compounders. They like to buy their variety of plastics at the same supplier, as it is easier to deal with one account manager. They select their suppliers on price and quality, but mostly on the likability of the account manager. Company E received some regranulate for testing from a Dutch compounder, but they do not want to work with it as they fear an unstable cycle time for production. They highlighted the correlation between regranulate quality consistency and production costs, due to the failure rate and cycle time. This last term ‘cycle time’ is the time it takes for the plastic to be changed from granules to a product. Crystallization time is the time the plastic needs to cool down and become solid. Crystallization time is a big part of the cycle time, which can be influenced by adding nucleating agents, a type of additive which can be added by a compounder. The quality of the regranulate, having many aspects, therefore determines a part of the price for the final product. Interviewee E said that the regranulate which company B makes will probably cost about the same as virgin plastic, because the quality is also the same. But it remains uncertain, if the customers are willing to pay the same for products made from recycled material, as stated by interviewee E.

Relationship: Recycler - Compounder

This relationship is partly governed in the Netherlands by the 'Raamovereenkomst', as explained in the governance paragraph. An important part is that the packaging industry puts money in a fund to pay for recycling. For example, company F, municipalities and logistical partners receive money from Nedvang for their recycling, collection and logistical activities. The rules set out for this fund allocation dominate the interactions and actions of the recyclers. Company F, the recycler, has contracted 80% of the market, which are the separated collected plastics from municipalities. They have contracts for the duration of 3 to 8 years. The contracts cover the separated collected PPW from households. Rigid plastics that are collected in the recycling centres of the municipalities are excluded from this stream, because it is not paid for under the Dutch 'Raamovereenkomst' fund. This stream of rigid plastics could be used by compounders to lock in their own stream of plastic and bypass the recyclers.

Interviewee B explained that there are lengthy relationships were the compounder locks-in their supply of recycled plastic with a contract. This is only possible if the collector also has long term contracts with municipalities, which is becoming more common in the Netherlands. Due to the termination of involvement from Nedvang in the ownership of PPW. This is an organization which has the task to direct the collection and recycling of packaging waste in general (Nedvang, 2014a). Interviewee B explained that this relationship will probably change in the near future, because Nedvang used to pay for every ton recycled material. This resulted in recyclers trying to recycle as much as possible, meeting the minimal quality requirements. After the discontinued involvement of Nedvang the recyclers could focus more on quality, because some compounders might pay more for better input improving their output quality.

The role of the recycler is shifting from pushing tonnage to managing quality stability. The compounders role in this relationship is also quality control and establishing long term contracts. Which gives the compounder the ability to deliver a stable quality to a converter over a longer period. Interviewee D claims to have eight-year contracts in place for their supply of commingled and separately collected plastics. The contracts are with the municipalities, where companies like Midwaste, Omrin and Attero collect the waste. These companies bring the plastics to the first separation machines that produce the bales with the DSD-standards, for example company F/G. The separation installations used are in Meppen (Germany) and Rotterdam (The Netherlands), after which the plastic bales go to the factory of company D.

Interviewee F claims that the amount of plastic that is available is stable and growing. This enables them to ensure stable shipments to compounders. This is a batch process, which requires keeping stock for the compounders to keep their installation running for a longer period.

Relationship: Compounder - Converter
This relationship will be discussed based on three topics.

Development time
The relationship has different specifications between the market segments, for example short and long cycle plastics. Interviewee B said:

> *"I have seen 5-year pre-design projects for automotive parts. This is impossible for recycling companies that cannot guaranty the same product over 5 years. The degradation is important for such parts and therefore must be evaluated over time. This is not the case with short cycle packaging plastics".*

Interviewee C also acknowledged this problem with development time. They said that the quality and composition of the recycling stream of plastic changes over time, therefore the whole chain must adopt. This means that the mechanical recycling process, extruder and settings of the injection moulding machine must change. Company C therefore has this whole chain under one roof. These quality changes in the plastic make it problematic to be involved in compound development that takes multiple years.

Interviewee B claims to advise the converters on the possibilities with their compounds. They claim that the converters lack important material knowledge. This should decrease over-dimensioning the end product and improve machinery setup, resulting in overall costs reduction. So, the relationship can be characterized as relatively short and with an advisory role.

Interviewee D also talked about the problem of fluctuating quality of the recycled plastic stream. They compensate that by mixing different plastics: commingled, separate collected plastic, prime, master batches and additives. Where prime and master batches of plastic are leftover production batches of virgin producers, often the first and last parts of a batch production. Mixing by the compounder is a process that is constantly monitored and adjusted, resulting in a regranulate that has the same quality every time they make it. With the same quality they mean, having a MFR bandwidth of 6, for example if a customer asks for MFR 30 than it will be between 27 - 33. Interviewee D claims that this bandwidth enables them to enter development trajectories with Philips and Jardin. They say that the development time is very dependent on the organization. They are working with Philips for one year and there is still no production, whereas Jardin had the first prototype in two months. Although they will probably have a steady flow of materials after one year. Interviewee E said that it tested with a regranulate a couple of years back which had a MFR bandwidth of 1 or lower, which was a small batch which may not be representative. The bandwidth of the MFR was very impressive, but the crystallization time was not good enough. Interviewee E sees the first initiatives from bigger corporations to involve the use of recycled plastic. They recently started a testing project for the development of foldable crates for groceries. The end customer asked for the use of recycled plastic. However, interviewee E could not confirm that they are willing to pay more for it. It is safe to say that Interviewee E is open for usage of regranulate if their customers want it.

Margin pressure converters

Interviewee C explained an interesting observation about the market pressure on converters, which was also confirmed by interviewee D and E. The converters have lost almost all margin due to their low bargaining power. The converters are under pressure from big compounders on their supplier side, for example SABIC and Dow Chemical, and from big branding companies on their customer side, for example Philips or Unilever. Converters setup their machinery to work with the specifications of the plastic from the compounder, this process takes time and often results in a first test batch which must be discarded. Changing plastic grades therefore involves switching costs. The bargaining power of compounders increases due to these switching costs. Interviewee C explained that there was a point in time that rPET was very popular and widely used, because of its usability and price advantage over virgin PET. There was a big demand for rPET what made it more expensive than virgin PET, however this did not result in converters switching back to virgin PET. This remained for a while, because of the switching costs. Another factor in this power struggle is that there are around 12.000 converters in Europe according to interviewee C, which is too much, resulting in higher bargaining power for the branding companies who can switch to another converter. Moreover, the big compounders in the Middle East are also building their own converters. They are able to invest in new machinery and innovations with their high profits on oil and plastics. European converters do not have the money for innovations and new machinery, due to the low margins. Summarizing, the following factors diminish the margins of converters:

- Changing plastic grades results in switching costs.
- Lower bargaining power on both supplier and customer side.
- Competition from Middle East converters with more innovation power.

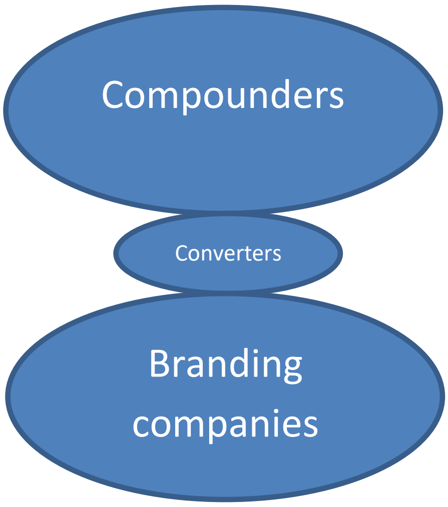

Figure 21, bargaining power

Interviewee E however, said that this is changing. They have experienced that converters were unwilling to produce their small series and therefore integrated into the value chain by buying a converter. They claim to be cost competitive with low wage countries in the east of the EU, because the machines initial investment is the same, but electricity costs are lower and higher educated personal enables them to have lower operational costs. Their unique selling points are:

- Faster reaction time on customer demand
- Electric power is cheaper
- Lower logistic costs
- Less communicational problems.

They see that more competitors are switching back from centralized production to local production. Interviewee E also claimed that switching costs for them is very limited, because they have a highly skilled workforce who knows how to setup the machines before production.

Branding companies integrate approach

Decreasing margins for the converters results in risk averse behaviour, preventing the use of recycled plastic. The relationship between compounders and converters therefore stretches further to the branding companies, who can benefit by applying regranulate as a marketing tool. They must be convinced of using recycled plastics and then oblige the converter to use it. This integrated approach, thus convincing the customer of the converter, is used by every compounder that was interviewed. Interviewee D emphasized that this integrated approach results in more revenue: *"You have to setup your own projects with the branding companies to increase the use of recycled plastic".* They have multiple projects: their first is with SSI Schäfer, regrinding and upgrading broken containers resulting in a regranulate usable for new containers. Project with Philips and Jardin are also underway, as discussed previously. This integrated approach is new according to interviewee D: *"it used to be a very closed industry with little collaboration or integrated projects"*. This was also confirmed by interviewee A.

Figure 23, Jardin garden chair (Jardin, 2015)

Figure 22, SSI Schäfer containers (Schäfer, 2015)

Interviewee D is convinced that converters could benefit from using regranulate for another reason: the price is more stable. Interviewee E as converter has acknowledged this but claims that the price difference must be bigger than €400 per ton to be profitable at the moment. They have identified two problems for the use of regranulate:

1. The end consumer or customer is not willing to pay more for products made with regranulate. This conclusion was made after an unsuccessful introduction of a plastic bucket made from regranulate.
2. The production yield is lower and cycle times are higher, making the production more expensive.

The difference must be €400 to keep the required margin, which could change if the customer is willing to pay the same or more for the recycled products. This price difference is currently only reachable when the oil, therefore virgin plastic price is high. The purchasing of virgin material is a batch process, which happens if the prices are low and the storage is emptying. This is the mechanism for company E to mitigate the fluctuating oil price.

Findings

Figure 20 draws the lines between companies in their different functions, representing their relationships. This was required for gaining insights in the element market segments and critical success factors. The CSFs from this paragraph and the USPs from the company profiles can now be grouped into order qualifying (characteristics that enable participation in these markets), and order winning (critical factors which lead firms to succeed). Were order qualifying characteristics apply to all transactions per relationship and order winning characteristics are company specific:

Relationship	*Order qualifying characteristics*
Recycler – compounder	The recyclers input and output towards the compounder needs to comply with the Dutch 'Raamovereenkomst' packaging and therefore meet the quality requirements from the DSD-standards. Furthermore, three to eight-year contracts are required for the compounder to ensure enough and stable input for their output requirements.
Compounder – converter	The interviewed compounders and converters showed a close relationship is necessary to enable the usage of regranulate and the compounder must be able to deliver a stable quality over a longer period of time. The compounders need to extend the relationship towards the customer of the converter to convince and advise on using regranulate. Actively proposing projects is necessary to increase the use of regranulate.

Company	*Order winning characteristics*
Company B	Technically distinguishes itself by using a hot washing process, which makes their regranulate quality better. They furthermore say that they have many lengthy contracts and a highly skilled workforce, which enables them to supply a stable regranulate for a longer period of time.
Company C	Makes logistical plastic pallets from bales and directly from the plastic waste stream in one factory. This enables him to have quality control over the recycling, compounding and converting functions.
Company D	Claims to have 8-year contracts to lock in a stable supply of separately collected and commingled plastic waste. They mix these streams with prime and master batches virgin plastic to compensate for seasonal fluctuating quality of the waste stream.
Company E	Integrated into the value chain by buying a local converter, which enables them to have quick response and delivery times to distributors. Their direct connection gives them an efficiency and thereby a cost advantage.
Company F/G	Are the only one making bales in the Netherlands from separately collected household waste, which gives them a monopoly position in the market.

The CSFs do not appear to be volatile, except for the order qualifying characteristic of the quality requirement within the relationship recycler – compounder. The quality is determined by Nedvang which influences if the recycler gets subsidy for the processed material. The interviewed recyclers noted that this will change. The quality will be determined by the compounder, which they expect to increase the competitiveness in the value chain among recyclers as the quality will not be fixed or limited to the predetermined set of requirements from Nedvang.

For the element producers accessing final markets the CSFs of different buyers are analysed and can be found in the CSF overview on the previous page. The previous paragraph in this chapter shows an example for a dynamic buying function: the decreasing bargaining power for the converters. This is one of the reasons that compounders extend their relationship with converters to branding companies. Strategic judgements on sources of supply were found with all interviewees. Company E has a preferred supplier based on personal preference or likability. Company B makes key suppliers' partners by letting them participate in their venture and other companies keep close relationships with key actors in the value chain through personal contact.

For the element barriers to entry and rent, three rents can be analysed from the results in this paragraph: organizational, relational and resource rents. No rents originating from a difference in organisational efficiency was found or could be detected. All interviewees had different organisation style and size, but the difference could not be related to a barrier to entry and/or rent. Relational and resource rents are connected for the value chain of the plastic recycling industry, because good relations are needed for securing resources of PPW for a longer period. Which is required for fulfilling the order qualifying characteristics of the compounder – converter relationship. Company B managed to get an investment from the holding company of company F/G. Getting this investor enabled them to secure the resources from company F/G. This gives them a source of rent and an advantage over the other actors together with a barrier to entry for new entrants. Interviewee D claims to have good relations with German companies which provides them with access to that market, securing resources and accessing buyers.

5.4. Barriers to Entry and Upgrading

Profit or rent can be secured by creating barriers to entry, which are obstacles that make it difficult to enter a market or market segment. They can be created with capabilities that are unique and difficult to copy. These capabilities can come from upgrading processes, which is innovation relative to the competition. Interviewees were therefore asked about their innovation processes and capabilities.

R&D - innovation

Compounder B has multiple R&D or innovations projects. One of these projects is an opportunity in quality control of their input bales. The current quality control is done by taking one bale from the truck and checking the content. Compounder B wants to use the data from the Near Infra-Red (NIR) system of the supplier that is responsible for the content of all the bales. Thereby giving an overview of the complete input material, instead of a sample. This data is currently not stored according to interviewee B. Interviewee A and F claimed that this is indeed possible. There is one limitation that makes this idea difficult to implement. The processing by company F is a continues process, resulting in a continues stream of plastic which ends up in a big container or bunkers. This is transformed into bales with a batch process, after mixing the bunkers. The data of the continues NIR stream can be extracted, but it is not possible to pinpoint which data applies to which bale due to the mixing process. Interviewee B has no patents, they claim not to believe in them. The other interviewees had the same standpoint, with interviewee A being the exception. His current client UMC uses the patented MDS technology to differentiate itself from their competition. The new factory layouts for Compounder B could be seen as intellectual property, which they would want to licence out as they believe the market is big enough. All the machines that are used in the recycling process are bought from specialized companies. The knowhow about the settings of each configuration of machinery seems to be the intellectual property, which cannot be patented because it is tacit knowledge and would have no commercial value as it is factory specific.

Interviewee D states during the interview that they do not do any R&D or innovation other than in the lab, producing plastic compounds for regranulate. In the lab they can influence the mechanical properties and deliver a steady product. After some questions they explain that they innovate on multiple places within the organisation. They are going to change the hours of the employees and switch to a five shift 24/7 working process to increase production. During production, the quality is measured every 30 minutes, which enables them to adjust the mixture for quality control. An unusual process is that they shred the plastic to 50mm flakes, which is big for recycling, enabling advantages during washing and drying. This requires a special dosing device for the extruder, which was developed in cooperation with an engineering company. They furthermore try to remove bottlenecks in the recycling line, for example the water treatment capacity was expanded recently. The next bottleneck is the shredder, which can be mitigated by cleaning the input before the shredder to reduce the wear and tear on the blades. It can be concluded that company D is innovative, aiming for more production and quality control. Which is contrary to what they say during the interview.

Interviewee F indicated that they now recycle 45% into mono streams of PP, PE and PET. Leaving 45% mix stream and 10% rest stream:

They thereby comply with the minimum 45% mono stream Dutch ‘Raamovereenkomst’ rule of recycling plastic packaging. However, the other 45% of mix stream, which goes into end of life products like park benches, cannot be recycled again. They indicated that it is technically possible to process 70% into mono streams, leaving 30% of rest stream for incineration.

This would be better from a durability standpoint, because 70% will remain in the plastic loop instead of 45%. However, they will only receive money from the packaging fund for the 70% of the input instead of the 90% in the current situation. This is not acceptable for the municipalities or logistical partners who also receive money. For company F this could be financially possible, because they earn more money on the 70% mono - 30% rest distribution when selling it. The mono stream sells for approximately €250, where the mix and rest streams sell for a negative value of -€100.

Interviewee F sees further improvement possibilities in the processing of their bales into granules, for example better micro filters in the extruder. This should eventually improve the regranulate which makes them usable for thin walled non-food applications, for example the laundry basket.

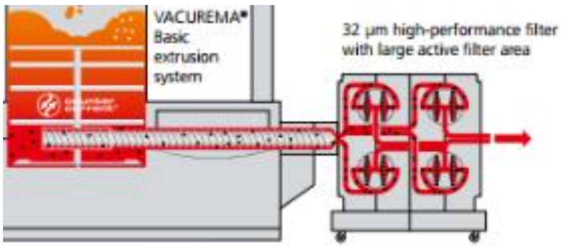

Figure 24, Erema micro filter (Erema, 2019)

Interviewee G indicated that they continuously try to optimize the process by working together with:

Packaging industry — They have meetings with big producers of consumer packaging to improve the recyclability of their products. For example, the black detergent used to come in a black bottle, which is not recyclable by the NIR systems, it now is a recyclable white bottle with black rapper.

Machine suppliers — Improving the hardware and software of the machines by providing data for the developers. This resulted in:
- The ability of the NIR machines to detect the difference between PET bottles and trays with an accuracy of 80%
- Foil stream improvements by adjusting the whirl in the wind shifter.

Which increased the overall yield of the processing installation.

Interviewee G is convinced that they will be able to shrink the mix stream to 20% - 30% in 2 years, thereby increasing the mono stream and their profit.

Interviewee F indicates that the growth of the recycling market is depended on the governance set in place by the government. They would like to see an increase in communication between the commercial companies in the industry and the government to improve the rules for the future. Interviewee F gives an easy example: caps of bottles which can be made from PP or PE, selecting one or the other has no influence on the usability of the cap. Forcing the industry to use only one grade would improve the value of the cap waste stream and simplify the PPW contents. Another complexity in the value chain is the diversity of plastic grades, there are for example hundreds of flavours PP plastic. Limiting the number of grades would improve the overall recyclability of plastic, but this is complex to achieve and could have other limitations on technological innovation, as stated by interviewee F. They nevertheless said that the government should initiate a dialog with the industry to work towards a workable solution, because the impact on the reuse could be enormous.

Compounder C has difficulties attracting higher educated personnel. They assume that the image of the industry is not 'sexy' enough. Interviewee D agrees and claims there is not a specific educational program for the knowledge of upgrading plastic materials. Which is strange, because material sciences are represented in most of the technical universities in the EU, for example Technical University of Delft has a special recycling research group. It could however be true that most of the material science graduates go to non-waste related companies.

Sources of Schumpeterian rent

Interviewee C says that making profit in the recycling business is hard:

> *"They currently collect around 160K ton in The Netherlands, most of it is exported to Germany. Competition with virgin plastic is killing, the middle east produces plastics for €400 and recycling costs €800 per ton. Bales of waste PP or PE are valued around €200 per ton. Virgin is sold for around €1000 per ton, so you have to make regranulate for less! Making profit is therefore hard"*

Interviewee C continued by stating that PP can be sold in different ways with market price indication between brackets: agglomerate (€400), regrind (€600), regranulate (€800) and virgin (€1400). These prices show the economical challenge of recycling when the recycling costs are €1000, including the purchase of raw material. They are therefore trying to decrease costs, for example on logistics by building a factory next to the collector of the PPW. Upgrading logistical processes can therefore be a source of rent according to Interviewee C.

Interviewee B sees grow potential in both rPP and rPE:

> *"The growth potential of rPP is big, because the material specifications can be adjusted more easily compared to rPE. The volume of the rPE market shows more promise, however the separation of rPP and rPE needs to improve to fully enable that market."*

Interviewee D indicates that the market can grow, if regular deliveries with constant quality can be guaranteed. This is only manageable if you handle large volumes, which improves the mixing processes. A big hurdle for this up scaling is doing big investments to process more material and securing a continuous source of material. A barrier to entry and a source of Schumpeterian rent is therefore securing a continuous high-volume material stream. Interviewee D would furthermore like the government to adjust the rules for food grade recycled plastic. For example, Great Brittan already approves rPET food grade plastic for the food industry.

Converter E sees three big limitations for further growth for the industry:

1. The food-grade limitation: a lot of their products must be food approved.
2. Density of the regranulate compared to virgin granules, this increases the cycle time and weight of the product, therefore production and logistics costs.
3. Production yield is too low, which influences the production costs.

Recycler F says that there are only two real reasons to use recycled plastic: to make it cheaper and/or for marketing purposes. They see a little shift towards the usage of recycled material for marketing purposes, which influences the price positively. The end result, regranulate, of the cooperation between company B and F will probably be in the same price range as virgin plastic. Meaning that the new regranulate must be used for marketing purposes to add value, as virgin plastic will be chosen if the price is equal.

Recycler F is constantly improving their processes. They stopped subcontracting the building of the installation to develop the knowledge within the company, to be able to keep optimizing the processes continuously. Two additions to their process could potentially increase their profit: separation of black plastics and a better solution for the separation of PET trays and bottles. Interviewee F thereby indicates that installation knowledge can be a source of Schumpeterian rent.

Findings

Supply chain innovation policies were found throughout the value chain for the element producers accessing final markets. Recycler F/G approaches packaging designers to improve recyclability of packaging and compounders are looking for collaboration projects to recycle their product directly or make new products especially designed to their regranulate specifications.

Technology rents created by an owner of a scarce technology can be analysed from the results in this paragraph for the element barriers to entry and rent. Numerous actors in the value chain claim on their website to have special technologies or machines that differentiate them from their competition. However, the interviews yielded only one patented machine from UMC, who is keeping the technology scarce to create technology rents for their business. Company D has some machinery that an engineering firm made to accommodate their factory specific characteristics (larger flake size). This could also be made by other companies and is therefore not a scarce technology.

Interviewee D claims to be more efficient with this larger flake size than others, which is a form of technology rent. The other companies purchase machinery from specialized suppliers. Their ability to buy the machines and use them is enabling them to generate rent but cannot be called technology rent, as they are accessible by all if they have the resources.

This paragraph furthermore describes multiple innovation processes for the element upgrading, which can now be characterized as chain, process, product or functional upgrading. Company E does functional upgrading as they moved their focus of activities from branding to production. They now focus on core competences as quick response and delivery times for distributors. Companies B, D and F/G pursue process upgrading, thereby innovating their internal processes to become more efficient than their competition and securing a source of rent. The following processes were found during the interviews:

- Company B is planning on using the data of their suppliers to increase the knowledge of their input, which they want to use to improve the processing of the input.
- Company D is changing the work shifts to increase the efficiency of their factory.
- Company D is constantly working on improving the production line in the factory.
- Company F works together with machinery suppliers to improve their machinery and add new capabilities.
- Company F does not outsource the construction and combining of the machinery to increase internal knowledge about their factory.
- Company G educates packaging designers on recyclability to increase the recyclability of their input, which can also be characterized as chain upgrading.

The last 4 points are dynamic capabilities which facilitate the ability to upgrade activities over time. This can provide profitability in the long run and is an indicator for Schumpeterian rent. It is therefore not a surprise that Company D and F/G are currently market leader in their link in the value chain.

Companies B and D also show signs of pursuing product upgrading, each in their own way. Company B is trying to create one basic regranulate which is stable over time. They claim to be able to do this by securing high volume input. Company D is aiming for a custom regranulate for their customer. They work together with the brand owner and designer to customize the regranulate characteristics to the design of the product and vice versa. Both companies see a potential rent source in convincing the branded company to use regranulate for marketing purposes, as they will be able to make a stable regranulate for the same price as virgin granules and consumers start to favour products made from recycled plastic. Cooperating with suppliers and customers in new product development is chain upgrading, which was therefore observed with companies B and D.

Another indicator of Schumpeterian rent are barriers to entry that can be created with capabilities that can come from upgrading processes. However, a clear barrier to entry was not found during the interviews. Company B could create a barrier of entry in the future, when they achieve to lock-in most materials available in the market.

6. Conclusion

The objective to create insight in the plastic recycling industry was achieved with the results and findings from the value chain research in chapter 5. This insight in the industry makes it possible to answer the six sub-questions, starting with the identification of the influential activity of the value chain.

1. ***What is the most influential activity in the recycled post-consumer PPW value chain?***
   The branding activity has the most influence on the value chain regarding increasing the use of recycled post-consumer PPW. Order qualifying characteristics from paragraph 5.3. Input-output relations shows that the relationship between compounder and converter extents to branding companies, for example Philips. Which is caused by the decreasing power of the converter and the necessity for the compounder to convince the branding companies to use regranulate. The decision to use regranulate is made by branding companies. They determine the characteristics of the plastic based on the product requirements. The requirements are sent to a converter, who makes the plastic products and selects a plastic grade while keeping costs to a minimum. At this point, converters can choose for regranulate to save costs or use regranulate per request from the branding company. Which included regranulate in the product requirements, for example to function as a marketing feature for the product. The activity branding in the value chain is therefore the most influential in the recycled post-consumer PWW industry. Paragraph 5.4. Barriers to Entry and Upgrading furthermore shows that the use of regranulate for marketing purposes is going to be a new source of Schumpeterian rent, as consumers are starting to prefer products made from recycled plastic. Compounders are convincing the branding companies to use regranulate for marketing purposes, as they will be able to make a stable regranulate in enough quantity for the same price as virgin granules. Establishing long term contracts for PPW sources is required for the quantities needed for high volume consumer goods. The owner of PPW sources and the recycler are therefore important actors in the value chain. Which makes the recycling activity, that has the ownership of the PPW, another influential activity next to branding.

2. ***What is the required quality of plastic waste for the production of recycled plastic?***
   Recycling plastic in the Netherlands is currently only possible with subsidy through the 'Raamovereenkomst' and its fund. Paragraph 5.3. describes that the quality requirement for receiving money from that fund is documented by the DSD-standards. This is therefore the only quality requirement currently used. However, the requirements for the relationship between compounders and converters in paragraph 5.3. shows that a stable quality is needed for using regranulate, as this impacts the production yield for the converters and therefore the rent distribution in the value chain. The yield is directly related to the stability of the MFR and crystallization time of the regranulate, thus influencing the production costs. The material properties are considered stable as the difference of these properties is minimal between different samples of the regranulate. R&D and innovation practices in paragraph 5.4. show that stable quality becomes more important when the final product becomes more complex, for example a thin walled laundry basket versus a less complex thick walled logistical pallet. Locking in material sources and knowing their composition shows to be important to achieve a stable quality. The composition of the input bales is different per geographical area and is also influenced by seasonal fluctuations, for example Christmas changes the packaging temporarily. Mixing the right batches of recycled plastics from different geographical areas and from different points in time, can yield a stable output for the extruder of the compounder.

3. ***What influence has plastic quality on the use of recycled plastic within the value chain?***
   Higher quality of recycled plastic means more stability of the regranulate, which influences the usability of the regranulate as determined in the previous sub-question. Paragraph 5.3. describes that a stable regranulate also influences the switching costs for converters, where the costs will be lower with a lower MFR bandwidth and crystallization time. A stable regranulate is therefore required by the converter to increase the use of recycled plastic. Paragraph 5.4. R&D and innovation gives a couple of methods used by the interviewees that influences the stability of their regranulate: compensation for seasonal and geographical fluctuation of the PPW input by monitoring the input and mixing different batches, adjusting the additives used for compounding based on intermediate measurements and the use of new recycling technologies. Another influence for the quality and use of recycled plastic is the relationship between compounder, converter and branding company. Paragraph 5.3. Relationship: Compounder – Converter shows that joint projects between compounders and branding companies lead to increase use of recycled plastic in new products. The interviewees furthermore indicated that a reduction in the number of grades used for making plastic packaging would influence the quality, as it simplifies the recycling process and improves the predictability of the input for the compounder.

4. ***What is the influence of governance on the use of recycled plastic?***
   Two governance related influencers were identified in paragraph 5.2. Governance: the internal DSD-standards and the external 'Raamovereenkomst' in the Netherlands. The DSD-standards are widely adapted and are incorporated in multiple relationships between value chain linkages. This makes it difficult to change the standards for improving overall quality. The Dutch 'Raamovereenkomst' has a build-in improvement scheme. The required recycling yield for compensation from the fund will increase while the compensation reduces on a yearly basis. This will stimulate the market to innovate. It is described in paragraph 5.4. R&D - innovation that the rules of this agreement may also limit innovation, because the companies will only innovate towards the current recycling yield targets. Achieving these targets is necessary to maintain profitable but are not necessarily better for the overall increase and use of recycled plastic. The actors involved in this 'Raamovereenkomst' should therefore evaluate how to change the agreement to stimulate the market into the right direction. The influence of the agreement is currently important for the profitability of recycling. Interviewees judge that this will not change drastically in the coming re-evaluation of the agreement. Governance, specifically external rules and subsidies therefore, have a very high influence on the processing and profitability of plastic recycling in the Netherlands.

5. ***What is the influence of innovation on the use of recycled plastic?***
   The introduction explained that innovation is needed as current technologies cannot extract high grades of purity for the reuse of plastic in high-end products. Paragraph 5.4 showed multiple examples of innovation policies. The interviewees gave chain, process, product or functional upgrading examples that enabled them to secure a source of rent. Interviewee D, F and G explained process upgrading policies that are dynamic capabilities, which is an indicator for Schumpeterian rent. They can currently be seen as market leader in their link in the value chain based on processing volume. The dynamic upgrading policies can be one of the reasons they have achieved this status. Continuously upgrading or innovating their processes seems to have a positive influence on their market position. This position enables them to also apply product and chain upgrading which enables the chain to recycle more plastic into new products, which would otherwise go into the mix stream. Innovation therefore increases the use of recycled plastic.

6. ***In what segment of the value chain could the case company generate Schumpeterian rent on its innovation?***
   Recyclers want to increase the output tonnage to increase their profit under the Dutch 'Raamovereenkomst' and create the ability to win contracts with municipalities. They are therefore searching for new technologies to improve their own rent. Implementation in these already existing recycling plants to upgrade the value of their waste streams could be a good market fit. Building their own recycling street without in depth knowledge and experience about the recycling process seems risky, as knowledge for this activity might be hard to come by. Focus on the unique selling points of the MDS technology and start projects to validate these selling points. One opportunity found during this value chain research was the recycling of black plastic. Currently used NIR technology cannot separate black coloured plastic, which therefore ends up in the mix waste stream. This plastic can be separated with the MDS technology and returned to the mono stream to increase their rent.

It is now possible to answer the main research question from chapter 2, with the information from the sub-questions and findings from the value chain research in chapter 5.

What is required from the value chain of the plastic recycling industry to increase the use of recycled post-consumer PPW?
The analysis of the input and output relations in paragraph 5.3 of the value chain research shows that the quantity and access to a stable quality regranulate for the converter must increase, for the plastic industry to use more recycled post-consumer PPW. A stable quality means that the regranulate must have a stable MFR and crystallization time, which is required by the converter to limit switching costs. Another incentive to use recycled plastic is created when the branding companies requests the use of regranulate for marketing purposes. This is among the interviewees initiated by active sales from the compounders to the branding companies, highlighting the current possibilities with regranulate and setting up joint design projects to support the design process.

The active sales strategy from the interviewees is an extension of the relationship between the compounders and converters to the branding companies, as described in paragraph 5.3. Joint design projects between compounder, converter and product designers result in optimization of the product to increase the benefits of working with recycled plastic. This also facilitates the transition to regranulate for the converter, since the product is easier to make with the custom created regranulate from the compounder. The compounder makes the regranulate specifications MFR and crystallisation time specifically for the product to optimize the cycle time. Joint projects between compounders and brand companies lead to increase sales of regranulate. This has a positive influence on the relationship between the compounder and the recycler, and it makes the converter les hesitant to use regranulate from that involved compounder.

The quantity and access to a stable quality regranulate for the converter is also dependent on the input of the recycled post-consumer PPW at the recycler and compounder. Paragraph 5.4. R&D – innovations shows that they try to maximize their recycling output by the rules set out by the Dutch 'Raamovereenkomst' to increase their rent. These upgrading processes result in new technologies and better recycling results. However, the relationship analysis of the compounder in Paragraph 5.3. shows that they request higher volume mono streams to increase the use of recycled plastic, but the recyclers are upgrading towards the Dutch 'Raamovereenkomst', including a mix stream. A change in the Dutch 'Raamovereenkomst' and related output from recyclers is therefore required to allow for more innovation and increase the volume of the mono streams, which should increase the quantity regranulate that is available for converters. Paragraph 5.4. furthermore showed that the interviewees are actively looking for new sources of rent with upgrading policies. Some had dynamic capabilities that could result in new innovations that would give them temporary access to Schumpeterian rent and give the market new technology to increase the use of recycled post-consumer plastic packaging waste.

Paragraph 1.3. described that elements of recent value chain research tools, that are made after the globalization around 1990s, might not be applicable on the non-globalized plastic recycling industry. The executed value chain research showed that the participants in the interviews were hesitant to share quantitative data about production characteristics, efficiency and/or volume. Paragraph 5.2. company profiles shows an example where two employees from the same company give different production volume. This example shows that the data might not always be reliable enough to benchmark against other actors and triangulation was important to apply for this value chain research in this industry. The Kaplinsky and Morris handbook highlights that benchmarking should be applied, while the reliability could be questionable in non-transparent markets. It is therefore recommended to apply triangulation to the data retrieved from the interviews and assess if benchmarking would give reliable results if the value chain shows similar characteristics as the plastic recycling industry.

7. Discussion

7.1. Discussion

The Dutch 'Raamovereenkomst' determines how recyclers process the PPW, as compensation is rewarded to specified output. A discussion was started about the current and future developments in the agreement with Nedvang, the governmental organisation that governs it, at their office in Rotterdam. Nedvang explained that they are going to evaluate and improve it in 2017. The improvements that will be discussed below are ideas that originated from the interviews for the value chain research and the discussion at Nedvang. These improvements or alterations to the agreement are important for Dutch entrepreneurs in the recycling industry, because it has a direct impact on their profitability in the future.

Interviewee F explained that they are technically able to process the plastic in 70% mono streams, where they currently process the plastic in 45% mono streams, 45% mix stream and 10% goes to the incinerator. As explained and elaborated on in paragraph 5.4. The recyclers do this to increase their rent, because Nedvang pays them for both the mono and the mix stream, which is 90%. Where only 45%, the mono stream, can be used to produce regranulate. If the Dutch 'Raamovereenkomst' would not cover the mix stream, then recyclers would increase their mono streams. This would lead to a higher volume reusable regranulate. However, the mix stream is currently used for park benches and other end of life plastic products. Removing the subsidy would increase in price of this product, which incentivise them to find another material. This would probably be a low grade virgin plastic, thereby decreasing the reuse of recycled plastic as a whole. The removal of the mix stream from the 'Raamovereenkomst' and the compensation therefore has positive and negative consequences. Further research is needed regarding the compensation of the mix stream under the 'Raamovereenkomst'.

Another possible improvement that more companies talked about is changing or creating a new DSD-standard. The current standard is created by a German commercial company. It is used as a guideline for the contents of shipments. However, Interviewee F, a big recycler, explained that it is logistically impossible to check the contents of all shipments for contaminations. New standards for the quality of material input for the recyclers do not seem to have any impact. Changing the standards to a form which can be maintained by the recyclers would add value. How this should look like remains unclear, further research is required to see if anything can be improved regarding the DSD-standards.

7.2. Recommendations UMC

For UMC the molecular difference between PP and PE shows to be interesting in the value chain of recycled plastic. It turns out that the specifications of rPE cannot be upgraded as easily as those of rPP. It is therefore of more importance to separate different sorts of PE before compounding it into rPE granules. The MDS technology of UMC can provide this benefit to the compounders. This could be an interesting business case for UMC to investigate, as the PE market is bigger than the PP market. A suggestion for a research direction for this investigation would be to see if the compounders are willing to pay more for better separated PE for the production or usage of rPE. Although this question could be difficult to answer, because the price is always negotiated and barely shared among actors.

The second thing that is noticeable, is that compounders want to sell regranulate different than they currently do. Compounders want to sell the same way as in the virgin industry, pre-specified regranulate, that is one grade that stays stable and available for a longer period. Currently, compounders make customized regranulate for the projects they started together with customers. This can be explained by the lack of knowledge by converters to use regranulate and/or the incentive to switch to regranulate. The compounders are therefore forced to use a project based sales model, looking for applications and convincing all the involved actors to use regranulate. This leads to a slow growth in sales, which seems inevitable, but should be anticipated upon.

UMC should create a maximum incentive for converters to adopt their UMC regranulate, if they plan on making their own regranulate. Making regranulate with specifications that has higher MFR and lower crystallization time than currently used virgin granulate, would be the ultimate solution. This will provide an incentive for the converter and help him with the implementation. Making regranulate better than virgin granulate sounds too good to be true, but is not impossible (QCP, 2015). The solution could lie in the equilibrium between the number of nucleating agents and other additives, thereby focusing on cycle time for the plastic and design.

A recycler said that they were trying to develop technology for the separation of black plastics. The MDS is colour independent compared to its technical rival the NIR machine. This could be a good niche segment of the plastic recycling market to enter.

7.3. How to repeat value chain research

The value chain research method from Kaplinsky & Morris showed to be a structured guide. The health warning on the inside cover of the book is a strong recommendation not to read everything before starting a value chain research. They refer in this warning to comprehensively covering all aspects dealt with in their handbook:

"Indeed to try and do so in this form would be methodologically overwhelming, and would certainly bore any reader of such an analysis to tears" (Kaplinsky & Morris, 2000)

This thesis provides a selection in chapter 4, for entrepreneurial initiatives within the recycling domain that would like to investigate their market segment, as advised above. An entrepreneur with a new initiative in a different recycling market segment should start by going through the elements from chapter 4.2, evaluate what is applicable for their case. Some prior knowledge about your market segment is required to select the elements. This can be done with Gereffi characterization tool, as described and executed in chapter 4.1.

Kaplinsky & Morris describe in their handbook on page 52 that the theory describes a clear focus, however the real world can be more complex (Figure 25). The first two interviews during this value chain research resulted in a structured outlook on the map. Which might be expected with other value chain researches. Furthermore, a precise research question is advisable for keeping the research manageable and focussed. Start, as advised by Kaplinsky and Morris, with an initial map of the value chain. This can be changed or simplified during the research. The next step is to research the governance, which may not be left out in the recycling industry. Select the top industry leaders and start to extract your data. Try to directly write down your findings and iterate on your interview questions to validate earlier findings. Keep in mind that a personal face-to-face meeting is probably going to yield more information.

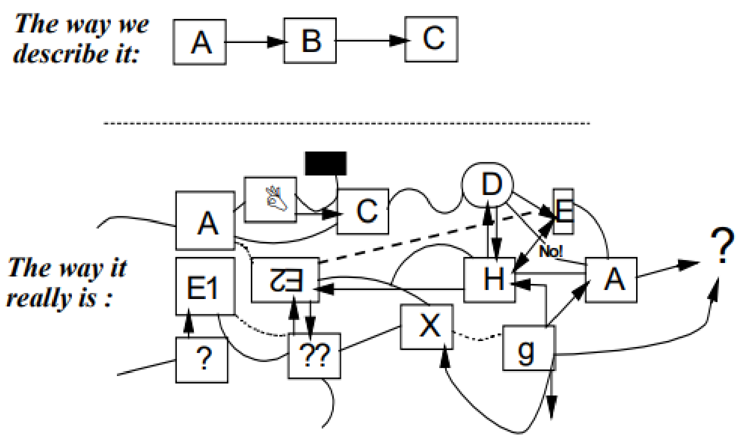

Figure 25, Value chain mapping: Theory and reality (Kaplinsky & Morris, 2000)

7.4. Limitations

The ambition at the beginning of the thesis was to research other countries within the EU, next to the home market of the case company: The Netherlands. Thereby researching 64% of the total EU market. However, this turned out to be impossible for two reasons:

1. Companies in other countries did not want to cooperate by doing an interview. Especially German companies did not respond well. It is unknown why the response rate was as low as indicated in chapter 5.2. According to UMC the number of inquiries is overwhelming, sometimes one research inquiry a day. UMC thinks that this is caused by recycling plastic being a hot topic. This could explain the reluctance to respond to the interview inquiry for this research.
2. One of the two responses from Germany said that they did not speak English. It could be that the language barrier imposed a problem for German and maybe French companies to undertake a questionnaire through phone or Skype. The response rate in England was better, although the two companies who agreed to do the interview ended up postponing indefinitely.

Another limiting factor for value chain research in the recycling domain is governance. Where external governance is different per country and internal rules can partly be different per country and therefore limits comparability of the value chain characteristics. Moreover, unofficial rules and governance enforced by visible or invisible actors internal to the value chains in other EU countries might be impossible to research, thereby further limiting the usability of the results of such a study.

It can be argued that the number of interviews is the minimum required to be able to answer the research question. Although, the amount of new information decreased after the first couple of interviews. Moreover, for most of the topics the information was overlapping which was required to apply the triangulation principle. Getting enough participants proved to be difficult, which should be anticipated with further research in this field.

8. Epilogue

The kick-off of this master thesis was in November 2014. Normally a master thesis should be written within six months, however this thesis found its end in August 2019. The question is therefore if this research and its conclusions are still relevant? This chapter will describe on three topics what did or did not change during these five years to answer that question.

European statistics presented by PlasticsEurope

PlasticsEurope is an association of plastic manufacturers that publishes an analysis of European plastics production, demand and waste data. These publications filled with Eurostat data and infographics have been used in this thesis (PlasticsEurope, 2013, 2015). They recently published a new version with 2018 in the title, however there is not always new statistics in the published work. In some of the graphs in this 2018 version data of 2013 and 2015 are missing (PlasticsEurope, 2018). Many of the statistics did not change enough to have any effect on the thesis. For example: European plastic converter demand by polymer types in 2017 for PE and PP types are 49.1% of the total demand and in 2013 this was 48.5%. Another not sizable change but worth mentioning is that 2016 was the first year wherein more plastic was recycled than landfilled, Figure 26. Whereas in Figure 5, Treatment of post-consumer plastic waste in 2012 (PlasticsEurope, 2015) that was 26% recycled and 38% landfilled. This change was expected as the EU has set an ambitious goal of zero plastics to landfill before 2020.

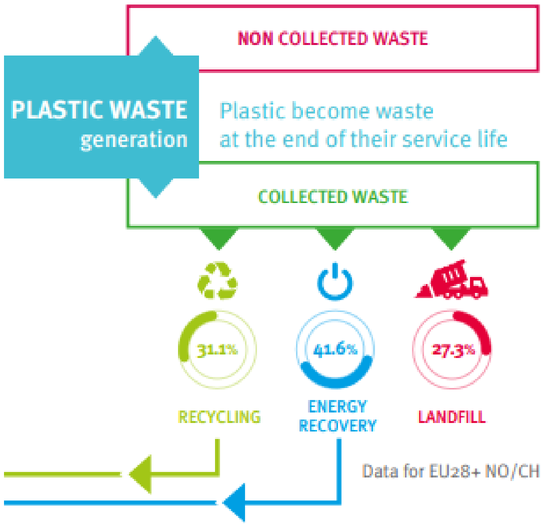

Figure 26, Treatment of post-consumer plastic waste in 2016 (PlasticsEurope, 2018)

Plastic Pact NL

On February 21th 2019 the Dutch Ministry of Infrastructure and Water Management signed the new 'Raamovereenkomst' called Plastic Pact NL with plastic producing companies, plastic using companies and some social organizations and knowledge institutions (Ministerie van Infrastructuur en Waterstaat, Plastics Toepassende Bedrijven, Plastics Producerende Bedrijven, & Overige Partijen, 2019). This pact is for the plastic industry only instead of the whole packaging industry and is for the period 2019-2025. It is furthermore different from the 'Raamovereenkomst' as there is no legal obligation to execute the goals and ambitions. Article 18.1. from the Plastic Pact NL describes this in Dutch: *"Partijen komen overeen dat de nakoming van de afspraken in het Plastic Pact niet in rechte afdwingbaar is"* (p. 17). The 'Raamovereenkomst' had the obligation to fill a fund that enabled subsidized recycling. This obligation was added to the Dutch law 'Besluit beheer verpakkingen' that came in effect from 2016 onwards (Staatssecretaris van Infrastructuur en Milieu, 2014).

In paragraph 7.1 Discussion it was mentioned that the new 'Raamovereenkomst' should focus more on mono streams, this is mentioned as an ambition in the Plastic Pact NL, however not supported with obligations or other incentives. Nedvang, the governmental institution that manages the waste fund, has published a regulation in 2018 that gives plastic packaging producers a discount based on recyclability of their packaging from 2019 onwards (Afvalfonds, 2018). It is called in Dutch: 'Regeling Tariefdifferentiatie Kunststof'. The discount is calculated over their obligated contribution to the funds based on newly produced packaging by weight. The goal of this incentive is to improve the recyclability of the plastic packaging waste and it will therefore increase the mono streams at the recyclers.

Urban Mining Corp

In 2014 and 2015 Urban Mining Corp was engineering a factory size installation that could enable them to produce their own plastic. Their website in this July 2019 describes that they are selling HDPE, PP, PS and PET flakes with high purity and have HDPE, PP and PET regranulate with high consistency available from Q3 2019 onwards (Urban Mining Corp, 2019). They have also published on the website that they found a joint venture called Plastic Recycling Amsterdam which is building their first plant, see figure 27 below.

Figure 27, Plastic Recycling Amsterdam plant with the MDS machine (Urban Mining Corp, 2019)

Is this research still relevant?

The new information above does not change the answer of the research question that the quantity and access to a stable quality regranulate for the converter must increase. It shows that the Plastic Pact NL does not have a direct impact and it seems that the Dutch 'Regeling Tariefdifferentiatie Kunststof' and the plant of Plastic Recycling Amsterdam will increase the quality of regranulate, as defined in the conclusion.

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B. Table of figures

B.1. Figures

B.2. Tables

C. Appendices

Appendix A - MDS technology

The MDS technology works by letting particles with different densities float in a laminar stream of magnetic fluid, so called ferrofluid. Laminar flow is a flow in parallel layers with no disruption between the layers. This fluid is influenced by a magnet which creates different densities in vertical direction. Heavier particles will now float closer to the magnet than lighter particles, this separates the different plastics. The particles are pushed towards the splitters at the end of the stream, see figure 2 for the graphical representation.

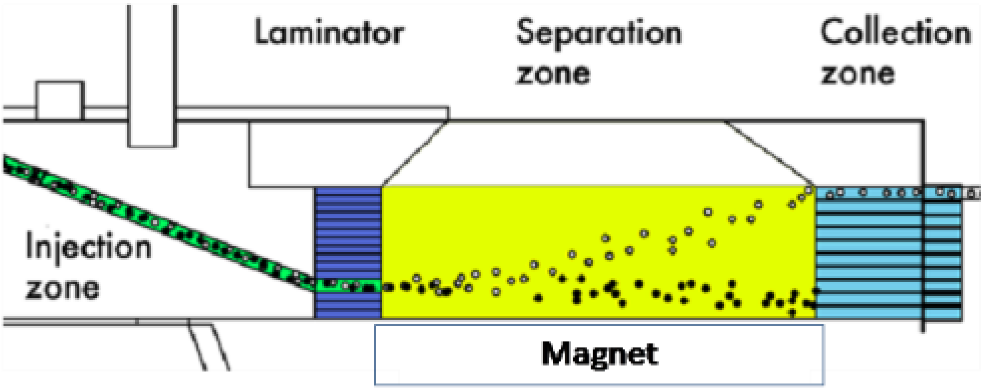


Figure 28, MDS (Urban Mining Corp, 2019)

This method enables the separation of so called polyethylene (PE) and polypropylene (PP), leaving a positive value waste stream (Hu, 2014). This means that the output stream can be sold for a higher value than the MDS machine operating costs. Near Infra-Red (NIR) sensing technology that is currently used often leaves a negative output stream, because of the impurity of the output material. This is all strongly dependent on the input material. This dependency will decrease with the MDS technology, because it is able to separate more complex mixtures of waste.

Appendix B - Plastic 101

What is plastic?

The word “plastic” is derived from the Greek “πλαστικός” (plastikos), meaning capable of being shaped or moulded. It refers to the material property of malleability or plasticity during manufacture, which allows it to be cast, pressed, or extruded into a variety of shapes (PlasticsEurope, 2019). Plastic is the general term for a wide range of synthetic or semi-synthetic materials used in a growing range of applications. Due to their relatively low cost, ease of manufacture, versatility, and imperviousness to water, plastics are used in an enormous and expanding range of products.

How it’s made

The raw materials for plastic production are natural organic products such as cellulose, coal, natural gas, salt and crude oil. New plastics made of these raw materials are called virgin plastics. Crude oil is the most commonly used raw material for plastics (PlasticsEurope, 2019). This process will now be explained using Figure 29, displayed below. The bold words in the text refer to the different illustrated steps in the figure.

The naphtha fraction from the **distillation** of crude oil is used to produce plastics. The naphtha mixture contains hydrocarbon chains (molecule strings of hydrogen and carbon molecules), which are heated to split the chains. This process is referred to as **cracking** and yields smaller hydrocarbon molecules such as ethylene, propylene and butylene for the production of different types of plastics. A large number of these hydrocarbon molecules are linked together to form a **polymer chain**. Polymers are large molecules composed of many repeatable subunits. Chaining these together yields the polymer chain. This process is called polymerization. So plastics contain polymer chain structures which determine many of their physical specifications. Additives can be added to influence these specifications, for example fillers, fire retardants, plasticizers and colorants. The final step is to process the mixture into so called granules, also called pellets, which are small particles that form the **raw material** for making plastic products (PlasticsEurope, 2019). Different technologies can be used for moulding the granules into plastic products, for example injection moulding or extrusion. The moulding technologies require different material specifications, but have no influence on the output of recycling processes. They are therefore out of the scope of this thesis and will not be evaluated further.

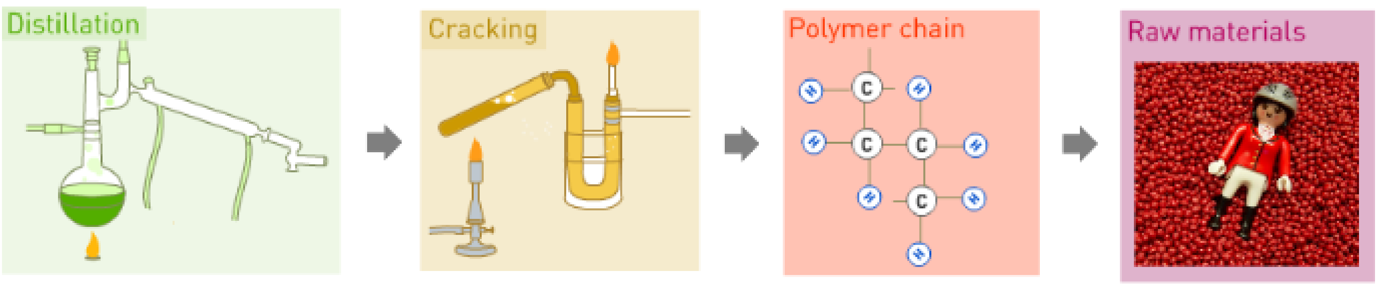


Figure 29, How plastic is made (PlasticsEurope, 2019)

Types of plastics

There are two basic categories of plastic materials:

- Thermoplastics, can be reheated and reused.
- Thermosetting or thermoset plastics, undergo chemical change when heated and are therefore difficult to recycle.

These two categories can be broken down into different sorts of plastics, also called resins or grades:

Thermoplastics:		Thermosets:	
PET	Polyethylene terephthalate	EP	Epoxide
PE	Polyethylene	PF	Phenol-formaldehyde
PVC	Polyvinyl chloride	PUR	Polyurethane
PP	Polypropylene	PTFE	Polytetrafluoroethylene
PS	Polystyrene	UP	Unsaturated polyester resins
ABS	Acrylonitrile butadiene styrene		

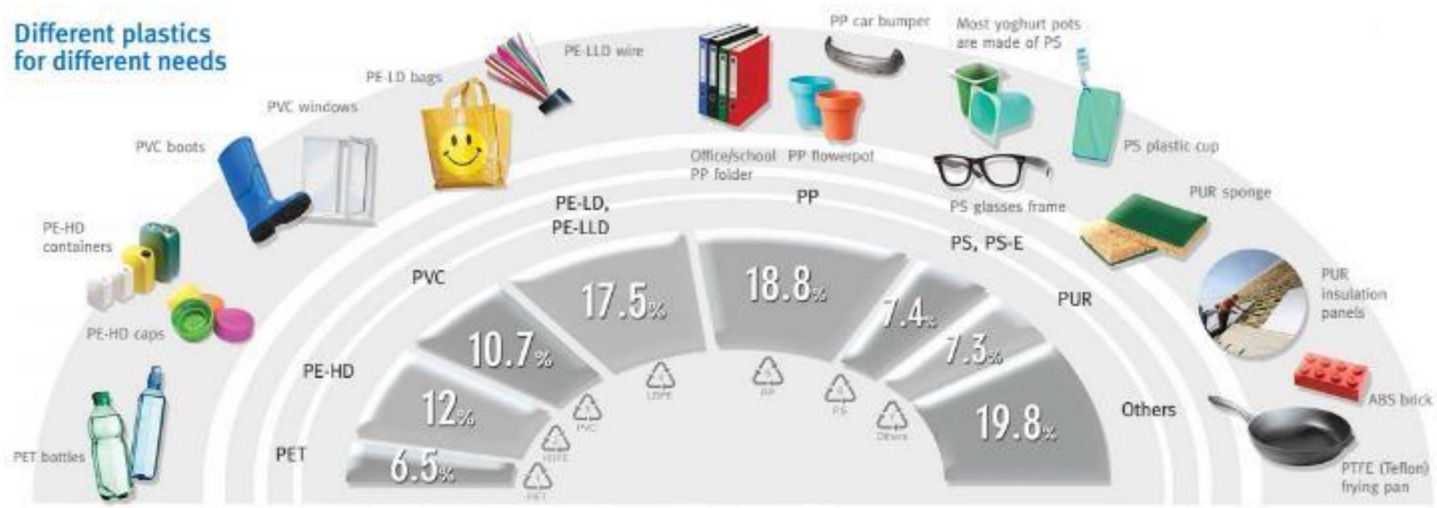


Figure 30, Different plastics resins for different needs (PlasticsEurope, 2013)

Figure 30 shows a diagram with the most used plastics and some application examples. The percentages represent their need of the total plastics demand in the EU. The diagram also shows some subcategories: PE-HD, PE-LD, PE-LLD and PS-E. PE-HD or HDPE, High-density polyethylene is such a subcategory commonly used for the hard-plastic caps on bottles. Multiple plastic categories have subcategories, which create hundreds of plastic grades with their own character. These sorts can be further specialized for its application by adding additives to the mixture. Some examples are:

- Fillers, reduce the plastic fraction to reduce material costs.
- Fire retardants, increase the fire resistance.
- Plasticizers, increases the flexibility.
- Colorants, add colour.

Recycling plastic waste

Plastic recycling is the process of recovering waste plastics and reprocessing the material into useful products. There are two plastic waste streams (OECD Environment Directorate, 2010):

- Post-industrial or pre-consumer plastic waste, generated during converting or manufacturing processes. (22% of total waste stream in 2007)
- Post-consumer plastic waste, generated by end-of-life products. (78% of total waste stream in 2007)

99% of the post-industrial waste stream was recovered, thereof 80% was recycled. This is possible because the composition of the waste stream is known and not mixed as in post-consumer waste (OECD Environment Directorate, 2010). The EU recovered 61.9% of the post-consumer plastics waste stream in 2012 (PlasticsEurope, 2013). The EU further characterizes recovery in two categories:

- Energy recovery, the use of waste as a fuel to generate energy.
- Recycling, the process of reprocessing into products or raw materials.

The term 'plastic recycling' can be broken down in 4 different terminologies (Hopewell et al., 2009), this to further understand the terminology. The different recycling terminologies have their own end product and therefore their own place in the value chain, which will be explained in the next chapter.

ASTM D7209 – 06 Standard definitions	Equivalent ISO 15270 standard definitions	Other equivalent terms
Primary recycling	Mechanical recycling	Closed-loop recycling
Secondary recycling	Mechanical recycling	Downgrading
Tertiary recycling	Chemical recycling	Feedstock recycling
Quaternary recycling	Energy recovery	Valorisation

Reprocessing plastic waste by melting, shredding or granulation is called mechanical recycling (European Commission DG ENV, 2011). Shredding plastics results in flakes which can be separated, melted and granulated. The resulting granules from these processes are referred to as regranulate and indicated with a non-capital letter 'r' before the plastic name: rHDPE. With chemical or feedstock recycling the plastic polymers are chemically broken down into their constituent monomers which can be reused in refineries. Regranulate is often used for other products than the previous application, with lower or other quality requirements, these recycle processes are being referred to as downcycling. Closed loop recycling is when the regranulate is moulded back into the same product. Because there is always some contamination of the mixture this is rarely the case (Hopewell et al., 2009). The Society of the Plastics Industry (SPI) developed resin identification codes in 1988 to allow efficient separation of different polymer types for recycling.

Figure 31, Resin identification codes (NatureWorks, 2008)

Plastic value chain and life cycle

To provide more insight in the plastic value chain a short version of the total value chain is given in Figure 32.

Raw material suppliers supply oil, other chemical feedstock and additives. **Producers** make the plastic resins and **compounders** prepare plastic formulations by mixing resins and additives into granules. Plastic **converters** form the granules into semi-finished and finished products that are used by **product distributers or users**, for example OEM manufacturers, who put the plastic products onto the market. Finally, **end-of-life businesses** thus waste management companies, recyclers and energy-from-waste operators recover the plastics and put them back into the value chain as regranulate. With chemical recycling the plastics go back to the producers, with mechanical recycling back to the compounders and converters. Only 61.9% of the post-consumer plastic waste stream is recovered and 38.1% is disposed. Figure 33 provides an overview of the life cycle of plastics within the EU. It shows that 57 ton plastics are produced by the compounders. 45.9 ton ends up at the converters and 25.2 ton thereof ends as post-consumer plastic waste.

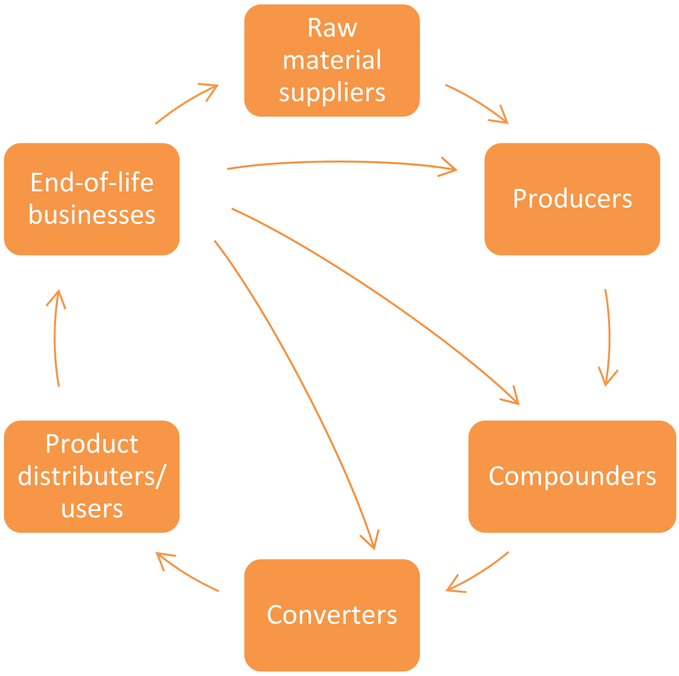


Figure 32, Plastic value chain

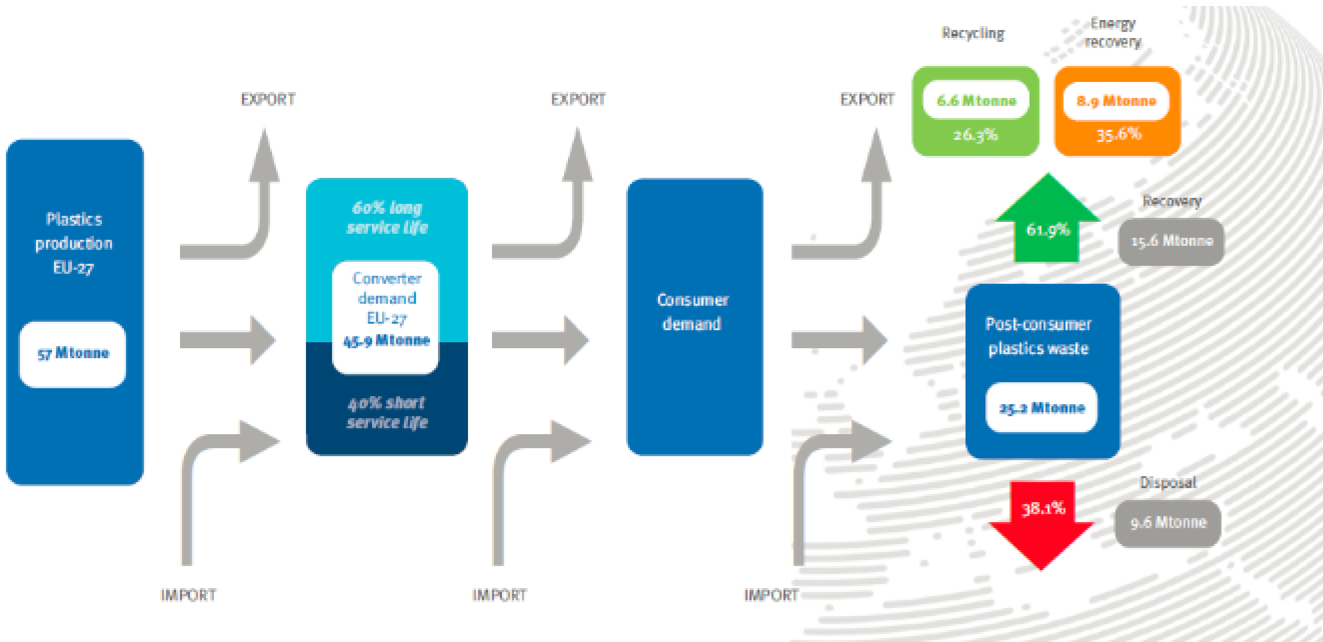


Figure 33, Life cycle of plastics in 2012 (EU-27+N/CH) (PlasticsEurope, 2013)

Appendix C - Required data

This appendix summarizes the required data to create a clear goal for the value chain research interview questions. The data that is required for answering the research question is:

An initial visual map of the value chain with:

- Connections between actors.
- List of main activities.
- Final market segmentation, rough estimate of number of enterprises involved.
- List participants.
- Relationship connections.
- Market segment selection.

A "tree" of input-output relations with key variables:

- Physical flow ton per year (t/y), quality of flow, total and regranulate quantity, chain share.
- Key suppliers and customers.
- Geographical location of suppliers and customers.
- Requirements for suppliers, order-qualifying and order-winning requirements.
- Requirements for customers, order-qualifying and order-winning requirements.
- Change in quantity and/or quality with buyers and sellers.
- Indication of long-term and high-trust relationships.

Data on Governance, Barriers to Entry and Upgrading:

- Key technology control, licenses or patents, giving distinctive competence.
- Investments in R&D.
- Holder of market identity, brand name.
- Rules set by key actors in the chain.
- Quality, environmental standards and on-time-delivery rules.
- Sources of rent, for example: technology, organizational, marketing, relational and resource rents.
- Unique selling points (how they add value), uniqueness and difficult to copy.
- Internal processes that facilitate learning.
- Product upgrading processes, internal and in cooperation with supplier or customer.
- Cooperation with suppliers or customers to meet governance rules.
- Consequences of not meeting those rules.
- Upgrading enablers and blockers: CEO committed to upgrading, R&D management, processes for continuous improvements, resource allocation, adequate skills.

Appendix D - Interview questions

Introduction questions

Can you introduce the company?

(Production process, departments, product streams)

Which plastic application has the biggest sales? High or low MFR?

What is your production capacity? How much recycled material do or can you use in the process?

In which application area do you see the biggest grow potential?

Do you see a shift in using more recycled material?

What is, according to you, the biggest hurdle for using more recycled plastic?

Input-output relationship questions

How do you select your suppliers? Tenders?

Are there minimum quality input requirements for achieving your own product?

Could you describe your relationships with suppliers? (Time, lock-in, innovation)

Do you experience problems with the promised quality of the input material?

What quality requirements do your customers require from you?

Is it more common to mix recycled and virgin plastics or to use recycled material directly?

Do you think that your customers could use more recycled plastics?

What is needed to achieve this?

Could you describe your relationships with customers? (Time, lock-in, innovation)

Innovation

What are your core competences? USP?

Are all your products custom made? Do you supply a constant quality / brand? How do you maintain this quality?

Do you own patents or have access to special technologies?

Do you have relationships or partnerships that enable you to be better than competitors?

Could you describe your activities around product innovation?

Could you describe a recent innovation?

Appendix E - Dutch one-pager

Omzet verhogen van de plastic re-granulaten waarde keten

Er zijn tegenwoordig steeds betere technieken beschikbaar om plastics te recyclen. Hierdoor zal de plastic output van de recyclers in kwaliteit toenemen. Voor mijn afstudeerthesis zoek ik voor de Technische Universiteit Delft uit hoe de waarde keten van de re-granulaten er uit ziet. Hiermee als doel de gevraagde eigenschappen van re-granulaat verwerkers beter in kaart te brengen zodat er meer gerecycled plastic gebruikt kan worden. Wat uiteindelijk moet leiden tot een verhoogde omzet in de industrie. Het is absoluut niet de bedoeling de continuïteit van de deelnemende bedrijven in gevaar te brengen, daarom proberen we geen bedrijfsgevoelige informatie te vragen. Mocht u tijdens het interview toch het idee hebben dat dit het geval is, weiger dan gerust te antwoorden!

Het interview:

Introductie:

Kunt u een korte introductie geven over wat u bedrijf doet?
Hoeveel ton plastic kunt u per jaar verwerken?
Welke product categorie is voor u het belangrijkste?
Welke product categorie heeft volgens u de meeste groei potentie?
Welke materiaal eigenschap is belangrijk bij welke categorie?
Ziet u in de toekomst meer bedrijven gerecycled plastic gebruiken?

Input-output relaties:

Hoe selecteert u leveranciers? Gebruikt u tenders?
Gebeurd het vaak dat u wisselt van leverancier? Wat is daar voor nodig?
Is er een minimale input kwaliteit die u nodig heeft om uw re-granulaten te maken?
Gebruikt u contracten om leveranciers vast te leggen voor langere periode?
Komt u wel eens problemen tegen met de input? Wat voor problemen?
Zou u nog meer gerecycled plastic willen verwerken?

Welke en wat voor eisen stelt uw klant aan uw product?
Denk u dat uw klanten meer re-granulaten zouden moeten gebruiken?
Heeft u vaak wisselende klanten of blijven de klanten vaak bij de zelfde leverancier?
Worden leveringscontracten vaak getekend voor meerdere jaren?

Innovatie:

Wat onderscheid u van de markt?
What are your core competences? What is your USP?
Do you have a brand name for your product? why?
What effect does this brand name have on the market?
Do you hold key technology and/or have patents/licenses to key technology?
Do you have key partnerships which enable you to do something which competitors cannot?
What activities do you have around product innovation?
Do you invest in R&D? In what, how? Not how much.
Do you have internal processes that facilitate learning?
Do you work together with your suppliers or customers to innovate your products?
What is the latest innovation or change that your company implemented into the processes?

Appendix F - Database overview

Find below a picture of all the companies indexed for the Netherlands. Please contact Urban Mining Corp in reverence to this thesis for the original data file, which also contains Germany, Great Britain, Italy, France, Belgium and Austria. Of which Belgium and Austria were not in scope but companies showed up in the sources lists.

	A	B	C	D	E	F	G	H
1	Name:	Activities:	Plastics:	Waste:	Size (t/y):	Location:	Country:	Link:
2	4Pet Recycling	sorting, grinding, washing, gran	rPET	consumer	25000	Westervoortsedijk 73, 6827 AV, Arnhem	Netherlands	http://www.4petrecycling.c
3	A.M.A recycling bv.	sorting, grinding, de-dusting, w	PP, PS, ABS	yes		Kaperstoden 9, 7547 TJ Enschede	Netherladns	http://www.amarecycling.co
4	AKG Hartiproducts	converter	Plastic	no		Kalkwijk 5, 7681 DV, Vroomshoop	Netherlands	http://www.akg.nl/Hartiprod
5	AKG Mouldings	converter	Plastic	no		Kalkwijk 5, 7681 DV, Vroomshoop	Netherlands	http://www.akg.nl/Mouldings
6	AKG Polymers	sorting, grinding, washing, gran	PP	yes	30000	Kalkwijk 5, 7681 DV, Vroomshoop	Netherlands	http://www.akgpolymers.com
7	Attero BV.	collecting,sorting	Plastics	yes		Vamweg 7, 9418 TM, Wijster	Netherlands	http://www.attero.nl/
8	AVK plastics	trading, converter	PE	yes		Gaaikemastraat 62 8561 AN Balk	Netherlands	http://www.avkplastics.com
9	B.V. v/h Fa. H. de Vries	collecting	Plastics	yes		Vlierdenseddijk 6, 5705 CK, Helmond	Netherlands	http://www.devriespapier.nl
10	Barnet	recycling, trading, compoundin	plastics	yes		Hulststraat 2-4 6911 KX Pannerden	Netherlands	http://www.barnet-europe.c
11	Bordal Rubber & Plastics BV	converter	HDPE, LDPE	yes		Bedrijvenpark Twente 193, 7602 KG Alr	Netherlands	http://www.bordal.com/
12	BessTrade	trading	plastics	yes		Edisonweg 7, 8071 RC Nunspeet	Netherlands	http://www.besstrade.eu/
13	Beutech	converter	Plastics	no		Oevers 11, 8331 VC Steenwijk	Netherlands	http://www.beutech.nl/
14	Broeckx Plastic Recycling	collecting, grinding, washing, tr	Plastic	yes		Notelstraat 47, 5085 ET, Esbeek	Netherlands	http://www.broeckx.nl/
15	Broeckx Plastic Recycling BV	collecting,recycling,					Netherlands	http://www.broeckx.nl/Nede
16	Carada Polymer Recovery	granulation	PE	yes	15000	Industrieweg 101a, 7202 CA Zutphen	Netherlands	http://www.plasticrecycling.
17	CeDo Folien und Haushaltspro	collecting, warehousing	Plastic	yes	MI 305 turnover	Hennef-Weiswiler-Allee 18, D-41179 M	Germany	http://www.cedo.com/
18	CeDo Limited	collecting, warehousing, conve	Plastic	yes, no	MI 305 turnover	Halesfield 11, Telford, Shropshire, TF7 4	United Kingd	http://www.cedo.com/
19	CeDo Recycling B.V.	sorting, grinding, washing, gran	Plastic	consumer	MI 305 turnover	De Asselen Kuil 15, 6161 RD Geleen	Netherlands	http://www.cedo.com/
20	CeDo S.A.S.	collecting, warehousing	Plastic	yes	MI 305 turnover	4 rue Émile Baudot, 91120 Palaiseau	France	http://www.cedo.com/
21	CeDo Sp z o.o.	converter	Plastic	yes, no	MI 305 turnover	Ul Nowowiejska 32, 55-080 Katy Wrocla	Poland	http://www.cedo.com/
22	Daly Plastics	collecting,sorting, grinding, wa	Plastic	yes		Industrieweg 101a, 7202 CA Zutphen	Netherlands	http://www.plasticrecycling.
23	De Pauw Recycling	collecting, trading	Plastics	yes	70000	Jadestraat 15, 7554 TZ Hengelo	Netherlands	http://www.depauwrecyclin
24	Drupet	collecting,sorting, grinding, co	APET	industrial		Industrieweg 10e, 6651 KR, Druten	Netherlands	http://www.drupet.com/
25	DSM Engineering Plastics	compounding, trading	Plastics			Urmonderbaan 22, 6167 RD Geleen	Netherlands	http://www.dsm.com/corpor
26	Dusseldorp B.V.	collecting	Plastics	yes		Dieselstraat 7, 7131 PC, Lichtenvoorde	Netherlands	http://www.dusseldorp.nl/
27	ELHI						Netherlands	http://www.elhi.nl/en/conta
28	FM Plastics	compounding, trading	Plastics	no		Beukenhof 8, 8332 VA Steenwijk	Netherlands	http://www.fmplastics.nl/
29	Folietechniek International	converter	PP, PET, rPET, Pl	no		Moerval 1, 4941 SK, Raamsdonksveer	Netherlands	http://www.folietechniek.co
30	Grain Plastics	converter	PE, PP	yes		Marsweg 2, 8912 BG Leeuwarden	Netherlands	http://www.grainplastics.nl/
31	H&P Moulding Emmen	Converter	Plastics	yes		Vasco da Gamastraat 18 7825 VJ Emmer	Netherlands	http://www.hpmoulding.com
32	HERMION	Consultancy					Netherlands	http://www.hermion.nl/home
33	Hardijk Verpakkingen	converter	Plastics	yes		Westzanerdijk 388, 1500 AE Zaandam	Netherlands	http://www.hardijkverpakkin
34	Hudaler Afvalverwerking & Re	collecting	Plastics	yes		Kampstraat 22, 6163 HG, Geleen	Netherlands	http://www.hudaler.eu/
35	Huhtamaki Nederland B.V.	converter	Plastics, paper	yes		Zuidelijke Industrieweg 3-7, 8801 JB FR	Netherlands	http://www2.huhtamaki.com
36	Hummel Recycling	collecting, trading	Plastics	yes		Muldersspark 17, 9351 NR Leek	Netherlands	http://www.hummelrecyclin
37	Inverko Compounding	grinding, washing, compoundin	PP, HDPE, PS	yes	20280	Eerste bokslootweg 17, 7821 AT Emmen	Netherlands	http://www.inverko.nl/comp
38	Inverko Polymer	trading, granulation	HDPE, LDPE, PP,	no		Stevinstraat 8, 9351 VK Leek	Netherlands	http://www.inverko.nl/polym
39	Jansen Recycling en Transpor	collecting	Plastics	yes		Klingelbeekseweg 57, 6862 VS, Oosterb	Netherlands	http://www.jansenrecycling.
40	KRAS Recycling	collecting,sorting, trading, grir	Plastics	yes		Zeedijk 1, 1131 GG Volendam	Netherlands	http://www.kras-recycling.c
41	KRN	collecting, grinding, washing, tr	Plastic	yes		Eisenhowerweg 13, 5466 AB, Veghel	Netherlands	http://kunststof-recycling.n
42	Kunststof Recycling Van Werv	sorting, grinding, washing	Plastics	yes		Biddingringweg 23, 8256 PB Biddinghu	Netherlands	http://www.vanwerven.nl/
43	Langezaal Afvalverwerking B	collecting,sorting	Plastics	yes		Industriestraat 3-5, 7482 EW Haaksber-	Netherlands	http://www.langezaal.eu/
44	M. van Happen Transport	collecting	Plastics	yes		Weijerbeemd 10, 5651 GN, Eindhoven	Netherlands	http://www.vanhappencont
45	MEWA plastics	recycling, granulation, compou	plastics	yes		Huygensweg 3, 5482 TH Schijndel,	Netherlands	http://www.mewaplastics.co
46	Milieu Service Zuid	collecting,sorting	Plastics	yes		S. Haubenweg 5, 6051 AL, Maasbracht	Netherlands	http://www.milieuservicezui
47	Morein	sorting, grinding, washing, gran	PE, PP, PS, PC, A	yes		Twentestraße 2, 48527 Nordhorn	Germany	http://www.morein.nl/
48	Morssinkhof Rymoplast	sorting, grinding, washing, gran	HDPE, LDPE, PET	yes	150000	Mercatorstraat 22, 7131 PX Lichtenvoo	Netherlands	http://www.morssinkhofplas
49	OMRIN	collecting,sorting	Plastics	consumer		De Dalton 11, Heerenveen	Netherlands	http://www.omrin.nl/
50	Ovimo Plastics	collecting,sorting, grinding, wa	HDPE, LDPE, PP,	yes		Twentepoort West 10-6a, NL7609 RD Al	Netherlands	http://www.ovimoplastics.eu
51	Papierrecycling Utrecht B.V. G	collecting	Plastics	yes		Groeneweudsedijk 5b, 3528 BG, Utrech	Netherlands	http://www.papierrecyclingu
52	Peute Recycling	sorting, grinding, washing, gran	Plastics	yes		Baanhoekweg 4, 3313 LA Dordrecht	Netherlands	http://www.peute.nl/
53	PHB Plastic Herverwerking Br	sink-float,sorting, grinding, wa	PP, HDPE, PET, P	yes		Duikerweg 30, 5145 NV Waalwijk	Netherlands	http://www.phb-recycling.c
54	Plastic Recycling Company (P	collecting, grinding,sorting, tra	PE,PP,PS,C,PA,	industrial, consumer		Van Leeuwenhoekweg 30, 5482TK Schi	Netherlands	http://plasticrecyclingcomp
55	QCP	Recycling, Compounding	PE, PP	yes	100000	Mauritslaan 49 - 6129 EL Urmond	Netherlands	http://www.qcpolymers.com
56	QPALL	converter	plastics	yes		Taylorweg 2 NL-5466 AE Veghel	Netherlands	http://www.qpall-plastic-pal
57	Recycling NL							
58	REK Europe BV	recycling, regranulation, comp	Plastics	yes		Koopvaardijweg 54 4906 CV Oosterhou	Netherlands	http://www.rekeurope.com/
59	Resin BV	compounding	plastics	yes/no consumer, industri		Goolkatenweg 10 7521 BG Enschede	Netherlands	http://resin-technology.com
60	RPC Packaging Kerkrade	converter				Spekhofstraat 16, NL-6466 LZ Kerkrade, The Netherlands		
61	Rutgers	recycling, grinding,sorting, de-	plastics	yes		Valkstraat 86 7006 RW Doetinchem	Netherlands	http://www.rutgersmilieu.nl
62	Shanks Nederland B.V.	collecting,sorting	Plastics	yes		Lindeboomseweg 15, 3828 NG, Hooglan	Netherlands	http://www.shanks.nl/
63	SIMSrecycling	recycling,collecting	WEEE	yes	75000	Hastelweg 251 5652 CV Eindhoven	UK	http://www.simsrecycling.co
64	SITA Papier en kunstof recycl	collecting	Plastics	yes		Mr. E.N. van Kleffensstraat 10, 6842 CV	Netherlands	http://www.sita.nl/arnhem.h
65	Snelcore	converter	PET, rPET	no		Bruningweg 1, 6827 BM, Arnhem	Netherlands	http://www.snelcore.com/
66	SNELTRAY	converter	PET, rPET	no		Nijverheidsstraat 79, 6681 LN, Bemmel	Netherlands	http://www.sneltray.com/
67	SONEPA	recycling, trading, warehousinc	plastics	industrial,consumer		Jacobus Lipsweg 81 3316 BP Dordrecht	Netherlands	http://www.sonepa.com/con
68	Sortiva Papier en Kunststoffe	sorting, grinding, washing, tradi	Plastics	yes		Spoorstraat 5, 1687 AE WOGNUM	Netherlands	http://www.sortiva.com/
69	Synoplast	sorting, grinding, washing	Plastics	yes		Feldkappel 19, 49779 Niederlangen	Germany	http://www.inverko.nl/synop
70	Synbra Technology	converter	EPS, EPP, PLA			Zeedijk 25, 4871 NM Etten-Leur	Netherlands	http://www.synbratechnolog
71	TCR Plastics	trading	LDPE, MDPE, HD	no		Overakkerstraat 90-92, 4834 XN Breda	Netherlands	http://www.tcrplastics.eu/
72	TRH recycling BV	recycling,sorting, granulation,	LDPE,PVC	yes		TRH Recycling BV Charles Darwinstraa	Netherlands	http://www.trh.nl/
73	UPLUS TRADING B.V.	trading	Plastics	yes	50000 t/y	Kurt Cobbstraat 15, 3067CZ Rotterdam	Netherlands	http://www.uplusbv.com/
74	UPR Universal Plastic Recycli	collecting,sorting, grinding, wa	Plastics	yes		Nijverheidsstraat 9, 5331 AA Bladel	Netherlands	http://www.upr.nl/
75	Van Der Elst Recycling	collecting	Plastics	yes		Weesperstraat 136, 1112 AP, Diemen	Netherlands	http://www.vanderelstrecyc
76	Van Gerrevink B.V.	collecting	Plastics	yes		Sint Maarten 2, 7332 BG, Apeldoorn	Netherlands	http://www.vangerrevink.nl/
77	Van Maren Systems	recycling, converting, collectir	Plastics	consumer		Van der Helstlaan 20 1412 HK Naarden	Netherlands	http://www.vanmarensystem
78	Verhoeven B.V.	collecting		yes		Eikdonk 13a, 4825 AZ, Breda	Netherlands	http://verhoevenbv.info/
79	Viral Recycling Groep	collecting,sorting	Plastics	yes		Haven Z.Z. 21, 9679 TD Scheemda	Netherlands	http://www.viral.nl/kunststo
80	Wildenberg Recycling B.V.	collecting	Plastics	yes		De Werf 50, 2544 EK, Den Haag	Netherlands	http://www.wildenbergrecyc
81	Sita Recycling Services	Collection,sorting	Plastics	consumer		Waalhavenweg 50, 3089 JJ Rotterdam,	Netherlands	http://www.sita.nl/rotterdan
82	Houweling International bv	Converter	Plastics	no		Klappolder 104, 2665 LP, Bleiswijk	Netherlands	http://houweling.nl/verpakk

Appendix G - Interviews

The interviews which were held are described below. The company names are used anonymous in this thesis, references are made to the corresponding alphabetical letter. The interviews were conducted in Dutch. The reports in this appendix are translations and interpretations of the conducted interviews. The first interview was a preliminary interview, to validate the prior knowledge about the value chain, from sources on the internet. It therefore deviates from the structure seen in the other interview reports.

Consulting:

Interviewee A 2015-02-24 - Recycling Avenue

Compounders:

Interviewee B 2015-03-06 - QCP, Quality Circular Polymers

Interviewee C 2015-05-15 - Van Maren Systems

Interviewee D 2015-05-28 - Inverko Compounding

Converters:

Interviewee E 2015-06-11 - Sunware

Recyclers:

Interviewee F 2015-06-12 - Sita

Interviewee G 2015-06-25 - Sita

A comparator for the interviewed companies is their capacity, as seen in the table below. This is the capacity as claimed by the interviewee. The capacity between parentheses is the intended tonnage they are planning to grow to.

Interviewee:	Capacity per year (intend to grow to):
A	Not applicable (consultancy)
B	35.000 ton (100.000 ton)
C	Not disclosed
D	12.500 ton (35.000 ton)
E	Not disclosed
F	100.000 ton (200.000 ton)
G	30.000 ton (100.000 ton)

2015-02-24 - Recycling Avenue

Company:	Recycling Avenue
Time:	11:00 - 12:30
Address:	YES!Delft, Delft
Attending:	Norbert Fraunholcz - Recycling Avenue, UMC Boudewijn van Sambeek - student TUDelft
Activities:	Consultancy for UMC
Capacity:	not applicable

Plastics are chained together molecules, also called a polymer.
For injection moulding a material with a high MFR (Melt Flow Rndex) is required, which is the same as MFR (Melt Flow Rate). This material characteristic relates to the viscosity and the length of the polymer chains. So high MFR for injection moulding means that the material has a low viscosity and short polymers, which makes the material easy to push inside a mould. Opposite is the requirements for the blow mould technique, which requires a low MFR, high viscosity and therefor long polymer strings.
A typical used plastic for blow moulding is PP. PP is also popular for recycling, because the long polymer chains are relatively easy to cut in smaller strings with peroxide to make it usable for injection moulding. Gluing the polymer chains together requires more effort and is therefore not commonly used. Peroxide does not work for PE, another often used plastic grade. It is therefore required to separate the different PE grades better with mechanical recycling, i.e. with machines, instead of upgrading or changing them with additives.
We furthermore separate two sub classes:

coPP	-	copolypropylene	-	PP with other plastics attached in the polymer chain
hoPP	-	homogeneous PP	-	pure PP, not coPP

Cross linked polymers do not melt, the polymer chains are linked to each other and therefore cannot move (melt). For example, if molecules are heated they move around, e.g. boiling water evaporates (small molecule, low viscosity, high MFR). If polymers are heated they move around just like molecules, they melt (High MFR, low viscosity, short polymer chains).
Which is the currently biggest problem in the plastic recycling industry for the expansion of the market? A big player in the recycling business can guarantee 20k - 40k ton plastic per year. Whereas for a fast moving consumer product you need to make between 250 and 500 ton plastic per year.

2015-03-06 - QCP, Quality Circular Polymers

Company:	QCP, Quality Circular Polymers
Time:	10:30 - 13:30
Address:	Mauritslaan 49, 6129 EL, Urmond
Attending:	François Essers - Innovation Manager, QCP Marcel van Enckevort - Account & Application Development Manager, QCP Boudewijn van Sambeek - student TUDelft
Activities:	Compounder & recycler
Capacity:	Are building first factory in Geleen with 35k ton annual capacity, sizable to 100K ton.

Introduction:
Marcel worked at Sabic and sold about 140k ton plastic a year. The bigger part of the price was based on monthly price negotiations. The contract prizes are based on the price reference from ICIS, with a volume discount. Important quality key performance idicators are:
rHDPE MFR, density (Which is the same as stiffness for PE)
rPP MFR, stiffness, impact strength
MFR value is not important, as long as it stays constant, because the machines need to be adjusted when it changes.

Input:
Bales of post-consumer plastic PP and PE. They use the DSD-standard D324 for PP and D329 for HDPE. Suppliers have to guaranty the quality and proof the quality with test samples. Normally 70% of the input can be used to produce regranulate. The other 30% can sometimes be recycled by other companies. This output stream increases if the contents of a shipment are contaminated. They hope that the prices of these bales will change in the future, based on the quality. Where it is currently based on supplying the minimum of the DSD-standard. SITA will be the main supplier in the beginning. They also have interest in an as good as possible output, i.e. high quality regranulate, because they are also shareholder in the company. The input quality is based on the fraction on contaminations, e.g. PVC or silicon cartridges may never be in the mix. A shipment containing these two will be send back.
The relationships with the suppliers are short term relationships.
We prefer post-consumer waste because it is a continues flow of goods, whereas post-industrial waste is a batch process with changing contents. The flow and content of the post-consumer waste is fluctuating with seasonal influences, but very predictable.

Recycled material standard (DSD-standard D324, PP; D329, HDPE):
DSD-standards recycled plastic quality which are made by DKR.de, which is a commercial party who do 50% of all the German plastic waste. Plastic bale quality is now being checked by taking a sample from a truck. It would be great if the suppliers of the bales could also send the NIR machine data to check the whole shipment.

Product Output:
Our output is a constant quality regranulate PP and HDPE, both high and low MFR grades. Which will consist of 90% recycled material. Eventually we want to grow to a portfolio of 20 different grades. We focus on short-cycle plastics for consumer packaging of non-food applications, e.g. packaging in the DIY stores. We sell our regranulate to brand owners of these packages instead of converters. Making food grade recycled plastic is expensive or legislative impossible in the Netherlands. For example, paint buckets don't have to be food grade or high-quality due to their short live cycle. This will probably be our first application. We do not try to sell to long-cycle plastics, e.g. automotive applications. This would require long time investments in the development, as these trajectories can

take up to 5 years. The continuity required for these development trajectories are almost impossible, because the plastic may change during these years due to innovation on the virgin plastic market. We also don't focus on low-end products like park benches and posts.
Material based on PP bales has a typical MFR of 10 and higher. For HDPE this is between 0,2 – 0,3, which is suitable for blow moulding.
The currently available recycled material is not good enough. This happens because the recyclers have a lack in material knowledge. Some batches available on the market are very bad quality. This damages the belief in good quality at the converters. This regranulate is created without upgrading with additives. When you do that right, a similar quality as virgin material is possible. The brand owner or the converter are hard to convince about the similar properties, because they also lack the required material knowledge.
The price is based on the price of virgin plastic, but the price should be higher when the same material properties are met due to the added durability value. Relationships with customers are intensive, because of the advice function about the material and machinery. The process of making the bottle with blow moulding has more impact on the strength of the bottle that the material properties. There often is over dimensioning with products because the material and the process are not aligned. This is where a lot of extra value can be added by helping to save material costs.

Growth potential plastic industry:
The growing potential of rPP is big, because the material specifications can be adjusted more easily compared to rPE. The volume of the rPE market shows more promise, however the separation of rPP and rPE needs to improve to fully enable that market.

Company characteristics:
USP:
- Hot washing -Knowledge about polymer / material
- Scale
- Knowledge about machines
- Relationships with machine suppliers
- Logistical expertise

Our process is as follows: - flaking – dry washing – hot washing in 50/70 degrees with soap – centrifuge drying – density separation – NIR separation on flake scale – Sink float.
They hold no patents or have access to special technologies.
Hot washing is not being applied that often, because of the profitability / costs.
We are setting up two lines with double extruders, cascade configuration.
We use existing technologies that we combine to get the end result, i.e. the constant quality.
To achieve the European commission goals for plastic recycling, the combined capacity of 10 QCP's should be available. This is 60% of the total plastic waste as estimated in 2030. This is why I think that we should share the technology more, instead of protecting it. They are therefore prepared, under consideration, to license out the construction setup of their factory. This would increase the total market which is good for all actors in the value chain.
The current market size is 22 million ton PP and PE.
Sita is a strategic partner to lock-in the supply of bales, where DSM is a financial partner.
They are currently working on a lab scale extruder to do product innovations, in cooperation with potential customers. Important in this progress is the use of DOE, Design of Experiment method, not trial and error. The biggest investment is the procurement of the flakers.

Big brand owners want to use more regranulate in their products, because of the durability and brand image added value. These companies are also the most likely to pay virgin prices for the QCP regranulate. Which QCP perceives as more than normal, because it has the same material properties as virgin plastic. Important is that these brand owners cannot find enough quantity with stable quality. This can be solved by increasing the plastic waste stream by collecting more or importing more from for example Germany. Some input contracts currently have a duration of 8 years, because they are not through the Nedvang organization. This enables the industry to start making 5 year contracts for the output, which is interesting for many companies and stimulates growth.

Miscellaneous:
LDPE is mostly foil. Most of the PP has the same density, the additives and fillers change the density or actually it increases it. DIY store 'Toom' (part of REWE) in Germany tries to oblige their suppliers to always use packaging that is made from regranulate.
Nedvang used to pay the MRF's (Material Recycling Facilities, e.g. SITA Rotterdam) per ton separated material. MRF's made sure the output bales complied with the regulations, i.e. the DSD-standards. It is most likely that the output quality will increase because this money will start to go to the municipalities and they will pay for the separation. This gives the incentive to do it better than others to collect the most input. Virgin producers don't do anything with regranulate because it cuts in their own business. Off-specs batches of virgin plastics are now sold as waste stream, which is actually virgin material but not completely the specs that were promised to the customers. Sometimes the starting batch and the last batch of making virgin plastic is sold as off-specs.
PE density is between 915 – 960, but density doesn't say anything about important material properties. Often plastics, blends, are combinations of multiple materials and are sometimes composited in multi layers. This makes the density enormous complex. An example is that we make PP with density of 936, which normally is PE. This disables the recyclability in future density separators.
A German university is working on a laser spectrum system which will be able to separate with very high accuracy. But it will probably be a while before this will come to market.
Polymers and recycle end products like regranulate are not obliged to confirm with REACH, additives do.

2015-05-15 - Van Maren Systems

Company:	Van Maren Systems
Time:	11:00 - 13:00
Address:	Kerkstraat 7, 3755 CK Eemnes, Netherlands
Attending:	Jean-Marc van Maren - Van Maren Systems, Owner Boudewijn van Sambeek - student TUDelft
Activities:	Consultant, recycler, compounder & converter.
Capacity:	not disclosed, building new factory close to Omrin.

Introduction:

Input:
Mix bales and mix stream bulk plastics in trucks.
This can be sourced at Sita, Attero and Omrin in the Netherlands, who collect and sort the plastics. They currently collect around 160K ton in The Netherlands, most of it is exported to Germany. Competition with virgin plastic is killing, the middle east produces plastics for €400 and recycling costs €800 per ton. Bales of waste PP or PE are valued around €200 per ton. Virgin is sold for around €1000 per ton, so you have to make regranulate for less! Making profit is therefore hard.
Where the mixed plastics and foils have a negative value. Meaning that the recycler has to pay someone to pick it up.

Product Output:
Mr. Van Maren consults Omrin and Sita about handling the waste streams, i.e. contracting it to other parties. He is only responsible for 50% if the processed material at Sita. He furthermore produces his own logistical pallet from recycled plastics. This requires him to further recycle and compound the plastic into regranulate or flakes, depending on the complexity of the pallet. The logistical pallet should not be confused with the alternative name for regranulate or granulate, i.e. the pallet. They also offer regranulate, washed and unwashed regrind on their website. Although he must admit that he does not sell much, because he uses everything for his successful pallets.
Prices of PP, approximately:
Agglomerate €400
Flakes €600
Regranulate €800
Virgin €1400

Growth potential plastic industry:
There are about 12.000 converters in the EU and this number is declining. The margins are under pressure because they have big compounders with bigger bargaining power on one side and big brands on the other. The pressure is increased further by middle east compounders who are integrating into converting. There is a technical gap between the makers of regranulate and converters who have to adjust their machines for the regranulate. Converters are not likely to take a technical risk of adjusting the machines, an incentive is missing. For example, the converters have their machine setup for a specific grade from SABIC, a big compounder. They know the plastic will have constant material properties, so the machine settings can remain the same and ultimately have a constant product output themselves. With regranulate the material properties can fluctuate and therefore have an impact on their output. A constant monitoring of the quality and adjustments of the machines is required to guarantee a stable output. The already minimum margin of the converters prevents them to experiment with this, because this margin can be gone if a batch fails. Seasonal influences and geographical areas have impact on the contents of the waste stream this also determines the output of a recycler. To generate a constant quality regranulate the making of it must be adjusted constantly, which costs money.

Another growth potential point is the logistics that currently limited the profitability of the industry. These logistics costs money and time, that is why Van Maren Systems is building a factory next to the collection and recycling facilities.
A knowledge deficit is also limiting the industry to be more profitable. It is hard to find and keep higher educated personnel. He thinks this is because the industry is missing a sexy factor.
Another big boost could be if the government would limit the number of grades that are on the market. This would improve the recyclability of the plastic. Although it could be argued that this would limit the innovation on new grades.

Company characteristics:
Van Maren Systems does not use any special techniques or have any patents.
important is to keep the costs to a minimum, e.g. it is not always necessary to granulate the recycled plastic. Flakes can sometimes be moulded directly into a product.
"Near to prime" polymers are leftovers of the manufacturing of virgin plastic, also sometimes called off-spec. These batches can be leftovers, first or last production runs and as the name states batches that do not have the right specifications.

Miscellaneous:
rPET is already proven in the market, converters often use rPET for production of certain products. There even was a time where rPET was more expensive in the market than virgin PET. This was possible for the earlier mentioned adjustment risks (transition costs) with the machines.

2015-05-28 - Inverko Compounding

Company:	Inverko Compounding
Time:	11:00 – 12:30
Address:	Eerste Bokslootweg 17, 7821 AT, Emmen
Attending:	Coen Kolthof - Inverko Compounding, Director
	Boudewijn van Sambeek - student TUDelft
Activities:	Shredding, washing, drying and compounding.
Capacity:	35k ton material is processed, which results in 12,5k ton regranulate per year.

Introduction:
Coen Kolthof speaks German fluently on the phone. He learned this while doing business in the plastic industry. This is necessary because the German market is too big to not engage in it.

Input:
They buy bales of plastics conform the DSD quality standard.
The bales are bought through contracts with municipalities that have a duration of 8 years. The plastic waste comes from Midwaste, Omrin and Attero. This waste goes to recycling facilities of Sita in Rotterdam or to Meppen, Germany. They make the bales that go to Inverko. There are two types of plastic waste: commingled and separately collected plastic waste. The separately collected waste, e.g. plastic hero's initiative, holds more foils and netto weight compared to commingled collected plastic waste. Which is separated from regular household waste.
This is important because the foils cause congestions in the machine street and are harder to dry in the recycling process which causes bubbles and other irregularities while compounding into regranulate. However, the commingled plastic with less foil also holds more contaminations, e.g. sand. This causes high wear and tear to the machines, especially in the shredder which makes the flakes.
Another input are other flakes, granulate and master batches to mix with the recycled plastic. The overall most important part is to guarantee a steady input of material, know what it is and adjust your process on that.

Product Output:
The regranulate is transported from the extruder to silos outside the factory and sold in big bags to customers. This has to be done by active sales and setting up own joint projects. It is a pity that the converters don't ask for regranulate, you have to actively start your own projects. The price of regranulate has less price fluctuations than prime / virgin plastic. It would therefore be better to work with regranulate for the converter. Setting up own projects can be done in different ways, the lead time is different depending on the complexity. They have done projects for containers in two months and they are working with Philips which is already 5 years in progress. On average it takes one year to fully complete a project to the point we are in full production. It is difficult to switch to another compounder, because Inverko makes all the grades customized. Our regranulate has a bandwidth of MFR 6, i.e. between the 27 and 33 if the customer requires MFR 30. The sales go through the network of Inverko and we are currently working together with another company to create a wood grade.

Growth potential plastic industry:
Collaboration in the whole chain is important to increase the usage of recycled plastic. Inverko is actively working on that by engaging in projects that make products from recycled material. For example, we have a closed a recycling loop of containers from SSI Schaefer. They give us their old containers and we upgrade the plastic and make new regranulate. This regranulate can be used again for the same container.
The plastic recycling industry is a traditional closed industry. Which makes working together difficult to close such product recycling loops. To really engage in the market the size of the recycled material has to increase. This will enable them to produce more and especially more stable regranulate. Currently the market is very young and there is a lot of growth potential. The barrier of entry is high due to required large investments in the machinery.
Another thing that has to improve is the image of the industry. This will enable to attract higher educated personnel. Food grade is also something that the Dutch government has to allow, which is technically possible. The biggest impulse will probably be an obliged percentage of recycled material in virgin plastics, but the question is if this will ever happen.

Company characteristics:
USP:
- From bale to regranulate under one roof, less logistics.
- Customer can get complete end product with one party.
- 8 year contracts with suppliers will guarantee a steady input.

We could apply hot washing, but this is too expensive at the moment.
In 2013 we went public with the company, which enables us to invest into machinery for expansion. While we produce regranulate the MFR is measured every 30 minutes to enables us to adjust production parameters, ensuring a steady product quality.
Inverko will increase their output next month by working with 5 groups of employees with production 24/7. The production will only stop one week with Christmas and New Year's Eve and one week for maintenance.
We are preparing some strategic acquisitions of other companies to increase our market share. Inverko holds no patents on the regranulate. The moulds for products and other product related machinery is patented. One thing that is different in our factory is that we shred the plastic to 50 mm flakes, which is big. This enables better washing and drying, however the extruder had to be adjusted to handle this size of flakes. The director is claiming they do not innovate other than in the laboratory, where the grades are produced. They are thinking of washing the plastic prior to shredding, this will hopefully result in less wear and tear in the shredder which leads to increase operational time. We have to make sure the machinery in the factory keeps working above a capacity of 70%, else the company will go bankrupt.

Miscellaneous:
If the government stops with the deposits on PET bottles, then the PET will return into the normal plastic waste stream. This will increase this streams value, which is good for the industry. However, the price of rPET could be effected. But the key is that stopping the PET deposit system in the Netherlands is maybe not that crazy to say.

2015-06-11 - Sunware

Company: Sunware
Time: 14:00 - 15:15
Address: Kranenberg 10, 5047 TR Tilburg, Netherlands
Attending: André Jacobs - Sunware
Boudewijn van Sambeek - student TUDelft

Activities: Converter & Brand owner
Capacity: not disclosed

Introduction:
I met with André Jacobs from Sunware in Tilburg. Sunware is a well-known brand in the Netherlands from the containers and permanent food packaging they sell in popular stores like 'Blokker'.

Input:
98% of the input is non recycled granules. They have some products branded as recycled so they also buy regranulate, which makes up the rest of the total input stream. The granulates come in bags of 2 Kg and are combined on a 250 Kg weighing pallet. Some of the production waste material is reused internally in darker products. There are however not enough black products to use all the industrial waste, so a part is sold externally.
They use virgin material because the quality is constant and may be used for food applications. A lot of their products are food-grade labelled, even animal food containers have to be food grade. The regulation from the Dutch government that recycled material may not be food-grade makes it impossible to switch to regranulates. Another big influencer is the switching costs between materials. Every time we switch a material the machine has to be adjusted. This is fairly easy with virgin materials, because of the support of the supplier and consistent quality. This is also possible with regranulates, but you have to anticipate disruptions in the production process.
They have done some tests with material from AKG, who makes regranulates exactly as how you order it. So we ordered the same properties as the currently used virgin material, we asked a MFR of 15.50 and received 15.10 which was impressive. The downside was that the price was comparable with the virgin material, which made the transition pointless. The only upside was that the price of the regranulate is less dependent on the oil price fluctuations, which can be big nowadays. Last February the price of virgin granulate was 1100 and regranulate 1050, but in June the virgin price increased to 1500 and regranulate to 1100. This difference would make it interesting to use more regranulate for us, because 60% of the product cost is material. We need a difference of 400 to be able to put the product for a reduced price in the stores. Because customers are not willing to pay the same for a product made out of recycled material. They are currently buying virgin granulate if the price as low and use the storage as a buffer. The quality is always the same, if we detect a difference than we will get a discount on the next shipment. They select the supplier based on price and quality, but also base the decision on how they like the sales guy. However, there is not so many choice, they buy different grades and want to buy them from the same company, so the number of suppliers is limited.

Our input used to be products from converters, where we now have our own converter. But we sometimes still use other converters for large batches and reoccurring production products. The negotiation power in these price negotiations is shifting towards the converters. It used to be the case that converters needed more assignments, because a lot of companies were sourcing their plastic components in China. Because of this production shift a lot of converters went bankrupt. The current trend is that companies move their production back to Europe for logistical reasons and the lower number of left over converters have the upper hand in the price negotiations. Sunware has thought about moving the production to Poland or Hungary, but they have to switch fast when a certain product sells better than others. This requires short logistics and minimal language barriers. They therefore still do production in the Netherlands. Which is quite competitive with eastern Europe because of the lower power costs and higher level of atomization.

Product Output:
Plastic buckets, containers, small boxes, etc.. a lot is food-graded.
6-7 years back was the introduction of our recycled product the 're-life' series made out of regranulates. After the first production it turned out that we could not offer it for a reduced price compared to the normal product. The sales turned out to not that good and the product was discontinued. The demand is increasing, so we started to test with regranulates from QCP. We will probably make black foldable non-food crates for shopping pickup points from the Jumbo with their regranulate. André is questioning if the recycled packaging from TOOM is really made out of regranulates. He explains that even a laboratory cannot check of the used plastic was recycled plastic. So the suppliers could mix it with virgin to achieve more stability for the manufacturing of the packaging. But the most important part is that the consumers get convinced of the quality of recycled plastic. Then maybe the consumer is more willing to pay the same price for products made with regranulate.

Growth potential plastic industry:
There are 4 big disadvantages of using regranulate that limit the growth of this industry:

- Food-grade is not allowed in the Netherlands.
- The density is slightly higher, so heavier product, increased logistical costs.
- Cycle time for virgin products is 18 sec. and with recycled material 20 sec. This has enormous effects on the costs. The virgin material holds specific nucleating agents which reduces hardening time and thereby cycle time.
- There are more production failures due to the inconsistency of the quality.

The overall demand for products made out of regranulate and the price difference between the regranulate and virgin granulate must increase, that would increase the market size of regranulates. But if this happens than I still question if this new market can be verified and if there is enough material available to turn into regranulates.

Company characteristics

USP:

- Service oriented;
- Production in the Netherlands;
- Quick delivery and reaction to market demand.

Core business for Sunware is marketing, design and injection moulding capabilities to enable them to react quickly on market demand and make small batches. Sunware sells their products in Europe but mainly in the Benelux. They bought a bankrupted converter 4 years ago in Waalwijk. They currently do 60% - 70% of the production there. The rest is outsourced like they used to do. This enables them to be closer to the production and increase reuse of industrial waste, which is created during production. However, the machines have to produce all day and night to be profitable. Which requires delicate planning because the machines can only change products during the day. So for example, if you start a small batch in the beginning of the day and it finishes at 20h, than the machines will be still for the night. This was a reason for other converters to refuse small production batches. Sunware makes 80% of the revenue with 20% of the products, but the other 80% products are necessary to support the 20%. So they need small batches which resulted in the acquisition of the converter.

Miscellaneous:

They tested with AKG regranulate, because they were working together with another converter who recommended it. They were already producing buckets with the regranulates from AKG. Their consistent quality is proven in the market. They run into QCP during the DPI (Dutch Polymer Innovation program), but they didn't have a meeting yet. They have send a test batch regranulate which we will start testing shortly.

2015-06-12 - Sita

Company: Sita
Time: 09:10 - 10:15
Address: Waalhavenweg 50, 3089 JJ Rotterdam, Netherlands
Attending: John Geerts - Sita
Boudewijn van Sambeek - student TUDelft

Activities: Recycling
Capacity: 2.000 ton per week (twice as big after expension)

Introduction:
John Geerts manages the input streams to this recycling factory. Most of the input is recycled into separate streams, but some streams are traded directly to other companies. He is currently looking at post-industrial streams to set up circular recycling projects. An example is their own green Sita waste containers. Broken down ones are retrieved, cleaned, shredded, recycled and reused into new containers.

Input:
The input is soft post-consumer plastic through logistical partners from municipalities. Sita managed to secure an 80% market share by sourcing plastic from the municipalities and securing it with 3 to 8 year contracts. Hard rigid plastics goes directly to other companies from the municipality by their logistical partners. Sita also approved the municipalities to add laminated carton into the plastic collection bins. It is relatively easy to separate it from the plastic stream and the value is quite high due to the virgin paper that is required for making the laminated carton.
The quality of the input is difficult to control, which depends on what people through in the collection bins. Although this waste stream is quite stable and predictable.

Product Output:
The output of the recycling facility in Rotterdam are bales PP, PE, PET, foil LDPE and a mix fraction, all according to the DSD standards. The output quality is thereby fixed, although Sita could deliver a higher quality. Also the Dutch 'Raamovereenkomst' between all the industry participants limits the improvement of the quality. The €817 from this agreement that is paid per ton plastic that is processed is transparent. So everybody knows who gets what portion of this money.
A large portion of the output will shift to another company in a couple of months. This will impact our current customers. The agreements are that they get the output, depending on our input, so the amount is not locked in the contract. Which is important because it is a batch process. It is possible that the current customers, that will have less input in a couple of months, source their plastic somewhere else. This could also be hard rigid plastics from the municipalities directly.

Growth potential plastic industry:
There are only two reasons to work with recycled plastic, because it is cheaper and or for marketing purposes. The future growth of this market fully depends on regulations from the government. They see a shift in the price from costs based towards a marketing driven price. However, new regranulate is of so good quality that the price is almost similar to virgin granulate. They also see that big compounders are investigating making regranulate. The quality is improved with professional and ever improving micro filters. This enables the application of thin walled products that do not require a food grade granulate, e.g. laundry baskets. The dialog between commercial companies and governmental regulation must improve to grow the recycling market further.

Company characteristics:
USP:
- The only facility in NL that can make bales;
- Recently established link directly with compounder;
- Strategy to work together with partners.

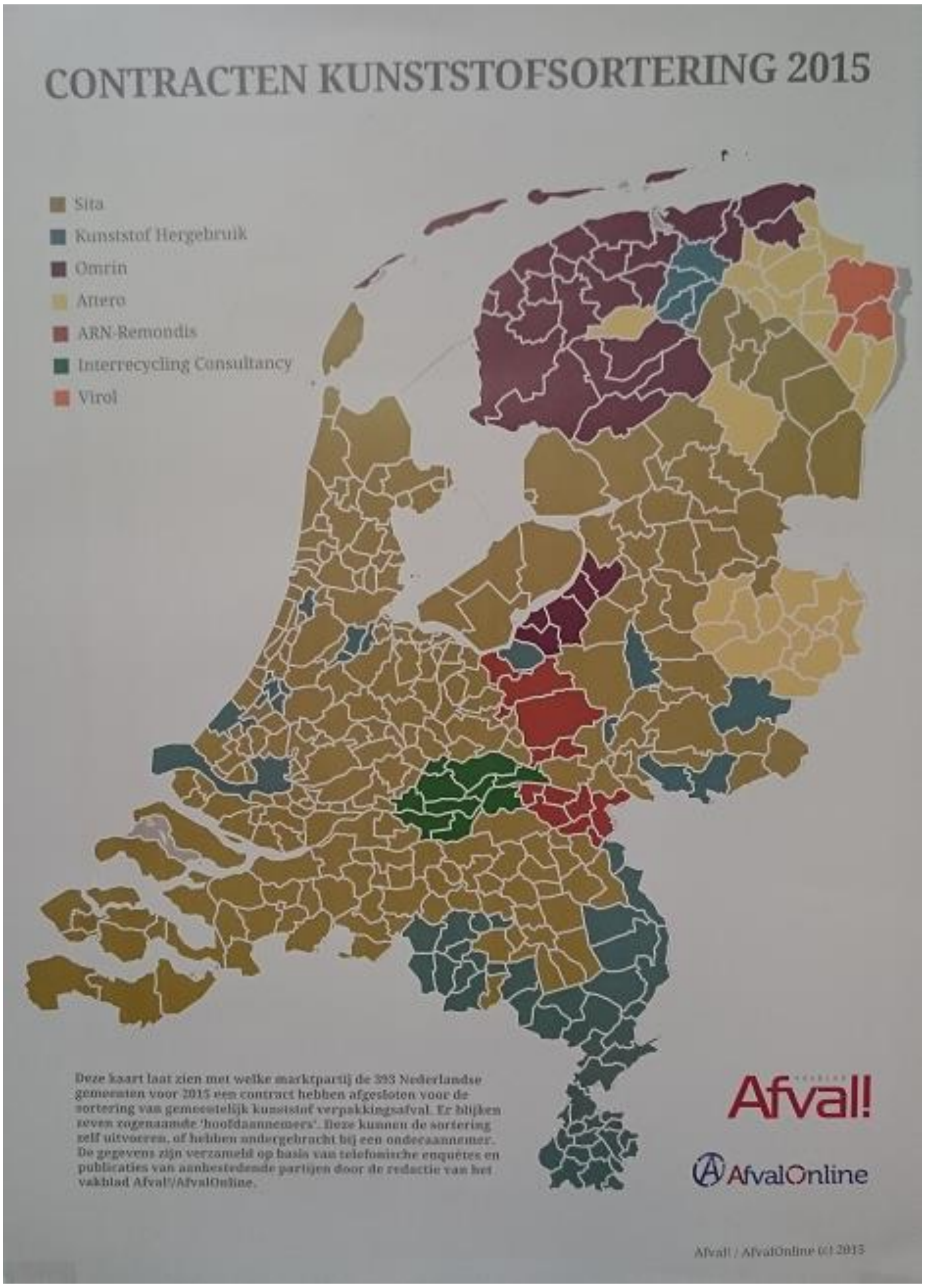
Sita has a very big facility that was built for 1.200 ton capacity, which currently is running 2.000 ton per week. The new expansion enables a separate second line to do again 2.000 which makes the whole facility able to process 4.000 ton plastic per week! The main technology used are NIR, Near Infrared, separators. John Geerts states that it looks like Sita is the only one that has a strategy to work together to close the recycle loop, working towards circular economy.
Sita has no technology of its own, all applied machines already exist. The specific combination is unique, which enable them to process all the material this way. They experienced problems while outsourcing the development of new technical solutions and parts of the facility. That is why Sita has made his own technical team that combines and optimizes all the machines. They however hire technical consultancy companies to check what their own team is doing.
Their team is constantly working on new innovations. They are currently working on:
- Separation of black plastics.
- Separation of PET trays from PET bottles.

Miscellaneous:
Dutch 'Raamovereenkomst' impact on Sita:
The agreement states that 90% of the post-consumer packaging plastic must be reused. Everybody in the chain of recycling puts their input and output material in the so called 'wastetool' from the government body Nedvang. Nedvang controls a fund which is filled by packaging producers, they have to pay a certain amount for every ton produced plastic. The waste streams are made visible in the wastetool which Nedvang uses to see if indeed 90% of the plastic is reused. Nedvang then transfers €817 per ton reused plastic to the owner of the plastic, i.e. the municipality. They subsequently pay the services that enable this, i.e. recyclers, compounders and logistic companies.
Sita asks €200 per ton for the recycling activities that make the plastic in the following streams:

45% of the input becomes mono streams, e.g. PP and PE bales, according to the DSD standards. These streams can be used to make regranulate. The mix stream is used for low quality requirement products, e.g. poles and park benches. Which cannot be recycled again. The 10% rest stream cannot be used in any product. The rest stream is burned to recover energy from the plastic. The mono streams are sold for an average of €250 per ton, the mix and rest stream have a negative value of around -€100.

Sita could separate 70% of the input into mono streams, however the rest product cannot be used anymore. This would result in a rest stream of 30%, therefore only reusing 70% of the input. Nedvang would not pay for that recycling, because the 90% is not met. However Sita could earn more money with that output, so that a subsidy form the government would not be necessary anymore. From an environmental point of view this would also be better, because the 70% can be recycled again.

70% mono stroom	30% rest


CONTRACTEN KUNSTSTOFSORTERING 2015
Sita
Kunststof Hergebruik
Omrin
Attero
ARN-Remondis
Interrecycling Consultancy
Virol
Deze kaart laat zien met welke marktpartij de 393 Nederlandse gemeenten voor 2015 een contract hebben afgesloten voor de sortering van gemeentelijk kunststof verpakkingsafval. Er blijken zeven zogenaamde 'hoofdaannemers'. Deze kunnen de sortering zelf uitvoeren, of hebben ondergebracht bij een onderaannemer. De gegevens zijn verzameld op basis van telefonische enquêtes en publicaties van aanbestedende partijen door de redactie van het vakblad Afval!/AfvalOnline.
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2015-06-25 - Sita

Company:	Sita
Time:	09:45 - 12:00
Address:	Waalhavenweg 50, 3089 JJ Rotterdam, Netherlands
Attending:	Albertino Pereira - Sita Boudewijn van Sambeek - student TUDelft
Activities:	Recycling
Capacity:	25-30 kton (after expansion 80- 100 kton)

Introduction:
Albertino Pereira is the facility manager of this location in Rotterdam. Sita has more recycling facilities in the Netherlands, but this is the only one recycling plastic. He is responsible for all the processes where plastic recycling is the main application. He is educated as process professional with knowledge about the plastic material that is processed. He is now working 3 years for Sita. His focus is mainly on the optimization.

Input:
Household packaging Plastic that is collected through special bins called: 'plastic hero'. The contents are not always packaging plastic, although there are requirements for what people may through in. This requires separation in the recycling street. In the begin, 2011, they had a contract with Nedvang that they received the plastic for the first 3 years. They processed the material for a fixed fee without becoming the owner of the material. In 2014 this responsibility shifted to the municipalities, who started to write out tenders. More than two third of the tenders were won by Sita. The material goes to their own depots and directly from the municipalities to the installation in Rotterdam. They have contracted that the shipments may not be more contaminated than 30%. In reality this is impossible to control or check before it is run through the installation. In the past 3 years there was only one shipment that was rejected, it was partly burned inside the truck which was easy to see and smell.

Product Output:
The output is bales of PP, PE, PET, LDPE foil, a mix fraction and a rest stream of 10%. All the bales are according to the DSD standards. We run laminated carton and aluminium streams as a by-product, they are easy to remove out of the plastic and are very profitable. They may have a maximum of 10% rest stream that they burn to recover the energy. They try to do more mono-streams than mix because they can earn more with that.

Growth potential plastic industry:
They can technically manage to achieve the maximum 10% rest stream. The separation of the caps on bottles that was added last year enabled that. Currently the mix fraction is 30 – 40%, which is 50% foil. They expect to improve the process where the mix fraction can be reduced to 20 – 30% within two years. The developments and improvements is done together with the machine suppliers, also on the software of the machines. The result of the installation is based on the configuration of the individual machines within the installation. The configuration or software is adjusted with the input from Sita. This process requires a constant dialog with the supplier.
Sita also has developments with the packaging industry, some examples:

- Unilever, attended a meeting with 25 people where they discussed the color of packaging. As a result, Unilever changed the packaging for black washing detergent to a white bottle with a black wrapper. This wrapper is removed by the machines so that the bottle can be identified by the NIR machines. Which they are unable to do with black materials.
- Heinz has changed their bottles to improve the ketchup to flow out. This resulted in a lower weight of the bottle in the installation, which improved the recycle rate.

The input of PET consists of 65% PET bottles and 40 – 45% PET trays. The problem is that the customer wants a maximum of 10% trays in the bale. They are therefore trying to improve the software of PET NIR systems, which can currently separate these two with a 80% success rate. Another recent innovation is the channel of the wind shifter installation. The tubes of these machines have chambers to create a whirl to drop the heavy plastics down and the lighter foils are sucked upwards. This improved the quality of the lighter foil mono stream.

Company characteristics:
In 2011 the facility was started up. They are now constructing an extra installation that will double the capacity and is ready at the end of July 2015. Of the total 120 kilo ton of plastic in the Netherlands was (until December 2014) 25-30 kton processed in Rotterdam, this facility. The rest was exported to two other facilities just over the border in Germany. With the new expansion we think to achieve a processing rate of 80- 100 kton. Because of the developed knowledge at this plant we decided to build the second installation here. There are multiple bypasses to increase the flexibility of the streams within the facility. For example, all the PET will be transported to the new machines, because the recovery rate is higher, the old machine can be used with other settings or as backup. This knowledge was build-up though the construction of the first installation, which was an entrepreneurial risk to build based on the initial 3-year contract.
There are multiple organizations that control the process within the factory, based on surprise visits:
Sita, the company themselves, checks all input and output by weighing and visually checking the input.
ILT - Inspectie Leefomgeving en Transport (inspection of living environment and transport / logistics). ILT is doing administrative audits from May 2015.
KIWA, an independent organization that provides highly qualified certifications, checks the contents of a bale ones a month to check if it is the same as the promised output specification.

Miscellaneous:
The process is 90% automated. The process starts with a manual operation of a crane that moves 8 to 9 ton plastic per hour from a bunker to a bag shredder. Most of the plastic is collected in the specially marked 'plastic Hero' bags. The operator removes cables and big chunks of hard plastic (car bumpers) from the stream. After the first big bag shredder a smaller one follows, where all the plastic is removed from the bags and the bags are foil pieces in the stream. A sieve drum divides the plastic in different sizes. The smallest stream is sub-divided in smaller streams by a vibration separator. This gives a rest stream that is discarded and a stream with bottle caps, which is transported back for further separation. A wind shifting machine sucks the foils out of the stream with an 80 – 85% success rate. A ballistic separator removes the plastic trays from the foil stream that slipped through the wind shifting machines. Than a magnet removes metals and a first NIR removes laminated carton. Removing the material that you want from a stream is called positive recycling. An eddy current machine now removes aluminium from the plastic stream. The laminated carton and aluminium are filtered with a negative recycling step, where after they comply with the DSD standard and are ready to be pressed into bales.
The PET, PP and PE are the remainders in the stream. A ballistic separator removes heavy hard plastics from the light packaging material. A series of positive recycling NIR machines create sequentially the mono streams PET, PE and PP. A last NIR removes some parts from the rest stream that are added back in the beginning of the process. The mono streams go through a last manual separation step that also functions as a visual check. Then the mono streams comply with the DSD standard requirements and are transported to bunkers. The bunker empties on a big conveyor belt when it is full enough and the press is empty. The press pushes the batch into a bale, which can be picked up and placed in warehouse awaiting his shipment by truck.
They do maintenance once a week for about 8 hours and every Monday morning they clean the complete installation to prevent clogging.

Appendix H - Glossary & Abbreviations

Glossary

Additives	are added to a mixture of resin to influence material specifications.
Bale	packed cube of material, normally sized so that it can fit on a pallet.
Batch production	producing in a non-continues way in stages which stop and start.
Buyer-driven commodity chains	consists of manufacturers that set up decentralized production networks in exporting countries, typically low wage countries. The most companies design and/or market branded products, but do not make them.
Chemical recycling	is chemically breaking down plastic into monomers.
Commingled plastic waste	plastic waste that is mixed with the normal waste stream.
Commodity chain	an economic chain of activities involved in design, production and marketing of a product.
Entrepreneurial surplus	extra value that can be accrued by purposive action which creates scarcity.
Economic rent	profit that arises in the case of differential productivity of factors and barriers to entry.
Economy of scale	when increasing the scale of production leads to a lower cost per unit output.
Economy of scope	when increasing the range of products produced by a firm reduces the cost of producing each one.
Feedstock recycling	see chemical recycling.
Granules	small balls that are the input material for machines that make plastic products.
Granulate	the process of making granules.
Industry converters	converting companies convert granules into semi-finished and finished products.
Intermediate goods	are input for the production of goods.
Laminar flow	fluid that streams in parallel layers, with no disruption between the layers.
Mechanical recycling	is reprocessing plastic waste by melting, shredding or granulation.
Monomer	a molecule that may bind chemically to other molecules to form a polymer.
Off-prime plastic	Newly produced plastics from oil, but not with the required specifications (off-spec).
Original Equipment Manufacturers	make a part or subsystem that is used in another company's end product.
Pellets	compressed plastic in the form of a tiny barrel. Same function as granules.
Plastic grades	different types of plastic within a sub group, e.g. HDPE and LDPE.
Plastic recovery	is collecting plastic waste and reprocessing into useful products or energy.
Plastic recycling	see plastic recovery.
Plastic resin	a type of plastic without additives, e.g. PE.
Polymers	large molecules composed of many repeatable subunits of monomers.
Post-consumer waste	waste after consumed by the end user. Could also be an industrial end user.
Post-industrial waste	waste after industrial use, e.g. residues from making plastic products.
Pre-consumer waste	see post-industrial waste.
Prime plastic	Same as virgin plastic.
Producer-driven commodity chains	have manufacturers that coordinate the production network, the backward and forward linkages.
Recovery	is any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a function.
Recycling	is any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other.
Regranulate	granules made from recycled plastic.
Regranules	another name for regranulate, but not used commonly.
Schumpeterian rent	for Schumpeter the economic rent is created when entrepreneurs innovate, creating ‘new combinations’ or conditions, resulting in returns on innovation which are a form of super profit.

Separately collected waste	waste that is collected separately from the normal waste stream, e.g. glass.
Upgrading	concept explicitly recognizes relative endowments, as distinct from innovation.
Virgin plastic	Newly produced plastics from oil.

Abbreviations

EU	European Union
EC	European Commission
FP7	7th Framework Programme for Research and Technological Development
MDS	Magnetic Density Separation
PPW	Plastic Packaging Waste
R&D	Research & Development
EU-27	European Union, limited to the first 27 member states
UK	United Kingdom
UMC	Urban Mining Corp
PP	Polypropylene
PE	Polyethylene
PE-HD	High-density polyethylene
PE-LD	Low-density polyethylene
HDPE	High-density polyethylene
SPI	The Society of the Plastics Industry
SWOT	Strengths, Weaknesses, Opportunities and Threats analysis
PEST	Political, Economic, Social and Technological analysis
SMEs	Small and Medium Enterprises
CSFs	*Critical Success Factors*
USPs	Unique Selling Points
PET	Polyethylene terephthalate
DSD	Duales System Deutschland standards
DKR	Deutsche Gesellschaft für Krieslaufwirtschaft und Rohstoffe standards
ILT	Inspectie Leefomgeving en Transport
MFR	Melt Flow Rate
MFI	Melt Flow Index (same as MFR)
NIR	Near Infra-Red
OEM	Original Equipment Manufacturer