

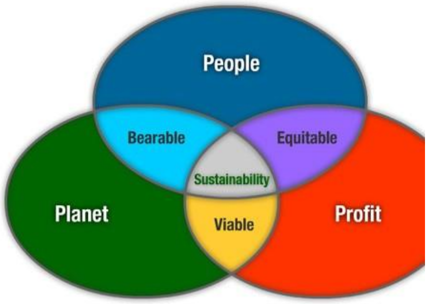

The circular economy in the port area of the Netherland and Vietnam: A case study on the sustainability of the export of recyclable plastics to Vietnam.

Master thesis in Urban, Port and Transport Economics Erasmus University Rotterdam

Tim van Zwieteren 356498

Supervisor: Dr. B. Kuipers Erasmus School of Economics

Second reader: Dr. E. van der Laan Erasmus School of Management

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Abstract

Due to different laws and non-matching supply and demand in some countries, is not an uncommon practice to ship waste stream from one country to another. This is not any different in the plastic industry. European plastic recycling B.V. is a Rotterdam based company than ships recyclable plastic from the Netherland to Vietnam. The activities related to this business have negative externalities such as, the emission of greenhouse gasses and lower social circumstances, but on the other side a higher profit.

This paper investigates in total four cases of incineration and processing LDPE with 98/2 and 80/20 quality in the Netherlands and Vietnam. All the cases save emissions, but they are not all profitable. It was found that processing in Vietnam is more profitable, but also more polluting. The extra emissions are monetized and internalized. After, it was still more profitable to export the activities to Vietnam.

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1. Introduction

In this part, the introduction to this research project will be outlined. The main topics will be discussed and linked together. Following this, the problem analysis, the research question in combination with the sub-questions will be covered. Finally, research strategy, research structure and relevance will be mentioned.

Sustainability is a hot topic these days. The meaning is this concept is not always clear. According to the Oxfort dictionary it means “Able to maintain a certain rate or level” (Oxford dictionary, 2015). To the masses it means for example; save the planet, have more green energy and reduce our waste. But to make something sustainable we have to think a couple of steps ahead. The first step is to realize the importance of the three P’s (planet, people and profit). In the ideal sustainable world, each one of these three subjects is taken into account and is harmonized. This can be accomplished in a closed loop supply chain where a company collects, remanufactures and uses certain parts again, which is profitable at the end. Or the company wants to improve their reputation via a greener image, which will give them more profit via sales. This is imperative because without any form of financial benefit, most companies will not concert about the environment if their business model is not profitable. The third P, which is people, is important because we also have to take the social aspect into consideration. This can be related to, for example good working environments and a decent wage for the employees. Some bad working condition are considered as not acceptable. For example: child labour or life-threatening circumstances. Others are acceptable but they have to be taken into account as a negative externality. To reach sustainability, a circular economy is needed. A circular economy means that all the used materials have to be collected, separated, and reused again in the most efficient way possible. This new economy has to condemn the ‘take-make-dispose’ economy to the realm of history books.

Port areas consist of a wide variety of companies that in a large number of cases support each other someway or another. By-products of production are shared, knowledge hubs are formed and companies have a tactical preferred position. Certain kinds of industries benefit from forming these kinds of clusters. Examples are the shipping-, petrochemical- and circular economy industry. It can be said that all these different industries form a small cluster in the big cluster.

A trade-off in the circular economy regarding the three P’s is the global waste transportation. This has a negative effect on the environment because transportation expels CO_2, but it has a positive effect on the profit side. This research will study a couple of cases to find out how the pros weight against the cons. In total, four cases will be included. A wider explanation of this problem will be formed in the next paragraph.

This paper is written in a combination with an internship at European Plastic recycling B.V. This company is located the Rotterdam area and it exports recyclable plastic from the port of Rotterdam to other destinations. These recyclable plastics are mostly homogeneous LDPE and PP plastics recovered from the industry. It is a new company with the initial goal to only export to Vietnam. It is interested in facilitating this thesis for mostly the following three reasons. First, it wants to use this report as support for getting finance. Second, EPR values sustainability and it wants and it is interested in this report itself. Third, they are looking for a future employee, which could possible be undersigned. Unfortunately, it is now searching for other export destinations. Even though they are currently not exporting directly to Vietnam, they do export indirectly with a third party. In the future, they will try again to export to Vietnam directly. Due to this future ambition, EPR is still willing to provide and internship and help with all the necessary information. It is interested in this research mainly for two reasons.

1.1 Problem analysis

This paragraph will give a deeper explanation of the problem. As stated in the introduction, there is a trade-off in the recycling industry. Certain goods are exported across the world to be recycled. Examples of worldwide traded recyclable goods are trash and steel. This has positive and negative consequences. It is expected that the profits and emissions are both higher. Besides the emissions and benefits, other externalities are possible. Knowing this, it is not sure if it is sustainable to have a worldwide recycling scheme. This paper will only focus on one stream, but this framework can be used for any other type of recyclable good. In this thesis, four comparing cases will be investigated. For comparing the emissions, only the greenhouse gas (GHG) CO_2 will be taken into account. This GHG is the main reason for global warming and thus from utmost importance (Peters, Andrew, & Boden, 2013).

To go deeper into this problem an analysis has to be made from beginning to the end. As mentioned in the introduction, it is important to have a circular economy. To have this type of economy, all the used materials have to be collected, separated and used again in a most efficient way. The most efficient way of handling used material is describes by the ladder of Lansink. This theory orders this as follows: prevention, re-use, recycling, energy combustion and disposal. When looking at this ladder, recycling seems to be the best option for plastic when it has been disposed after usage. But this does not automatically make it the best option. Within recycling there are different ways of how and where this process is executed. This thesis will mainly focus on the “where” variables. It will investigate how these “where“ variables will influence the sustainability of the recycling process.

To find out how the recycling location will influence the level of sustainability, the following four issues have to be addressed. The first issue is the exportation from the Netherlands to Vietnam. For this transport, shipping is the preferred mode because of the low marginal value of time. This means that the value of the cargo does not lose value over time. Since shipping is a slow and relatively cheap mode of transport, it is the preferred option. One case will use railing; this transport mode is included because it is expected to have the lowest emissions. Since there are many empty containers moving from the Port of Rotterdam to Asia, it can be argued that the only extra emissions will be caused by the extra weight of the cargo. Besides, in comparison to the inbound moves of the recycling installation, the outbound moves also have influence on the amount of emissions expelled. To also take this into account, information about where this recycled plastic is sold has to be gathered from both countries. It is imaginable that recycled plastic in the Netherlands is transported to Asia or the other way around. If this is the case, it is possible that the materials are transported around the world twice before it is used as raw material. The second issue is the reason why companies are willing to put the extra effort into exporting. Because apparently, there is a reason that it is more profitable to get this material processed in on the other side of the world instead of close to home. The third issue is the social differences. It can be assumed that the work conditions are better in western world in comparison the Vietnam. This can have a negative external effect. The last issue are externalities in addition to the emissions caused by transport. From the literature study, empirical research and information gathered from EPR and other third parties, possible negative and positive externalities will be gathered.

1.2 Research question

To argue the sustainability of this business case, the main research questions is:

How sustainable is it to export recyclable plastics from the Netherlands to Vietnam and how does this business contribute to the circular economy cluster in ports?

To answer the main research question of this paper, some sub-questions are formed. The sub-questions are:

- How much extra emissions are expelled when plastics are processed in Vietnam compared to when they are processed in the Netherlands?
- Is it more profitable to recycle in Vietnam compared to the Netherlands—including external costs?
- Are there any social differences between recycling in Vietnam compared to the Netherlands?
- Which other externalities occur alongside with this business? If so, how do they influence the sustainability?
- Are the port area’s in both countries attractive for the biobased and circular economy?

1.3 Research strategy

Multiple research methods are used to answer the main question. An internship combined with desk research and interviews with experiences people in this field of work. The desk research consisted mostly of reading scientific journals, relevant reports and background information about the subjects. The internship gained me insight in the business and gave information from the company. Finally, I had contact with several recycling companies in mostly the Netherland and some in Belgium, Vietnam and China.

1.4 Research structure

The first chapter of this paper gives a short introduction. It explains the problems, main question and sub-questions of this research. The research strategy, structure and as last the relevance are discussed as well. Chapter two and three will contain the literature on the following topics: The circular economy and the circular economy in seaports. Chapter four and five will discuss the circular economy in general and in seaports in the Netherland and Vietnam.

Chapter six will describe the case study. Chapter seven will contain the data, cases and methodological framework. Chapter eight will present and discuss the results and include as sensitivity analysis. As last, chapter nine contain the conclusion and limitations.

1.5 Relevance

As a consequence of humans living on the earth, it is believed that this has influence on the health of the world. This is due to the use of resources and extensive pollution. Plenty of academic research has proven this causation. Examples are: paper of human activity on climate chance (Pittock, 2009), pollution of the seas (Slat, 2014), marine life (McCauley & Pinsky, 2015), mammal extinguishing (Hayes & Hayes, 2013) and human health (McMichaela, 2013). It broadly believed that the humankind cannot continue in this way without getting into trouble. Due to this reason, more research is needed to find a better way to sustain the world.

A worldwide environmental problem is plastic solid waste (PWS). This problem is caused by the non-biodegradability and the massive worldwide usage of plastic. After usage, it is should be collected and recycled. In most developed countries there is a recycling system, but despite these systems, there is still a lot of plastic ending up in nature. Even when plastic is recycled, it is not always the optimal solution. There are different recycling options which all have different specifications and conditions.

The biggest problems within the plastic recycling industry are the homogeneity and the purity of the product. There are several different types of plastic and when they are mixed, it has to be separated first before recycling is possible. Despite the present technology to do so, a lot of plastics are still burned for energy. Purity of the product means that even when the different types of plastics are separated, they are still differences in colour. If it is mixed, it is not possible to make a homogeneous coloured recycled product. Due to these problems it is important to find better or more environmental ways to recycle plastic.

One major variable of how environmentally friendly the plastic is processed depends on where it is processed. A lot of different types of trash are transported around the world to get recycled. The method used in this paper can be used to calculate the sustainability of other sorts of recyclable good as well.

The circular economy is of great importance for as well the Dutch port as the government. As seen in section 4.4.4, all the Dutch seaports report circularity in their vision for 2030. Besides the ports, the government has funded different institution to report about the circular economy. Also abroad there are quite some government-funded centres that look into the circular economy. Examples are the Centre of Life Cycle Analysis in the US founded in 2006. In 2013 the China Association of Circular Economy was founded. The Indian city of Mumbai got the Research Centre of Fuel generation.

1.6 Methodology

This paper will contain an instrumental case study. This type of case study is explained as follow; the investigation of a case with the goal to understand and get insight about a related phenomenon (Stake, 2000) and it is an intensive and detailed research of a precise described and bounded phenomena. Thus, it is not completely focussing on the case itself, but the goal of this type of research is to understand what is related to the case (Luck, Jackons, & Usher, 2006)

There is no well-defined set of methods that have to be used for a case study like this; therefore the chosen methods are based on their capacity to meet the demand of the research and the ontological and epistemological choices of the researcher (Stake, 2000). In this study, the case describes the export of recyclable plastic to Vietnam, but the phenomenon that is related to this case if the sustainability of the worldwide trash networks.

2. The circular economy

This first part of the second chapter describes the circular economy. It includes what the circular economy is, why our economy is transiting towards it, what kind of new business are formed in this economy and on what scale they operate. At the end the bottlenecks and potential downsides are discussed.

The circular economy means that all the resources in the world have to be used as efficient and often as possible. It appears that the linear economy that has been used before is obsolete. This new economy is mainly caused by higher raw material prices, which on their turn are the result of a number of other causes (Ellen MacArthur Foundation; The, 2013a). Besides the linear system there are other drivers that direct our society towards this new economy.

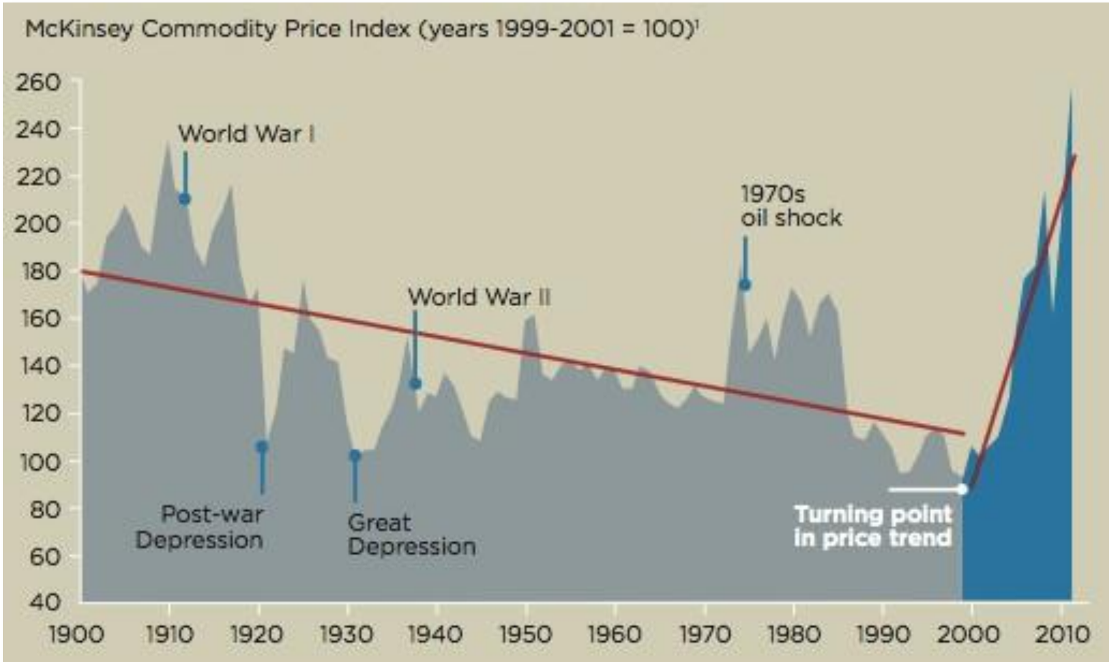
2.1 The turning point for the circular economy

2.1.1 Take-make-waste economy and its consequences

The western world has enjoyed many decades of steady economical growth and welfare. One pillar of this wealth is the intensive and unlimited usage of world' resources without taking into account how to handle these resources after usage. This type of economy is also called the take-make-waste- or linear economy (European commission, 2011). In 2000, this way of living began to show its flaws. As seen in figure 1, commodity prices skyrocketed. According to the report of the Ellen MacArthur Foundation (2013a), this increase is due to the rising demand for metals, which is mainly driven by the growth of China (Yu, 2011), the exhaustion of easy-to-reach reserves for oil and gas, political shocks and the innovation in financial markets.

As an effect of these causes, there was an increase in demand for raw materials. Which again had a huge impact on the health of the world. This is due to the fact that some resources are limited and/or others cause extensive emissions. If the worldwide economy will not make a structural change in how it uses these limited available raw materials, it could exhaust them in a couple of decades (Kok, Wurpel, & Ten Wolde, 2013). This fact will lead to a dual challenge. On the one side, economic growth has to be established, but on the other sides, the sustainability of raw materials in the world has to be controlled. To succeed in this challenge, fundamentally changes within the generation of energy, the industry, agriculture, fisheries, logistics, producers and consumer are needed (European commission, 2011). In other words, this transition consists of going from a take-make-waste economy to an economy where resources do not get wasted, but get reused in an environmental friendly matter.

Figure 1: McKinsey's Commodity Price index for 2011



Source: Ellen MacArthur Foundation (2013a)

A second insuperable consequence of the take-make-waste economy is waste. Waste comes from the production chain, packages or end-of-life waste. Waste in the production chain is due to leakage, poor efficiency and spills. The end-of-use wastes are products that are not used any more (Ellen MacArthur Foundation; The, 2013a). In the European Union and in many other countries worldwide, the waste electronic and electrical equipment (WEEE) law is in force. This law states that the producer of all electrical products is also responsible to take care of the recycling of this product (Ongondo, Williams, & Cherrett, 2011).

The third problem of the take-make-waste economy is pollution and emissions. When production is taking place, this is inescapable. There are costs attached, but they are not charged to the producer. Due to this reason, pollution and emissions are negative externalities (Kok, Wurpel, & Ten Wolde, 2013). When these externalities are not internalized, an imbalanced market will be the consequence. Internalizing externalities means that the polluter has to pay for negative externalities. Because this is not the case, the costs for the products are lower and this results in higher demand. More demand, means more pollution than it would be in the optimal situation. Next to pollution there are other negative possible externalities like climate change, shortage of land, health risks and social costs like bad working environments in third world countries and child labour (Raad voor leefomgeving en infrastructuur, 2013).

The fourth consequence is the scarcity of some raw materials. A variety of bulk commodities like oil, minerals and specialized metals a getting scarce. Since the wealth in the world is still increasing, the demand of these recourses is also still rising. This will lead to more scarcity and an increase in price (Kuipers, de Jong, Meesters, & Sanders, 2015).

2.1.2 More stable future

As shown in figure one, the raw material prices around the world are volatile. Sander (2014) mentioned that high prices for oil and electricity are positive drivers for the circular economy. This is favourable because it increases the attractiveness to invest in alternatives. At present, prices for fossil fuels are low. Due to the recent low prices, this is now a negative effect. While on one side, this volatility of commodities is negative; it can also be seen as positive. It can trigger countries and companies to invest in alternatives for conventional raw materials. By doing so, they do not have to rely on unstable countries and the world economy any more; they should find a way to take control in their own hands. Recycling and reusing the materials already circulating inside the economy and using alternative sources, can achieve this.

2.2 Circular economy in theory

The circular economy is not a new term. The first economist that wrote about this principle was Kenneth Boulding in 1966. He described the circular economy as a long-term program compatible with economical growth, optimal usage of resources; sustainable and no waste (Kok, Wurpel, & Ten Wolde, 2013) (Greyson, 2006). Although it is an old term that is developed in 1966, due to recent activities, it is a popular subject at this moment.

2.2.1 The principles of the circular economy

The circular economy in an industry that is restorative by intention; it aims to trust on renewable energy; tries to keep the usage and tracks of toxic waste as low as possible or eliminate it. The focus goes beyond the mechanics of production and consumers of goods and services. This concept is conditioned with the thought of non-linear systems (Ellen MacArthur Foundation; The, 2013a). A few principles are central in this concept.

Design out of waste

Waste does not exist and it is achieved with design for recycling. Designers should not only take the function and cost into account, but they also have to take recycling, durability and possible refurbishment into consideration during the design process. When a product is perfectly designed according to this principle, there will be no waste after the product is used and handled in the right way. Natural non-toxic materials can be returned to soil, products are easy to dismantle and all the different components can be recycled. Still usable technical materials get recovered, refreshed or upgraded and used again.

Resilience

This term stands for flexibility of production. Producers have to be able to shift between different types of productions and capacities. Resilience is important due to the uncertain and fast-developing world. This new world can cause external shocks that will quickly lead to changes in the demand and quantity of products. Production systems have to be able to adapt quick, else this can lead to over- and/or under stock.

Renewable energy

Nowadays, a lot of energy is generated with scarce resources. This is not circular and because of this reason, they should be replaced with renewables.

Change in the way of thinking

Another important shift towards the sustainable economy is the shift in mind set. The industry should go from thinking in one straight line, to thinking in closed loops. A good example is the performance service. More information about this topic will be given in the next section.

Waste is food

The penultimate principle is: waste is food. The heart of this idea is that all the used biological nutrient products should be returned in a non-toxic way. The essence to create value from these types of product lies in the opportunity to gain added value from these products by using it in a different sector. A good example is the coffee industry. This sector has a yearly waste 12 million tonnes. This waste is the perfect growth media for high-value tropical mushrooms (Ellen MacArthur Foundation; The, 2013a).

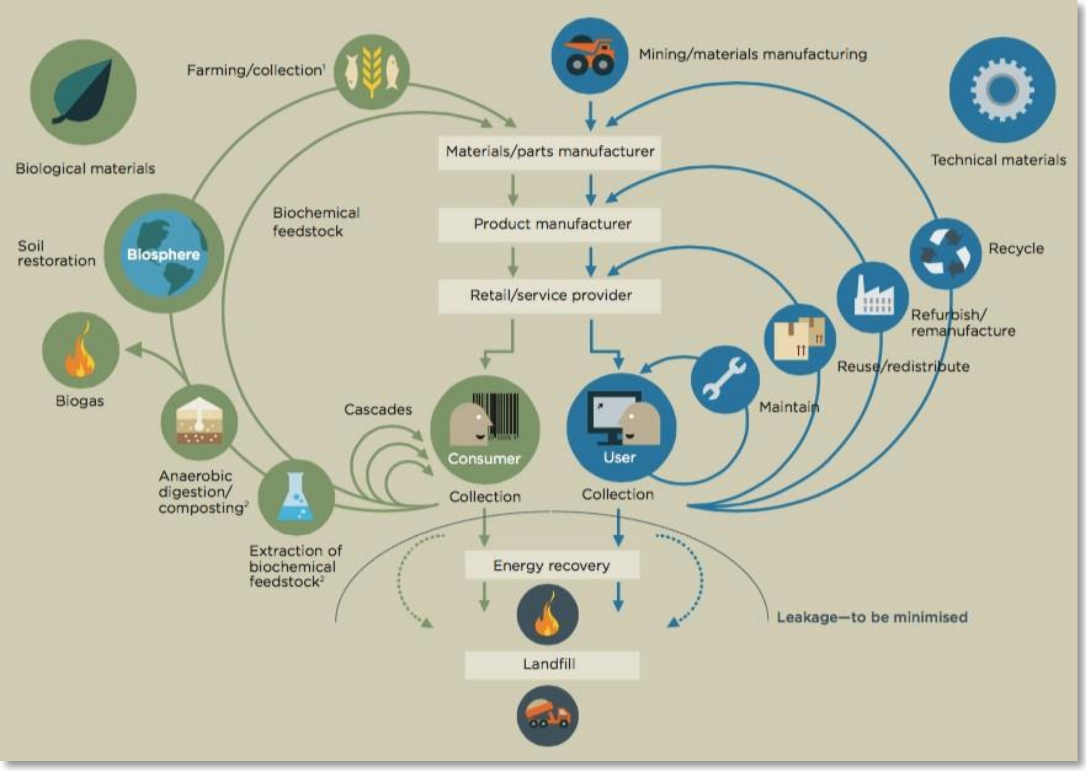
Up-cycling

Finally, when recycled, the material should be up-cycled instead of down-cycled. The difference between these two forms of recycling is the quality of the recycled material. If this material has less quality after the recycling process, it has been down-cycled and vice versa (van de Westerlo, 2011).

2.2.2 Bio- and technosphere

The principles regarding the circular economy are visualized by the Ellen MacArthur foundation in figure 2. This figure illustrates two loops, the biosphere and the technosphere. The first represents the biological nutrient based materials. The goal of this sphere is to keep the loop short and to maximize the energy and quality, i.e. for every nutrient that enters this loop, it is important to optimize the quality and energy recovery. The ladder of Lansink is used to determine the optimum (Bergsma, Vroonhof, Blom, & Odegard, 2014). On the right side of the figure the technosphere is visualized. This contains all the man made materials. Here, it is important to close to loop, i.e. the design out of waste principle (Ellen MacArthur Foundation; The, 2013a). For this sphere, it is also crucial to keep the loops as short as possible. As seen in the figure, first try to maintain the product and after comes reuse/redistribute, refurbish/remanufacture and finally recycling. In this research, the biosphere can also be referred to as the biobased economy.

Figure 2: The circular economy



Source: Ellen MacArthur Foundation (2013a)

2.3 The circular economy in practice

This chapter contains some practical applications of the circular economy. It includes the topics: the performance economy, closed loop supply chains, recycling and the energy supply.

2.3.1 Performance economy

The circular economy will lead to a sharp distinction between the ownership and the usage of the product. It advocates for a "function service". With this kind of service the retailer becomes a lessor and service provider. This is the most practical for household products like washing machines and refrigerators. When the product is broken, the lessor of the product is responsible to repair or replace it. These schemes promote an efficient and effective take-back system and they stimulate product designers to design for recycling and design to last. Design to last means that designers optimize the product life span. This results in lower repair- and replacement costs, but the lessor does not lose profits. Before, sellers want to optimize sales volume. Due to this reason, machines where designed to fail. This leads to more end-of-life products and thus more sales volume. Because the sales volumes drop, fewer materials are needed for production (Ellen MacArthur Foundation; The, 2013a).

Nearsourcing is an important issue for service providers to minimize costs (Manyika, et al., 2012). Firms want to stay in control over their valuable goods and keep the costs low. To do so, they prefer to have the companies' assets and the needed companies in the close region. For example, have recycling companies nearby for when the machine is end-of-life and the production and/or refurbishment in a close region (Raad voor leefomgeving en infrastructuur, 2013).

2.3.2 Closed Loop Supply Chain process

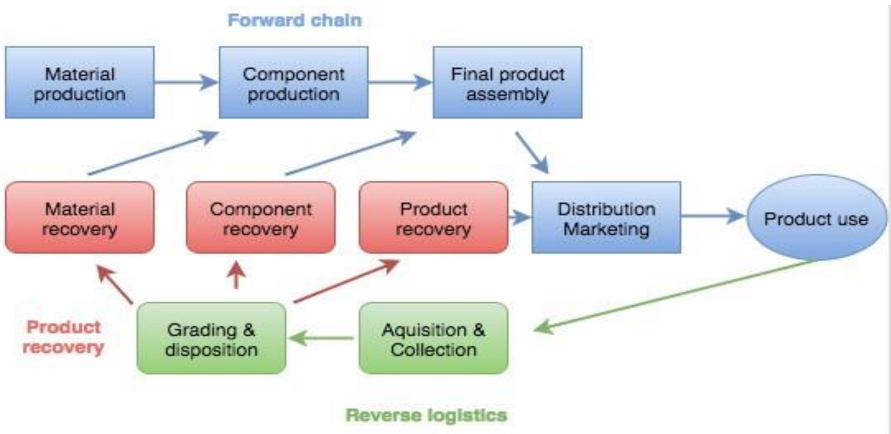
A closed loop supply chain is part of the circular economy. It is the study that focussed on turning open production loops into closed loops. The definition by Atasu (2008) is as follows:

" The design, control and operate of a system to maximize value creation over the entire life-cycle of a product with dynamic recovery of value from different types and volumes of returns over time".

This field of study is based on the design, control, operate, collect, recycle and reuse of the sold product inside companies. For example: Thierry (1995) investigate the new green Xerox copier line. This paper led to eight managerial implications to improve the entire chain.

A basic reverse logistics supply chain is build up as seen in figure 3. First, the product is made with virgin material in a normal forward supply chain. At the end of this chain the product is end-of-life and the forwards supply chain ends. This is also the starting point of the reverse chain. The products enter this chain when the user disposes it. After collection, all the products are graded and send to the right place further treatment. Products can be graded as material recovery, component recovery and product recovery. After the product is processed, it is key to re-market the recovered parts. As seen in the picture, the different components go to different stages in the forward chain to close the supply chain loop (Geyer & Jackson, 2004).

Figure 3: Standard reverse logistics scheme



Source: Geyer & Jackson (2004)

2.3.3 Energy and biobased economy

When transitioning to a circular economy, both the energy supply and demand will have drastic changes. The supply will make a shift from fossil fuels to renewables and the total demand will decrease.

The first discussed effect of the circular economy is the reduction of energy demand. This is mostly due to less production and more secondary materials. One of the consequences of a product service is the reduction in production volume. Before, products got designed to fail, where, in this new economy they are designed to last. The second reason for energy reduction is the increase of secondary materials. One of the side effects is reduction of energy use. This is primary caused by the lower energy needed for recycling in comparison to mining new raw materials. This is especially the case for metals, for example, recycling steal uses three and a half, copper uses five to seven and aluminium uses approximately 20 times les energy than virgin material (Wernick & Themelis, 1998).

The second effect of the circular economy on the energy supply is the increased usage of renewable energy sources like solar- wind energy. To minimize material input, all the generated energy should be from renewables. Since fossil energy sources like oil and coal are scarce and polluting, they cannot be used infinitely and are not circular. In this philosophy it is believed that resilience in the energy supply is important. It is crucial due to the fact that there are peeks in the demand for energy. Resilience in the energy supply can be reached with the following measures. First it is important to use diverse- and decentralized energy generation. This can be accomplished by avoiding large-scale utilities that control the peek price. Secondly, avoid scarce and non-renewable energy sources (van de Westerlo, 2011).

Besides electricity, companies in the biosphere branch use biological based material to make other energy sources like bioethanol, biofuels and biogas. It uses crop starch, vegetable oils, residual proteins and cellulose (from wood and straw) to produce products like lubricants, solvents, polymers, surfactants and chemicals that are usually made from fossil fuels. (Langeveld, Dixon, & Jaworski, 2010)

2.4 Bottlenecks of the circular economy

In theory, the development of the world towards a circular economy looks easy and the achieved results look promising. But, there are many bottlenecks that hold the circular economy down in the development. These bottlenecks can be divided into five groups. These obstacle groups are: financial, institutional, infrastructural, societal and value-related and the technological, knowledge and data.

Financial obstacles

To make a change from the linear economy to the circular economy, big up-front investments are necessary. For decision makers it is hard to make a calculated decision on how to invest their money. Macroeconomic analysis predict hundreds of billions of euros of profit (European Comission, 2013), but this are just predictions on a not well developed industry. An example is the product service model. Big investments are required in comparison to a normal transaction model. Nowadays it is already hard to get funding for “normal” companies, it is even harder for companies that want to invest in a new business with high risks (Ellen MacArthur Foundation; The, 2013a).

Besides the high costs for investment, operational costs can increase as well. Effort has to be put into innovation, inventory planning, production planning, distribution planning and managing of the reverse logistics. Besides, in most of the cases, recycled materials are even more expensive than non-recycled ones, mostly due to economics of scale (Sarkis, Helms, & Hervani, 2010).

Institutional obstacles

Politicians often show sympathy towards the development of the circular economy, but unfortunately there are still many rules and regulations that obstruct the development. This will not lead to a level playing field. Politicians do not try to block the development, but the problem is the out-dated legal system. It is often still focussed on the linear thinking, instead it circular (Jonker, 2012).

There are many of these obstacles, but only two will be discussed here. In most developed countries, labour is relatively high taxed in comparison to material consumption. Since a product service based business model needs relatively more labour than a conventional selling business model, taxes can rise dramatically (Ellen MacArthur Foundation; The, 2013a). The second institutional obstacle is the anti-cartel forming law. It can be beneficial for companies to share market information and work together to start a new business that can be profitable for all the stakeholders. But due to laws against sharing information and working together, this is not possible (Recyclingmagazine.nl, 2012).

Lack of developed Infrastructure

To have a successful closed loop, the infrastructure of the forward supply chain and the reverse supply chain has to be well developed. Because the reverse logistics is quite new, this part of the loop is often underdeveloped. And till now, it is not developing as quick as hoped for. This is partly due to the lack of interest of companies to be a first mover. Besides, there is a lack of success stories of businesses that implemented reverse logistics into their business model. This will lead to uncertainty for companies that consider making the first step (Kang & Wimmer, 2007).

In the new product service business, lease contract can be complex and cause uncertainty. It requires a new pricing mechanism and without a lot of experience, it is hard and cost intensive to construct such a new contracts. Companies do not know how consumers will take care of the product and their behaviour is not constant. (WBCSD, 2011).

Societal awareness and vested companies

In today's society, product ownership is a part of peoples' self-esteem (Tukker & Tischner, 2004). This is severely slowing down the transition towards a performance economy for two reasons. People are not interested in leasing and this will consequently lead to low priority for policy makers. Because their priority is low, they will not have a high incentive to stimulate measurements that will help this industry.

The most important macroeconomic measurement of a countries financial success is the gross domestic product (GDP). This measurement is mostly focussed on the linear economy and not on the circular economy. It calculates the flow of money inside the economy and does not take into account how this money is made. This is not a stimulus for policy makers to encourage the transition (Lawn & Clarke, 2010). The problem is caused by the lack of sufficient knowledge of material and energy indicators, no transparent auditing, and not standardisation on measuring social impacts. To have a better performance measurement of a country, these aspects have to be fixed (Geng, Fu, Sarkis, & Xue, 2012).

The last social problem is the established order. Most of these companies do not or cannot adapt to this new economy and they try to barricade this development. They will lobby to control politics and improve their existing product to fight against the new order (Rotmans, Kemp, & van Asselt, 2001). Policy maker can resolve this by internalization of externalities or chance the subsidies for resources (Pauli, 2007).

Technology and culture

An issue of today is the available products on the marketplace. A big percentage is not designed for reuse. This, together with the limited sorting technologies makes it hard to separate efficiently (Wurpel, van der Akker, Pors, & ten Wolde, 2011). This is a result from the lack of knowledge on circular design. It is often the case that engineers do only take the physical attributes into account and forget the user and recycling part (Maussang, Zwolinski, & Brissaud, 2013). These two barriers lead to another problem, namely the lack of the right quality and quantity of recycled materials. This, together with the current recycling technology leads to a deficit in recycled raw materials (Andersen, 2007).

The last barrier is the linear culture. Because it has been around for, the whole infrastructure is set thereon. This makes the transition hard because decisions made in the past determine to a certain level the possibilities of today (Runhaas & Driessen, 2007). Besides, new laws and regulations are mostly made to improve efficient and incremental innovation. This way of thinking is not improving circularity; they only try to make linear production less bad (Grayson, 2007).

2.5 Downsides circular economy

The development towards a circular economy does not come without criticism. In this transition, the biobased economy is probably the most controversial. It has two potential downturns, namely the food versus fuel and palm oil discussion. Regarding the circular economy, some conspiracy theories are known regarding the monopoly position on certain materials.

Some people believe that fuels derived from plant-based feedstock are taking away food from people in the poorest countries in the world. Because agricultural products are used for fuels instead of feeding it to people, there will be a higher demand, which leads to higher food prices. These higher prices will eventually make it harder for these poor people to buy food. There are plenty of reports that contradict this believe like Thompson (2012) and Langeveld (2010), but the Institution for European Environmental policy (2014) made a statement against the public support of biofuels generated from food stock.

The second issue regarding the biobased economy is the production of palm oil. Since this oil is by far the most cost efficient, it is seen as the future of biofuels. But, palm oil is also known for it’s big impact on deforestation. Especially in Indonesia and Malaysia, the two countries with the highest palm oil production. Although it is sure that this oil causes deforestation, there is still a lot of uncertainty about the exact impact (Koh & Wilcove, 2008).

The need to control rare metals is a big issue at the moment. The circular economy is helping to prevent the lost of these types of materials. Especially the design to recycling principle is encouraging to retrieve most of these materials. There is also one possible downturn. An industry source mentioned the risk for monopolies on certain resources that are encouraged by the service economy. As an example, he mentioned Johnson Control International (JCI). This is the largest producer of electrical car batteries. To produce these batteries, lead is necessary. Because JCI is performing a closed loop supply chain on a high level, they control a large part the worldwide available lead. Besides JCI, China is also trying to control the rare earth metals (REM). REM’s are a set of seventeen naturally occurring non-toxic materials that play a big role in the high tech devices all over the world. At this moment, they are mostly owned and exporter from China. It is estimated that the country hold as high as 97% of the world production (Global Policy, 2014).

3. The circular economy in seaports

The second section of the literature contains theoretical information about the circular economy in seaports. This discussion will include why ports are ideal settling spots for circular economy related companies and what types of companies those are.

3.1 What makes seaports attractive for the circular economy?

The locations factors (LF) for a firm depend on the type of company. Since the CE can be divided in the techno- and the biosphere, there are different location factors for both sectors (Kuipers, de Jong, Meesters, & Sanders, 2015).

Location factors biosphere companies

- Presence of a developed infrastructure;
- Proximity to the production of organic material (input) and customers (output);
- Proximity to the a port with a big capacity to attract biobased streams;
- The presence of a wide variety of biobased production facilities; potential synergy;
- The presence of trading desks and circular events;
- An entrepreneurial and innovative environment;
- Collaboration between companies, government and universities (especially at the early stage of development);
- Supporting policies (both the port authorities as the government);

Locations factors technosphere companies

- Presence of a developed infrastructure;
- Proximity to the a port with a big capacity to attract input streams;
- The presence of a wide variety of waste treatment facilities; potential synergy;
- The presence of trading desks and circular events;
- The presence of specialized companies and the possibility to produce and/or treat products that are not directly shipped on a big scale;
- Proximity to a city with an extensive waste production;
- An entrepreneurial and innovative environment;
- Collaboration between companies, government and universities (especially at the early stage of development);
- Supporting policies (both the port authorities as the government);

3.2 Which types of circular businesses can be found in the port area?

As mentioned in the paragraph before, different CE related companies want to settle themselves in port related areas for different reasons. This paragraph will focus on the different types of companies for which it can be attractive to be located in a port area.

Recycling industry

Port areas are attractive for the recycling industry. The main reason for this is the proximity to big cities, industries and the sea terminals. They are the providers of the supply for the recycling installations. The feedstock provided by big cities and the industry is generated locally. The sea terminal generates international feedstock. Besides the input, proximity to output is important. The presence of industrial production facilities can improve the attractiveness of an area.

Circularity hub

To change the economy from linear to circular, a holistic approach is needed. In this transition, a leasing concept will develop. Here, the lessor stays the owner of the good and the customer pays a fixed price per month. For this price the seller is responsible to repair or replace the product when it breaks down. To realize this new type of service, it is crucial to minimize the total chain costs. This can be realized via nearsourcing and keeping related companies as close as possible. In an ideal situation, it is possible to recycle, transport, store, repair and produce in the port area. But, this is most of the time not the case in ports located in developed countries. Especially the production is often found in countries with low wages (Manyika, et al., 2012). The nearsourcing trend is causing European companies to take their production from China to Turkey and American companies to produce in Middle America (Fossey, 2012).

Bio Industry

For biobased companies there are the opportunity to replace fossil fuel streams, it can import feedstock and buy by products from other companies as input for the machines (Stevens & Vis, 2015). Besides the bio fuels, other ecological based companies can be attracted to the port. For examples: biomaterials, bio chemicals, pharmaceutical products and bio plastics. Although the potential for this cluster looks promising, there is still a lot of uncertainty. This is mostly due the uncertain economical feasibility, unfinished research and the still undeveloped markets (Kuipers, de Jong, Meesters, & Sanders, 2015).

Trading desks

An important driver to develop a circular industry is the presence of commodity trading desk. Since most of these desks are vertically integrated, they control the whole chain. If an office is closely located to a port, it will give that port a competitive advantage over others (Jacobs & Huijs, 2015). Because they have such an influence on where these commodities will be transported to, it can attract other companies.

A group of sixteen firms control more than half the world's traded commodities. They are taken into the " Trillion Dollar Club" from Reuter. Their annual revenue combines is higher than one trillion dollar. Most members of this group are located in tax havens like Switzerland (Reuters, 2011).

Start-ups and knowledge institutions

The presence of universities, incubators and companies with high R&D will provide an innovative environment that attracts more business. It is of great importance for both the biobased and circular economy. This type of environment leads to new products, processes and services for both industries. Besides attracting new business, it stimulates new start-ups (Kuipers, de Jong, Meesters, & Sanders, 2015).

4. The circular economy in the Netherlands

This third chapter will discuss the CE in the Netherland in general and in seaports. It will first cover the location of the CE, followed by the role of the government, the current performance and finally in the seaports. At the end there will be a conclusion.

4.1 The Netherland in General

Rotterdam and Amsterdam are probably the biggest two circularity hubs in the Netherlands. Due to their urban environment, industry and ports, they have big opportunities. At this moment they built up a good international reputation due the fourth place for Amsterdam and fifth place for Rotterdam in the ARCADIS sustainability world index (Arcadis, 2015). The city of Amsterdam has the ambition to become a complete circular city. To reach this goal, it applies a circle scan method. This method sees where materials and resources in the city come from and where they enter the city. After, the usage is analyses and they can make that loop circular. The city of Rotterdam has started its own program named the Rotterdam Climate initiative (RCI) and the port of Rotterdam started the Circularity Cluster (CC). These two programs must help the city improve the environment and the circularity in the city. More information about the circularity in the ports of Rotterdam and Amsterdam will be covered later.

At this moment, there is an innovation paradox in the Netherlands. This is caused by high research & development, but low implementation. The province of Brabant is named as one of the highest innovative areas in the world, but this is mostly due to the high private investments in the high tech campus in Eindhoven. The domestic application of this developed technology is still limited (Tomor, 2011). Especially the R&D for the biobased economy is highly developed (Kuipers, de Jong, Meesters, & Sanders, 2015).

Despite the relatively low applications of the new knowledge, there are plenty of CE examples starting up or are already implemented in this country. The Netherlands has the presidency of the council of the European Union in the first half year of 2016. During this period, one of the main pillars in this campaign is to show how the Netherlands is developing the circular economy as a hotspots industry (duurzaam-ondernemen.nl, 2015).

4.2 The Dutch government

The government plays a role in the transition towards circularity. It controls rules and regulation, subsidies and other kinds of support. Most of the current laws are still focussed on linearity instead of circularity.

Since the Netherlands is part of the European union (EU), it is not completely autonomous in creating its own laws. First, the influence of the EU will be discussed, after this; the policy of the Dutch government will be covered.

The influence from the EU

Regarding the laws and regulations for the circular economy and the environment, the EU has a quite big influence. This is due to the importance of this topic on the entire continent. Since the followed policy of a country can have environmentally and economically consequences on others, the EU finds it important to have it centrally controlled. When this control is central, the damage on the environment can be minimalized and the economical benefits can be optimized.

In July 2014, the European commission accepted the Circular Economy Package. This package was communicated in the rapport " Towards a circular economy: a zero waste programme for Europe" in combination some additional communications regarding green employment, actions plans for small and medium enterprises, sustainable building and legislation regarding waste. This total package got withdrawn due to some flaws regarding the exclusive focus on waste management without exploring synergies and the lack of country specific instruction. It is expected that the new circular economy package will be published at the end of 2015 (European Union, 2015).

The vision of the Dutch government

The Dutch government is actively trying to stimulate the circular economy. They put effort into closing loops, reduce waste, recycle and make it easy for companies to collaborate with them. The vision regarding the CE was given in a publication from March 2013 "Green growth: for a strong and sustainable economy" (Ministerie van EZ, 2013a). This vision contains the ambition to have a 16 per cent sustainable energy supply by 2020 and have it completely sustainable by 2050. To meet this and other ambitions, the government wants to use four pillars. First, internalize external costs of the product or service without disturbing the level playing field. Second, stimulate rules and regulations to work in favour of the circular economy. Third, stimulate innovation. Fourth, have the government as a partner towards a sustainable economy. If companies face governmental related problems, they can cooperate with the government through a green deal. These deals have the ambition to lower barriers (Ministerie van EZ, 2013a). There are multiple specific publications from the government regarding this subject: more value from waste (Ministerie van I&M, 2011), reuse and monitoring of packaging (Ministerie van I&M, 2014a), waste to material (Ministerie van I&M, 2014c).

As well as the environment as the economy are profiting from a developing circular economy. The economy can grow and there will be less pollution. NTO (2013) calculated the profits for both. Economy wise, there is an opportunity to increase the Dutch economy, in more than seven years, with a total of 7,3 billion euro and it can create 54.000 jobs. Besides, there are also some spin-off opportunities regarding the increase in knowledge. Regarding the environment, the potential reduction in emission is: 17.150 Kton CO_2, 2180km^2 of land use, 0,7 billion m^3 water and 100.400 Kton materials. The Ellen MacArthur Foundation (2013) made the same calculation regarding the European economy. In this publication, the total value for the European circular economy is valued at 380 billion, but in a transition economy is can reach 476 billion.

4.3 The Circular economy in the Netherlands

To describe the Dutch circular performance, there are different types of parameters to include. This is a lot of information. Since the focus of this paper is on the industry, waste management and ports, the discussed topics will all be related to these three subjects.

4.3.1 Overall performance

Since 2010, the global green economy index is a yearly-published report by Duel Citizen (2014). This report measures the national green economy performance for 60 countries. It focuses both on the real performance as on the perception of the performance. In this report, the Netherlands did not score very well and they where mentioned as a negative emerging trends. Together with Australia, Japan and the United states, the perception of the green economics of these countries is far higher than the actual results. The Netherlands scored a 5th place on the image part and a 21th on the performance part. Compared to other countries, the Netherlands is primarily lacking behind in leadership and climate change. This index looks at the Netherlands as a whole; it combines the businesses, government and people. These three parties are basically in a triangle. They all have to contribute to improve the circular economy and if one does not cooperate, the effort of the others will be diminished. Due to the 21th place, it seems like the state is not doing a good job. But this low performance can also be due to companies and/or people.

4.3.2 Companies

It is not easy to measure the circularity of companies in a country. One of the possibilities is to look at sustainability indices and other worldwide sustainability lists. An important index is the Dow Jones Sustainability index. This index makes a distinction in 24 sections. In 2014, three Dutch companies where leading in one of these sectors (RobecoSAM, 2014). This is relative high when the size of the Dutch economy is compared to the other countries. Another important list is the Global 100 most sustainable corporation in the world. In 2015, the Netherlands had three representatives, namely Koninklijke Philips Electronics, Wolter Kluwer and ASML Holding. Compared to 2014, the Netherlands had four companies in this list and two companies have lower rankings than a year before. This year, Royal Dutch Shell was not included. For comparison, the two northern American countries, the United States (20) and Canada (12) have a surprising large amount of representatives. Other comparable European countries are Sweden (4), Norway (3), Germany (5), France (12), Finland (5) and Denmark (3) (Corporate Knights, 2015). When the Netherlands is compared to the others, the performance is on average. Germany performs poor with only five rankings. These sustainability lists, do say something about the trend in a certain country. It does not give a very clear view about the sustainability of the entire country because it only looks at the top firms.

Innovation is a good measurement of sustainability. It is a good benchmark because to become sustainable, companies have to innovate. If companies stay the in a "business as usual" state-of-mind, nothing will change. The Netherlands always has a good name when it comes to innovation. For 2015, the Netherlands has the fourth place on the global innovation index (2015), up from fifth in 2014, and an increase of five places compared to 2011. According to this report, the strengths of the Netherlands are the institutions, creativity and knowledge & technology outputs. The weaknesses are human capital & research and market sophistication. The report also includes the ecological sustainability (28th place) and the ISO 14001 environmental certificates performance (34th place). The ISO 14001 certificate is a worldwide known certificate for sustainable middle- and big companies. The ranking is based on the purchase power parity (PPP), this can give a disordered view.

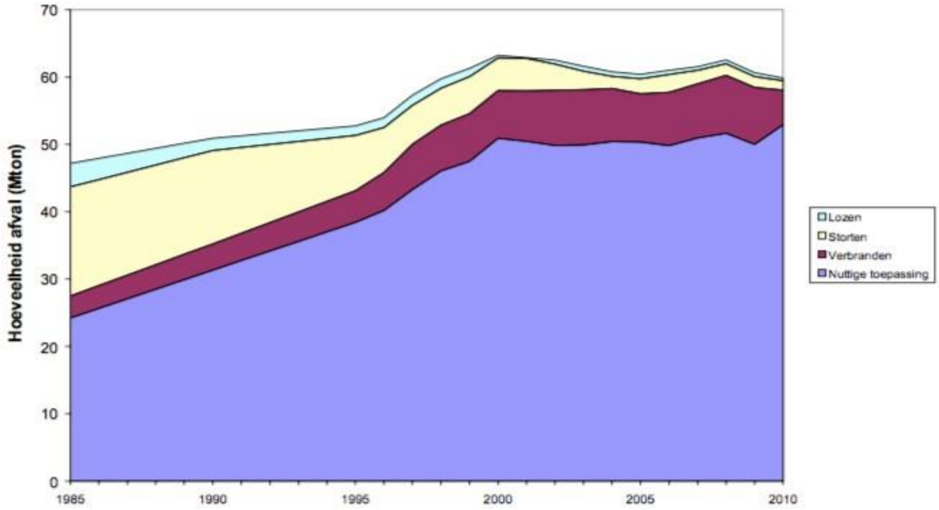
As last, corruption plays a role in the development towards circularity. When corruption is high, companies can take advantages of this. Companies can break environmental rules, or sabotage new ones in their advantage. In the Bribe payers index (2011), the Netherlands scores the first place of the total 28 biggest economies countries in the world.

4.3.3 Trash collection in the Netherlands

An important part of the circular economy is recycling. This is the link that converts waste to usable raw materials. Recyclable goods can be separated into three categories: consumers-, industrial- and imported waste. The Dutch law states that the government plays a central role in the waste management of the country. They are responsible for prevention, separation, licenses, and control of all the waste in the country. The municipality is responsible for the collection of all the consumers waste in their city (Ministerie van I&M, 2015).

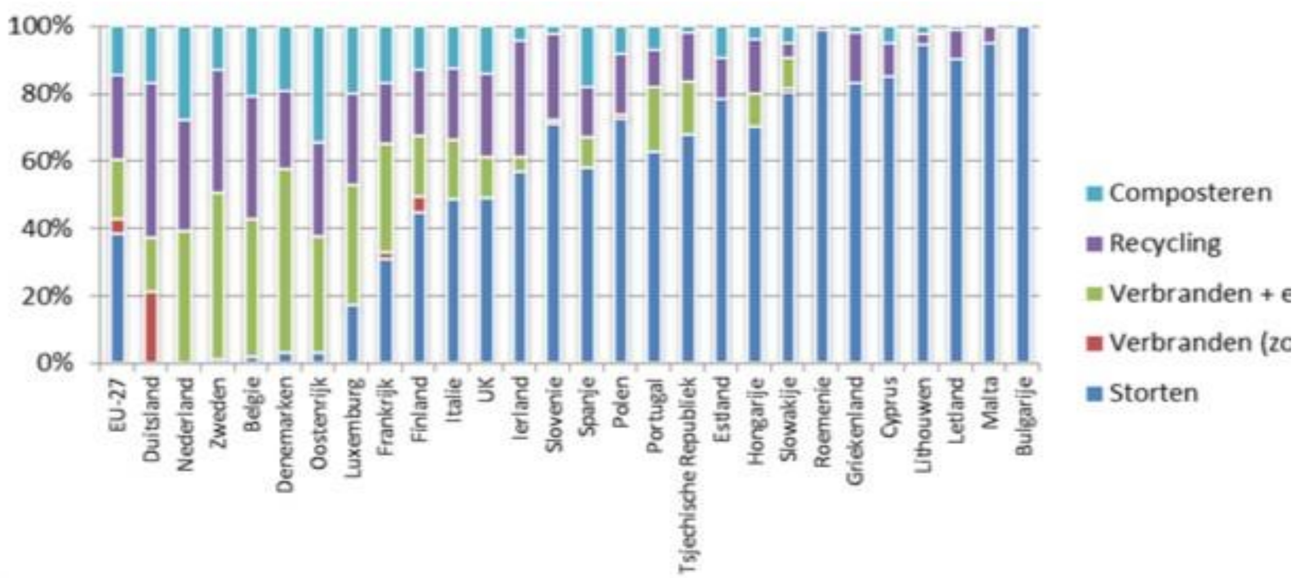
Over the years there has been an increase in annual waste of 47 Mton in 1985 to 63 Mton in 2000, and it dropped again to 60 Mton in 2010. This is a total increase of 27%. In the same period, the GDP grew with 82%. This results in a 54% material efficiency increase. This is mostly due to better technology, government policies, more efficient production and disposal cost. This development is almost completely caused by the industry, since the consumers waste did increase with the same rate as the GDP till 2007. After 2007, there was a small decrease (Ministerie van I&M, 2015). Figure 4 shows how collected waste is processed. The graph is arranged from least desirable at the top to most desirable at the bottom of the picture. The biggest changes occurred in the yellow "landfill" and blue "useful recovery" part. Landfill decrease from 35% in 1985 to 4% in 2010 and useful recovery increase from 50% to 82% in the same years (Ministerie van I&M, 2015). Compared to other countries in Europe, the Netherlands is doing a good job. Figure 5 compares the processing mix from "household waste" in 2010 of 27 EU countries. Here, the Netherlands belongs to the top countries.

Figure 4: Garbage management the Netherland from 1985 till 2010



Source: Ministerie van van I&M (2015)

Figure 5: waste processing in Europe of household waste



Source: Eurostat; data 2010

The recent results are good, but the government still wants to improve. It wishes to increase in the useful recovery to 99% and within this 99%, the percentage of burned waste for energy has to be reduced. To reach this goal, the authorities made a report in 2014 that includes the chosen approach. It focuses mainly on minimization incineration, helping municipalities to improve waste management, inspire households to increase separation at the source and separate waste from offices, stores and public space (Ministerie van I&M, 2014c). To reach the first goal, the amount in burned trash from 2012 “10 Mton” has to be halved in 2022. At this moment there is an overcapacity of incineration installations. When the domestic incinerated waste would decrease, this overcapacity will grow higher. This will lead to the import of waste. More on this topic will be discussed in the next chapter (Wallgren & Dvali, 2014).

4.4 Dutch seaports

All the ports in the Netherlands are part of a national- and international network. They play a significant role in the Dutch economy. Nonetheless, ports pollute heavily. Port authorities themselves are no big polluters, but they do have influence on the companies inside the port (Faber, 2014). Due to this reason, they want to attract sustainable companies. This, together with the encouragement of the government to become more sustainable and enhance the circular economy, has lead to some turmoil in this sector (Kennisinstituut voor Mobiliteitsbeleid, 2007).

4.4.1 Biobased in Dutch ports

The biobased industry in the Dutch Ports is highly developed. The port of Amsterdam has companies like Greenmills (output of 125 million liter biodiesel, power for 15.000 houses, warmth for 3.000 houses, 4.000 ton fertilizer and 6.000 ton bio oil per year), Vesta Biofuels (output of 230 million liter biodiesel per year), Cargill (24.500 tons of electricity per year), ADM, LodersCrocklaan and Crown Van Gelder (Kuipers, de Jong, Meesters, & Sanders, 2015). The port of Rotterdam has in total five biofuel factories: Nestle Oil (800.000 tons biodiesel), Abendoa (480.000 tons bioethanol), Lyondell (400.000 tons ETBE), Biopetrol (650.000 tons biodiesel) and CleanerG (200.000 tons biodiesel) (Port of Rotterdam, 2014). Besides in the big ports, there are some smaller biobased parks in the province of Zeeland and in the west of Noord-Brabant. There are six parks in this area. They are located in Terneuzen, Flushing, Colijnsplaat, Bergen op Zoom, Nieuw Prinsenland and Moerdijk (Biobased Delta, n.d.). The used biomass is generated locally and internationally. The goal of the Dutch government it to generate 20% of the energy needs in a sustainable way by 2020. To reach this goal, about 40% of the input is generated locally and 60% has to be imported (Pelgrim consult, 2010).

Three member of “The Trillion Dollar club” are founded in the Netherland. Vitol and Mabanaft are founded in Rotterdam and Bunge in Amsterdam. Only the two Rotterdam based companies are still controlled from that city. Bunge’s head office is currently based in New York (Reuters, 2011). Amsterdam and Rotterdam are also home to smaller offices of the trillion dollar club. Of the club members Cargill, Noble, Louis Dreyfus is located in Amsterdam (Jacobs & Dongen, 2012). Besides the head offices of Vitol and Mabanaft, Rotterdam houses Glencore, Cargill, Trafigura, Koch Industries, Archer, Bunge and Louis Dreyfus. Mercuria has two offices in Utrecht (Wouter, 2014).

4.4.2 Technosphere in Dutch ports

The port of Rotterdam is creating a Circularity centre (CC). This is a cooperation of the port authority of Rotterdam, Rabobank Rotterdam, BIKKER & Company and Van Gansenwinkel. The aim of this centre is to develop knowledge and business for the circular economy inside the Rotterdam port area. The first project within this cluster is Plastic to Oil. With this technique it is possible to transform hard plastic back to usable oil (Circularity center, 2014).

The council for habitat and infrastructure, made a report in 2013 that stated that Rotterdam should develop to become the biggest circularity hub in Europe regarding high-tech, chemie and agrofood. Rotterdam already has the right infrastructure and knowledge, but it lacks the ability to produce and repair. If the port can realize these two functions, it can transition from a link is the chain to beginning- and end point of the chain. An upcoming business that fits inside this circularity hub is 3D printing. It can manufacture spare parts for broken products, make use of the infrastructure and use available recycled plastic (Raad voor leefomgeving en infrastructuur, 2013).

The recycling industry in the Netherlands is also located outside of the port area. There is a rough distinction between what material is processed and the size of the company. Big companies that process different types of waste, like van Ganzenwinkel and Sita are settled in the Rotterdam port area. They do sort household plastics and sell it afterwards, but do not recycle it. Recycling mostly happens by smaller specialized companies in the southeast of the country. This is often the same with ferrous and non-ferrous recycling companies. The smaller companies settle themselves in this region because of lower costs and proximity to producers.

4.4.3 Start-ups and knowledge institutions

Both Rotterdam and Amsterdam have a good settling environments for circular companies. Amsterdam has two universities, research centres and other projects. The “iconproject” circular Zuidoost runs the project “Circular design and Smart production”. Here, they design closed loops on an efficient scale (Kuipers, de Jong, Meesters, & Sanders, 2015).

The ecosystem of Rotterdam (this includes Delft) has a wide variety of universities and incubators. The Erasmus University Rotterdam, Hogeschool Rotterdam and the TU Delft have all necessary ingredients to create knowledgeable and innovative ecosystem. All the institutions have their own incubator.

- Erasmus University →→ Erasmus centre of entrepreneurship
- TU Delft →→ Yes!Delft
- Hogeschool Rotterdam →→ RDM Loods

These incubators try to connect institutions, students, startups and companies (Keesman, 2015). Currently the Cambridge Innovation Centre is working on a 13.000 m^3 innovation centre in the middle of Rotterdam. They want to house about 500 startups and bring them together with investors and innovative corporations (CIC, 2015).

4.4.4 The future of the circular economy in the Dutch Seaports

All the seaports in the Netherlands have, or are busy making a port vision for 2030. In all of them, sustainable growth is taken into account. This sustainable growth is divided in four different types; bio based economy, circular economy, sustainable logistics (optimization of the chain) and energy/CO_2 reduction. To realize this growth, collaboration between the port authorities, companies inside the port, knowledge institutes, CSO's and the government are needed. In this whole process, the port authorities have a guiding role (Ministerie van I&M, 2013).

Rotterdam has the ambition to become a Global Hub and Europe's Industrial Cluster regarding sustainability. Where the Global hub means stand for a cluster of sustainable companies, Europe's Industrial Cluster is more focussed on connecting companies within this cluster to create synergy. Regarding the circular economy, reduce, re-use and recycle is main message. The main focus of the port is on the bio-based industry (Port of Rotterdam, 2013).

In the vision 2030, the port of Amsterdam stats that it wants to promote synergy regarding the reuse of the by-products and waste streams that are available within the port area. Examples are household waste, sewage, e-waste and other by-product from the production process (Port of Amsterdam, 2014).

Havenschap Moerdijk has two main functions. The first is the chemical industry and the second is a hub within the Flemish Dutch Delta (Ministerie van I&M, 2013). Within the chemical sector they try to reduce fossil fuel and capture and use warmth, energy and CO_2. Within the hub function they want to optimize the sustainability of the whole chain (Havenschap Moerdijk, 2013).

The chemical sector is one of the most important sectors in the Groningen port cluster. The used materials are mostly based of biological and renewable sources. By 2030 it wants to create a sustainable and green raw material market with (inter) national sales (Groningen seaport, 2012).

Zeeland Seaport is the full operator of the port of Flushing and operates the port of Terneuzen in cooperation with the port authority of Gent. Till now they only have a vision for 2020. The vision for 2030 is still in process. In the vision of this port, it is important to make better use of the resources and stimulate existing and attract new companies that want to improve their sustainability (Zeeland Seaport, 2009)

The visions of all the five seaports in the Netherlands are mostly the same. They all want to attract new and stimulate existing companies to be more sustainable. Beside, they all encourage companies to recycle, use less and try to find synergy within the cluster. The only ports that go beyond are Rotterdam and Amsterdam. They have international ambitions.

Figure 6: The five big seaports in the Netherlands. From north to south: Groningen, Amsterdam, Rotterdam, Moerdijk and Zeeland.

Source: (Ministerie van I&M, 2013)

4.5 Is the Port of Rotterdam suitable for the circular economy?

As mentioned on page 20, multiple location factors determine the attractiveness of a port area. This part of the paper looks into how the Port of Rotterdam complies with these aspects. This port is chosen because it has the largest containers transhipment in the Netherlands and EPR B.V is based here.

Table 1 combines both the location factors of the biobased- and technosphere economy. It will be analysed based on the information taken into account in this chapter. Since not all the factors are relevant for the both industries, some answers are not applicable (N/A).

Table 1: Suitability Port of Rotterdam to the biobased- and technosphere economy

	Bio	Techno
Developed infrastructure	√	
Proximity to the production of organic material (input) and customers (output)	√	N/A
Proximity of a port with a big capacity to attract input streams	√	
The presence of a wide variety of related facilities; potential synergy	√	×
The presence of trading desks and circular events	√	
The presence of specialized companies and the possibility to produce and/or treat products that are not directly shipped on a big scale	N/A	×
Proximity to a city with an extensive waste production	N/A	√
An entrepreneurial and innovative environment	√	
Collaboration between companies, government and universities (especially at the early stage of development)	√	
Support from policies (both the port authorities as the government)	√	

Both the biobased- and technosphere economy seem to be pretty suitable for the port of Rotterdam. The biobased economy fulfils all conditions and the technosphere only misses two. Despite it only misses two factors; there are not a lot of TSC in this port area. This is mostly due to the high overall costs in the port.

4.6 Conclusion about the Netherlands

The Dutch government strives to be a hotspot for the circular economy with two main clusters in Amsterdam and Rotterdam. To realize this goal, the government, municipality and port authorities are willing to support. According to the global green economy index, the Netherlands is lacking behind in leadership and climate change. Also, valorisation is not optimal. R&D is high, but performed by international companies, which lead to low application inside the Netherlands afterwards. Garbage management belongs amongst the best in the world. Although the performance is good, the government is still thriving for higher useful recovery.

The biggest biobased- and technosphere clusters are located in the port areas of Rotterdam and Amsterdam. Besides these two, other clusters are based in Zeeland and south Brabant. Both the government and port authorities support these clusters. Besides, there is a thriving information and startup climate in the surrounding areas of Rotterdam and Amsterdam.

Inside these clusters, there are a wide variety of biobased factories. They get their input from both nation and international sources. The circular economy is less represented in these areas. This is mostly caused by the high costs of producing.

5. The circular economy in Vietnam

The fifth chapter of this paper will discuss the circular economy in Vietnam. It consists of five sub chapters. The first sub chapter discusses Vietnam in general, the second the Vietnamese government, the third the circular economy, the fourth contains the Vietnamese seaports and finally the suitability of the Ho Chi Minh City port area for the CE.

5.1 Vietnam in general

The circular economy of Vietnam is in transition. This, in combination with the flourishing economy makes Vietnam one of the most interesting Asian countries to keep an eye on. To get a better understanding of how the circular economy works here, some more knowledge of the country is required.

Vietnam is a country located in Southeast Asia. It borders Cambodia, Laos and China on the west side and on the east side it borders the South China Sea. In 2012 it had a GDP of 156 billion Dollar and GDP per capita of 1.773 Dollar.
During the last 25 years, Vietnam is one of the greatest success stories from Asia. Despite the global economical volatility, only China grew faster after 2000. The internal improvement is the greatest gain in the economy. There has been a shift from an agricultural society to a more manufacturing and service culture. Besides this change, there is a demographically divided youthful population that takes care of this growth (McKinsey Global Institute, 2012).

The overall growth is about equally divided amongst the two biggest sectors, the industry and service; they both take for about 40% of the total annual output for its account. The manufacturing industry was the fastest growing sector with an annual growth rate of more than 9% between 2005 and 2010. This is mostly due to the abundance of low-wage labour. Because of this growth, it is not only producing for the domestic market, but there is also an increasing export of mostly textiles and footwear. For Vietnam to keep this growth rate, it cannot relate on the abundance of people. The amount of people that migrate from the farmlands to the city will decline. To keep up, it will have to improve productivity within manufacturing and services (McKinsey Global Institute, 2012).

5.2 The Vietnamese government

Since Vietnam is still a third world country it is not surprising that it is lacking behind on sustainability; trash recycled rate is low, high overall pollution and the working conditions are not optimal. But, the Vietnamese government has turned into the path of sustainability. This development towards a cleaner country has started around 1990, but it was not very effective yet. Only in the last years, the actions seem to be taken serious. Due to this reason, there is no real type of circular economy as it is developing in western countries. Until now, they try to reduce usage, spoilage, emissions, pollution etc. and increase efficiency, awareness, productivity, recycling etc. But in comparison to the Netherlands they do not see it as a whole, but they are all small divided steps towards it.

In recent years, internationally agreed principles and objectives for a greener economy have been fit to meet the Vietnamese conditions. Significant improvements have been made, but there is still a long way to go. This new policy is facing big challenges. Due to the geographical location of Vietnam, the county will probably get hit as one of the first and one of the hardest by climate change. The natural resources have been seriously degenerated in the past years. Due to the war and recent environmental pollution caused by the economical development, the country it heavily polluted. In many parts of the country the production is very primitive and hereby energy inefficient. Besides most of the urban population does not take the environment into account with their lifestyle (Vietnam ministry of P&I, 2012).

The key goal in of the government is green growth. This aims for economical growth and at the same time tries to reduce climate change. They want to achieve this via reducing greenhouse gasses, efficient use to natural resources, use of modern technologies, improvement of the infrastructure, reduce poverty, coping with climate change and the promotion of sustainable economics growth (Vietnam ministry of P&I, 2012).

The focus is on the big cities and the industry. There are two big cities (Hanoi and Ho Chi Minh) and most of the heavy industry is located around this area. In these locations, most people live, and environmental improvement can have the biggest impact (Vietnam ministry of P&I, 2012).

5.3 The circular economy in Vietnam

5.3.1 Trash collection in Vietnam

5.3.1.1 Trash collection till 2014

The transition from farm work to factory work is comparable to that has happened in the recycling industry. But even day, there are farmer specialized in recycling. All of the in total 2.800 rural villages have some kind of secondary work. They have developed a speciality in times they are not planting of harvesting crops. Some make handcrafts for tourists, other recycle plastic, steel or paper. These biggest problems for these in-house recycle facilities are the dangers for the environment and the health of the workers (Pearse, 2010) (Van Ha, Kant, & MacLaren, 2008).

The waste treatment in Vietnamese cities falls under the jurisdiction of several governmental bodies at different levels. Because of this division in responsibility, there is no unified or standardized system for waste collection. This leads to inefficient and dangerous working conditions for waste collectors (Nguyen, 2005). The Vietnamese national strategy was based on reduce, reuse and recycle concept for the year 2020. Despite the good intentions of the country, there where still a lot of limitations of hazardous waste management (Nguyen, 2008).

- No requirement for the maximum concentration of hazardous waste;
- No responsibility at any national level for hazardous waste;
- Lack of fines for offenders of environmental laws and no encouragement sanctions;
- No fees for the treatment of hazardous waste;
- No regulation for the construction of storage and recycling plants;
- No support from domestic management agencies;
- No regulation for hazardous waste and other valuable waste streams;
- Structure of licenses and operational structure are unclear;

Besides the lack of management, different types of hazardous are not recycled. See Figure 7 for the overview. Due to this lack of proper treatment, the environment gets damaged. Toxic matters are dumped in the water or brought to landfills where it is not taken care of, with resulting consequences for nature and human health. As last, there is not any regulation for any industry regarding air pollution.

Figure 7: List of not recycled hazardous waste

Industries	Hazardous wastes
Chemicals, fertilizers, resins, drugs, and medicine	Organic and inorganic matter, chemical dusts, metal dusts, toxic gases
Basic chemicals	Organic and inorganic matter, acid and alkaline gases
Paints and printing inks	VOC: petroleum, toluene; organic and inorganic dusts
Glass production	Dusts, organic matter, VOC, As_2O_3, HF, B_2O_3, Sb_2O_3, and inorganic matter
Batteries	Metal dusts, MnO_2, volatile substances, Hg
Chemical fertilizers	HF gas
Pesticides and herbicide	Xylene gas, carbamate organic matter, solvents
Leather and leather products	Acid gases and solvents, H_2S, NH_3, Cr^{3+}
Rubber	Solvents, organic matter, sulfite
Electronic and electrics	Metal dusts, welding gases, chemical gases, solvents, detergents.
Mechanical	Metal dusts (Cu, Fe, Al), welding gases, chemical gases, solvents, detergen

Source: Nguyen (2008)

5.3.1.2 Trash collection after 2014

Due to these problems, the Vietnamese government is making new rules and regulations that confirm with the Basel convention. The Basel convention is set-up to regulate and control all the hazardous waste worldwide. The “Law on Environmental Protection 2014” is due to the first of January 2015. The first new regulation is the waste electric and electrical equipment (WEEE) law. This law obligate producers and importers to recycle a certain amount of produced and imported WEEE (Dragon Law Firm, 2013). A second new law allows companies to import waste into Vietnam under the following conditions (Vietnam Environmental administration, n.d.)

- Own a warehouse/area where the scrap can be stored. This warehouse should meet certain conditions for environmental protection;
- Certain standards for technology, equipment for recycling and reusing scrap;
- Only Import scrap for production;
- Treat impurities in scrap with technical regulations, i.e. they are not allowed to be sold;
- A deposit is required before import;

This new law is important for the case study. This is due to the fact that this new law generates opportunities for companies

5.3.2 Overall performance

In Global green economy index Vietnam is also mentioned as a negative emerging trend. Together with Ghana, Qatar, United Arab Emirates, Cambodia, China and Thailand they belong the fast growing countries that have a poor performance. Vietnam scores place 45 on the perception list and number 59 on the actual performance. There are in total 60 included countries, which makes the 59^{th} rank on the performance list is not a good ranking. Since all the comparable countries in Asia are included, it can be said that Vietnam is one of the most polluting countries in Asia. The biggest concern of this report is the highly inefficient transport sector (Dual Citizen LLC, 2014).

5.3.3 Companies

Sustainable indices can give a good indication of sustainability in a country. There are wide variety of indices; per region, country, and industry. By obtaining information via the Datastream network at the Erasmus University, the following was concluded. There are no Vietnamese companies in the worldwide sustainable indices. Besides this, they are also not taken into account in any smaller or more specific index. These lists allocate companies to the country where it comes from. There are firms on these lists that have factories in Vietnam, but because they founded aboard, they are not allocated as such.

The second indicator for a sustainable business environment is innovation. According to the World Bank (2014), the current Vietnamese science, technology and innovation is weak and the national innovation system is in a fragmented state. It is definitely developing, but there are still a couple of problems. Problems like overlapping research, sub-optimal scales, lack of resources like money, qualified staff and the right infrastructure. Vietnam is improving, in the annual global innovation index (2015), Vietnam is ranked as 52^{th} out of the 143 countries. It was ranked number 71^{th} in 2014. Compared to other Asian countries it is performing well. Only China (29^{th}) and Malaysia (32^{th}) are ranked higher, where Thailand (55^{th}), Philippines (83^{th}), Cambodia (91^{th}) and Indonesia (97^{th}), perform worse. According to this report, the strongest features are the innovation efficient ratio and the credit. This ratio measures the balance between input (institutions, human capital, infrastructure, market and business sophistication) and the output. Finally, Vietnam scores 41th place with the ISO 14001 environmental certificate. This is a pretty good score, but the number of

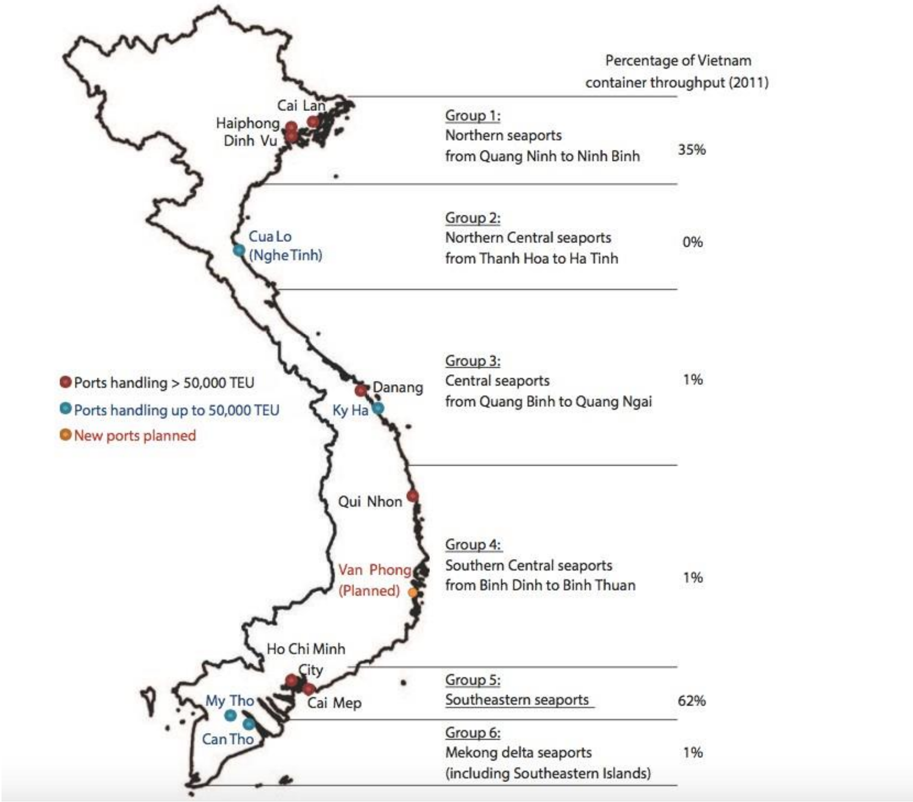
ISO 14001 certificates are in proportionate to the purchase power parity (PPP). Since this PPP is relatively small in Vietnam, this can be a distorted picture.

Dumping and corruption are a plague to the Vietnamese economy. They are both separated problems but the one also caused the other. Corruption is implemented in the Vietnamese culture. It happens at every level of society. People pay bribes to policemen to let off fines and companies pay bribes to government employees to give them advantages. Corruption influences the industry when not the best company but the richest company gets a contract (Rand & Tarp, 2012). In the past, the Vietnamese companies where not really bound to any environmental rules. All the by products could be dumped wherever companies wanted. This lead to health problems for people and soil pollution (Agusa, 2003). Since the Vietnamese government is implementing more environmental rules, it should be expected that dumping would decrease. But companies still bribe government officials and dump waste in a non-regulated place. Besides, local government prefer short-term economical growth above enforcing regulations. Most Vietnamese companies do not want to pay extra for more environmental friendly way of doing business (Khai & Yabe, 2013).

5.4 Vietnamese seaports

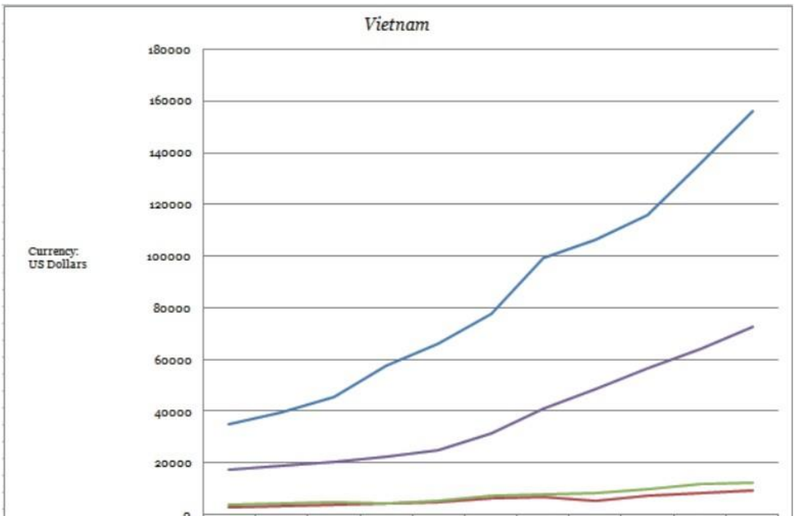
Vietnam has a long coastline, with the biggest marine activities around Hanoi (35%) and Ho Chi Minh City (62%), see figure 8. All these ports are underdeveloped and due to this reason, the country cannot benefit completely from its comparative

Figure 8: Map the ports in Vietnam



advantages over countries in the region. It has cheap labour, high education and a big working force. This potential is not completely exploited because shipping from and to Vietnam is relatively expensive as a result of the out-of-date infrastructure, limited connection to the sea, inadequate hinterland access and the insufficient depth of the access routes to the ports. Figure 9 give insights in how the Vietnamese import, export, GDP and foreign direct investment (FDI) have developed from 2002 to 2012. It shows that the growth of export (226%) and import (239%) are lacking behind compared to the FDI (316%) and GDP (344%). This is partly caused by the bad infrastructure (Morrow, 2009) (Ghosh, 2014). The government has a 2020 with orientation to 2030 port vision. The complete vision has never been published. Only a small summary is available for the public. This document contains a couple of unspecific goals and the projects they want to realize by 2020 and 2030. None of these goals was anyhow related to sustainability (Vietnamese Government, 1999).

Figure 9: Main economic indication Vietnam 2002-2012



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
GDP (Billions)	35064	39553	45428	57633	66372	77414	99130	106015	115932	135539	155820
Value of Exports (Millions)	2948	3272	3867	4265	5100	6460	7006	5766	7460	8691	9620
Value of Imports (Millions)	3698	4050	4739	4450	5122	7177	7956	8187	9921	11859	12520
FDI (Millions)	17439	18889	20499	22453	24853	31553	41132	48732	56732	64162	72530

Source: UNCTAD STAT, http://unctadstat.unctad.org

At this moment, the maritime industry in Vietnam is in development towards a western standard. It is one of the top priorities of the government. In the upcoming years, the complete infrastructure of the country will be upgraded for an estimated 60 billion Dollars. Most of this money will be spend on the port infrastructures. This is a large amount of money for a country with a GDP of 156 billion in 2012. Although, expanding this industry will give Vietnam the extra boost to become a stronger plays in the Asia Pacific region (Morrow, 2009).

5.4.1 Biobased in Vietnamese ports

The biobased economy in Vietnam had a big potential. A large percentage of the land is still used for agriculture. This results in a large amount of by products that can be used to produce biogas, biofuels and bioethanol (AFD Hanoi, 2012). Despite the abundant usable products, there are high barriers that stop Vietnam from exploiting this potential. The government supports coal as a power source, high upfront investments, the biomass is scattered throughout the country, lack of funding and the lack of knowledge (Ministerie van EA&I, 2012).

Of these three manufactured biobased products, only biofuels and bioethanol are commercially attractive. Biogas is only produced locally due to high infrastructural investment to operate on a large scale. Due to this reason, biogas is only produced in the countryside. Biofuels are mostly produced from fish fats and from Jatropha. Fish fat fuelled factories are located in the south and Jatropha fuelled factories in the north. The yield is still relatively small and the output is only used locally. Produced bioethanol is mainly exported, since domestic consumption is limited to medical and chemical usage. Producers are all based in and around the Ho Chi Minh City area. Although they are not located exactly in the port area, they are close (ADB, 2009).

Based on the websites of "The Trillion Dollar Club" members, most of them have some kind of office or storage in Vietnam. These locations a rather small and they have biggest Asian offices in Singapore and/or China. This concludes that Vietnam cannot be considered as an important location for trading desks.

5.4.2 Technosphere in Vietnamese ports

Despite the import of recyclable goods, processing companies are not located in the port area. This can be concluded from an interviewed industry source. This person quoted: "The port area only contains port related companies. There is no sustainability cluster. All the recycling and production companies are scattered throughout the city and in provinces around Ho Cho Minh City, especially in the north. Since transport is very cheap it is not a problem".

5.4.3 Start-ups and knowledge institutions

Vietnam is seen as an attractive market by venture capitalist from all over the world. The country has a fast growing economy, young population and a strong local tech talent pool with international connections. There are plenty of examples of this development. Across the country, there are more than 20 incubators; the Climate innovation centre incubator is especially focussing "green" startups (techinasia.com, 2015).

5.5 Is the port of HCMC suitable for the circular economy?

There are different location factors that improve the attractiveness of a port area. These factors will be discussed with regarding to the ports in HCMC. This region is chosen because it has the largest container transhipment and EPR B.V is based here.

Table 2 combines both the locations factors of the biobased- and technosphere economy. It will be analysed based on the information taken into account in this chapter. Since not all the factors are relevant for the both industries, some answers are not applicable (N/A).

Table 2: Suitability of the HCMC city area to the biobased- and technosphere economy

	Bio	Techno
Developed logistics	✗	
Proximity to the production of organic material (input) and customers (output)	√	N/A
Proximity of a port with a big capacity to attract input streams	√	
The presence of a wide variety of related facilities; potential synergy	✗	✗
The presence of trading desks and biobased events	✗	
The presence of specialized companies and the possibility to produce and/or treat products that are not directly shipped on a big scale	N/A	✗
Proximity to a city with an extensive waste production	N/A	√
An entrepreneurial and innovative environment	√	
Collaboration between companies, government and universities (especially at the early stage of development)	✗	
Support from policies (both the port authorities as the government)	✗	

Both the biobased and technosphere economy are not suitable for the port area of Ho Chi Minh City. The main reasons are the underdeveloped port infrastructure, the concentrated processing companies in the suburbs and provinces around HCMC and cheap logistics.

5.6 Conclusion about Vietnam

At first, the government does not seem to do a good job when it comes to improving the environment in the country. Since a couple of year it is starting to imporve. Especially the new laws look promising. But it is not focussing on circularity. Until now, they try to reduce usage, spoilage, emissions, pollution etc. and increase efficiency, awareness, productivity, recycling etc. But in comparison to the Netherlands they do not see it as a whole, but they are all small divided steps towards it.

Ports in Vietnam are lacking behind in development due to the out dated infrastructure. Especially the depth of the waterways block bigger ships from entering the port area. Because the port area is underdeveloped, the Vietnamese government is focussing on improving the general facilities at first. There are no intentions yet to built up a circular port cluster.

The biobased economy has a huge potential due to the high amount of local feedstock. Because of this widely available input, it does not need to import biomass. This also leads to a low number of biomass factories in the port area. The technosphere economy is like the biobased economy, also not really represented in the port area. Most of the recycling companies are based in the provinces around Ho Chi Minh city.

6. Case study: Export of recyclable plastics to Vietnam

In this empirical chapter I will calculate how much more emissions are expelled when recyclable plastics are exported from the Netherlands to Vietnam and compare this to the extra revenue made. It will start with an introduction of how European plastic recycling BV works, a broader introduction of the plastic industry and the plastic problem in general. After the introduction, the methodology will be discussed. Next, all the needed information will be gathered and the calculations will be performed. Finally, the outcome and conclusion on the empirical section will be formed.

6.1 European Plastic Recycling B.V.

At first sight, it does not seem logical to export recyclable plastic from the Netherlands to Vietnam. All costs in Asia are generally expected to be lower, shipment is needed and other hassle is involved in this whole process. But there are other circumstances. At first, as mentioned before, there is the new environmental law in Vietnam. This law states that since the first of January 2015, companies have to comply with the following rules to import scrap into the country.

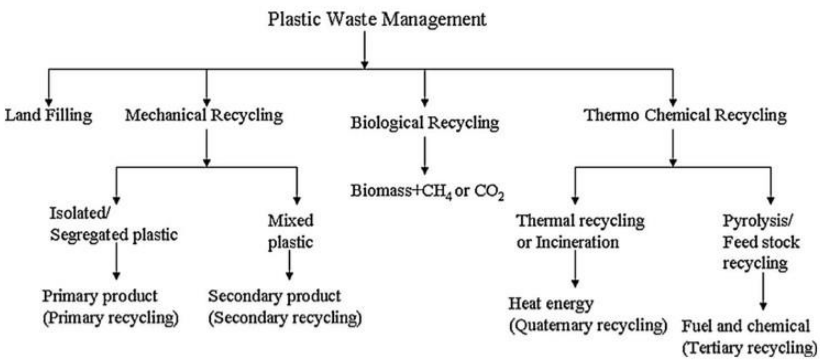
- Have a warehouse/area where the scrap can be stored. This warehouse should fit certain conditions for environmental protection;
- Having the right technology, equipment for recycling and reusing scrap;
- Only Import scrap for production;
- Treat impurities in the scrap with technical regulations, i.e. they are not allowed to be sold;
- A deposit has to be made before importation;

These new rules make it unattractive for companies to start and/or continue with their business. When some companies do not want to enter this market, it opens opportunities for others. The second attractive circumstance is the Vietnamese plastic market. The domestic plastic production is booming. Since 2008 there is an average yearly growth of between 20 and 25% of the total production. Besides, the government marks this industry as one of the most important sectors for the upcoming years. To maintain this growth, plenty of raw plastic materials are needed. Vietnam does have domestic oil reservoirs, but this is by far not enough to fulfil the demand. About 80% of the total input has to be imported (Concetti, 2013) (Vietnam briefing, 2014). The last circumstance is the lack of good quality input. The quality of recyclable plastic is displayed as 90/10, 80/20 etc. This represents how contaminated the plastic is. For example, in 90/10 the 10 represent the percentage of contamination in the load of plastic. The type of pollution can differ; it can contain mud and sand, other types of plastic or coloured pieces of plastic but from the same type. In de last decades, many loads of highly polluted plastics have entered the country. Processing these polluted plastics is expensive, even for Vietnamese standards. This caused the Vietnamese government to implemented stricter rules to control the import of scrap. Because of this overload of polluted plastic, the demand is high for relatively low polluted plastics of around 80/20. This type is widely available in western countries and it is considered as highly polluted there. This makes it attractive for exportation to Vietnam.

6.2 Plastic recycling

Figure 10 show the four ways to dispose plastic solid waste: landfill, mechanical recycling, biological recycling and chemical recovery (Luo, Suto, Yasu, & Kato, 2007).

Figure 10 Different routes for plastic waste management



Source: Panda, Singh & Mishra (2007)

6.2.1 Landfilling

Worldwide, the highest portion of PSW is subjected into landfills. However, this is rapidly decreasing. Plastic in a landfill generates greenhouse gasses like methane. Due to these reasons, national environmental agencies are applying new environmental rules to improve regulation and decrease landfilling (Garforth, Ali, Martınez, & Akah, 2004). Since plastic has a high volume to weight ratio, suitable landfill space is also getting expensive and scarce (Panda, Singh, & Mishra, 2010).

6.2.2 Mechanical recycling

This type of recycling converts plastic into new raw material (primary recycling) or other products (secondary recycling) like benches and boat docks. Primary recycling is only possible when the input is homogeneous; it needs to have a contamination level of at most around 98/2. Although, it looks like the most environmental friendly option, this process takes a lot of energy and water for cleaning, sorting and transportation (Mantia, 2002).

6.2.3 Biological recycling

Natural and synthetic isoprene's become resistant to bio-degradation when it is used to make an industrial product. This is caused by the presence of very effective antioxidants that are added during the manufacturing process (Scott, 1997). As a consequence of this non-degradation, researchers try make biodegradable plastics. This has lead to some form of biodegradable plastic that is used on a small scale for bags and throwaway cutlery. These types of plastic can in the right environment photo-degrade in six weeks. It has the potential to be used in more applications like computers and car components (Scott, 2007). These sorts of plastic seem to be useful in solving the problem. But there are a couple of concerns. First, it can only degrade if all the conditions are exactly right. For example, photodegradable plastics need light to degrade. If it is stored in a landfill, the chance is big it does not get any light and it still does not have any chance to degrade. Second, there is a possible increase in the methane, as methane is released when this plastic degrade anaerobically. Third, the combination of two types of plastic “normal and biodegradable” can make it complicated to sort the different types. As last, people may increase their usage of plastic because they assume the use is harmless (Waste online, n.d.). These uncertainties make biodegradable plastic not the dreamed solution in the short run. But it does have potential for the long run.

6.2.4 Thermal recycling/incineration

Energy recovery by incineration of plastic wastes a viable option. When fossil fuels are turned into plastic, depending on the type of plastic, the calorific value will not decrease. This value gives the efficiency of different types of fuels when it is incinerated. As seen in table 11, the calorific value of polyethylene is the same as fuel oil. This means that when oil is converted into plastic and burned after, there is no lost in efficiency (Scott, 2002)

Figure 11: Calorific values of plastic compared with conventional fuels

Fuel	Calorific value (MJ/kg)
Methane	53
Gasoline	46
Fuel oil	43
Coal	30
Polyethylene	43
Mixed plastics	30–40
Municipal solid waste	10

Source: (Scott, 2002)

Incineration seems to be a good solution and it is the most preferable by the local authorities because it is practical and generates energy (Scott, 2002). However, there are some concerns in western societies. They distrust the emissions of different greenhouse gasses and toxics (Seltenrich, 2013).

6.2.5 Chemical recycling

Chemical recycling aims to convert PWS into usable substances. It can be divided into three groups: partial oxidation, depolymerisation and cracking.

Partial oxidation

Direct incineration of plastic waste with a high calorific value can be harmful for the environment. Partial oxidation is a technique that uses oxygen and/or steam to make a mixture of hydrocarbons and synthesis gas out of recyclable plastics. This new method produces a dioxin-free and high-calorie purified gas (Panda, Singh, & Mishra, 2010)

Depolymerisation

Polymers like polyesters, nylons, polyamides and polyethylene terephthalate can be brought back to their raw material state. The problem is that most of these materials include polyolefins. When these two are combined, it is hard to recycle it all together (Panda, Singh, & Mishra, 2010).

Cracking/pyrolysis

Cracking, also known as plastic-to-oil, breaks polymer chains down into useful molecule weight compounds. It can be used afterwards as fuel or as other chemicals (Panda, Singh, & Mishra, 2010).

6.3 Types of plastic

All the fossil fuel based polymers are divided in seven groups. See figure 12 for all the different types. These groups are classified by the society of plastics industry in 1988 and the classification is still used today. The numbers allows consumers and recyclers to differentiate the different plastic types.

Figure 12: Different types of plastic

Plastic Type	General Properties	Common Household Uses
1 PETE Polyethylene Terepthalate	Good gas & moisture barrier properties High heat resistance Clear Hard Tough Microwave transparency Solvent resistant	Mineral Water, fizzy drink and beer bottles Pre-prepared food trays and roasting bags Boil in the bag food pouches Soft drink and water bottles Fibre for clothing and carpets Strapping Some shampoo and mouthwash bottles
2 HDPE High Density Polyethylene	Excellent moisture barrier properties Excellent chemical resistance Hard to semi-flexible and strong Soft waxy surface Permeable to gas HDPE films crinkle to the touch Pigmented bottles stress resistant	Detergent, bleach and fabric conditioner bottles Snack food boxes and cereal box liners Milk and non-carbonated drinks bottles Toys, buckets, rigid pipes, crates, plant pots Plastic wood, garden furniture Wheeled refuse bins, compost containers
3 V Polyvinyl Chloride	Excellent transparency Hard, rigid (flexible when plasticised) Good chemical resistance Long term stability Good weathering ability Stable electrical properties Low gas permeability	Credit cards Carpet backing and other floor covering Window and door frames, guttering Pipes and fittings, wire and cable sheathing Synthetic leather products
4 LDPE Low Density Polyethylene	Tough and flexible Waxy surface Soft – scratches easily Good transparency Low melting point Stable electrical properties Good moisture barrier properties	Films, fertiliser bags, refuse sacks Packaging films, bubble wrap Flexible bottles Irrigation pipes Thick shopping bags (clothes and produce) Wire and cable applications Some bottle tops
5 PP Polypropylene	Excellent chemical resistance High melting point Hard, but flexible Waxy surface Translucent Strong	Most bottle tops Ketchup and syrup bottles Yoghurt and some margarine containers Potato crisp bags, biscuit wrappers Crates, plant pots, drinking straws Hinged lunch boxes, refrigerated containers Fabric/ carpet fibres, heavy duty bags/tarpaulins
6 PS Polystyrene	Clear to opaque Glassy surface Rigid or foamed Hard Brittle High clarity Affected by fats and solvents	Yoghurt containers, egg boxes Fast food trays Video cases Vending cups and disposable cutlery Seed trays Coat hangers Low cost brittle toys
7 OTHER	There are other polymers that have a wide range of uses, particularly in engineering sectors. They are identified with the number 7 and OTHER (or a triangle with numbers from 7 to 19).	Nylon (PA) Acrylonitrile butadiene styrene (ABS) Polycarbonate (PC) Layered or multi-material mixed polymers

7. Data, cases & Methodology

This chapter will first describe the data, cases and methodology to compare the recycling of plastics in the Netherlands and Vietnam. At first, all the included date will be discussed. Why it is needed, how it is found and the final used data. After the introduction, the paths will be discussed in more detail. As last, the methodology is covered.

7.1 Data

There are four different pathways included in this paper. The beginning point is always Hengelo, in the Netherland. De Paauw, a company based in Hengelo is chosen as the supplier of the plastics. De Paauw is the chosen company because it is the main supplier of EPR B.V.

- Route one: incineration in the Netherland;
- Route two: recycling in the Netherlands;
- Route three: recycling in Vietnam with transport via shipping;
- Route four: recycling Vietnam with transport via rail;

For both the recycling in the Netherland and Vietnam, the processing location and the capacity of the factory has to be determined. Processing can be performed in- or outside a port area. More on this topic will be argued later in this chapter. The chosen capacity for the production plant is 100 tonnes per week. This is based on the planned capacity of EPR B.V. The chosen type of plastic is low density polyethylene (LDPE) film, since this is the most traded plastic by EPR B.V. Two different types of plastic quality are included, namely 98/2 and 80/20. They are polluted with different colours. It is expected that 98/2 will be more profitable in the Netherlands and 80/20 is more profitable in Vietnam. Because 80/20 has to be treated by hand before it can be recycled, it seems logical to produce this type of plastic in cheap labour countries like Vietnam. After manual sorting, the input has to be grinded, than washed and finally put into the extruder. See pictures 1. The social differences of processing in Vietnam and processing in the Netherlands have to be taken into account. For all the above-mentioned different options, the costs, emissions and differences in social circumstances will be determined. Finally, all this information has to be valued in monetary terms to be able to compare the paths indicated.

Picture 1: From left to right: 98/2 quality, 80/20 quality and the final product

Since prices and costs are not constant over the whole year, assumptions have to be made. To come to these assumptions, both internet- and industry sources are consulted. At first, the needed information was found in reports and paper on the Internet. After, this information was discussed with industry sources. More information about used industry sources can be found in Appendix I. All mentioned amount are in Euro.

7.1.1 The price

The buying price is always in Europe, but the selling price can be either in Europe or Vietnam. This depends on where is plastic is processed. Due to the market, it is hard to calculate and exactly determine the price to buy and to sell the plastics. The price depends on different factors like the oil price and supply and demand. Especially in Vietnam, the market is still immature due to the reason that it is a relatively new market. Because it is so underdeveloped, the prices are even more volatile than in a developed market. After determining the selling price it is multiplied with the level of clean plastics in the load. For example, if one tonne of 80/20 quality is cleaned and extruded, the output will be 800 kilo of new raw material.

For both buying and selling, two Internet sources are found. The average price of 2014 is chosen to optimize the assumption. After, the price is discussed with someone from [redacted] Nederland. See table 3 for the outcome. More information can be found in appendix II.

Table 3: Buying- and selling prices used in calculations

Contains confidential information. Available upon request.

Sources: see appendix II

Both the Internet sources seem to give good direction to the average costs for LDPE plastic of 2014. [redacted] and [redacted] both agreed with the 260 euro per tonne 80/20, but thought 700 was too high for 98/2. The two Internet sources for the selling price seem to include high numbers. [redacted] and [redacted] both suggested that the prices from Internet where for non-recycled LDPE, since secondary materials still have lower values than primary materials. They also both agreed that the price in Vietnam is always about 100 euro lower in Vietnam, than in the Netherlands. Since this paper included recycled materials, the suggested prices from the companies are used.

7.1.2 Transportation costs and distances

Costs for transportation per truck are calculated in the different countries. These costs are found in papers and reports on the Internet related to this subject. The distances travelled per truck are determined by using the route function from Google Maps. To determine the total handling and shipping costs for the transportation to Vietnam, information is gathered from industrial sources and an intermediary in Rotterdam. The cost for rail transport is collected from the railway company Hellman. Incineration takes place in Hengelo. See table 3 for the final outcome. More details can be found in appendix III.

Table 3: Transportation costs in euro

Trucking costs in NL per km	1
Trucking costs in VN per km	0,24
Shipping costs from NL to VN	1.061
Railing costs from Duisburg to VN	4.692

Sources: see appendix III

7.1.3 Processing costs

After transportation, the plastic is processed. Since plastic with a contamination level of 98/2 does not have to be cleaned, it can be extruded right away. Plastic with a contamination level of 80/20 does have to be cleaned before it can be extruded. To include cleaning- and processing into the model, information about the costs is needed. See table 4 for the final used costs. More detail can be found in appendix IV.

Table 4: Manual picking and processing costs in euro

Contains confidential information. Available upon request.

Source: see appendix IV

7.1.4 Emissions

CO_2 savings or emissions used in this report should be seen as an approximation. The actual savings depend on the specific chosen recycling technology and the exact choice of transport mode.

To calculate the extra emissions, the following information has to be considered. There are many containers shipped back from Europe to Asia without any cargo. This is caused by an export surplus from Asia to Europe. Due to this higher import than export, there is not enough cargo to keep the total amount of containers in Europe and Asia in balance (Song & Dong, 2012). Because many containers have to go back anyway, it can be argued that not all the CO_2 emissions have to be taken into account. Only the extra weight caused by the cargo should be used in the calculation. Both the variations will be used in the final calculation. The emission of trucks, shipping and processing will be calculated with publications of CE Delft. Since processing and incineration of plastics save the usage of other resources, they have a negative rate of emissions. A more detailed calculation will be given in appendix V.

Table 5: CO_2 Emissions and savings used in calculations

Emissions		
	Gram CO2 emissions per container per km	Source
Transport in NL	1555,2	(CE Delft, 2011a)
Transport in VN	3081,6	(CE Delft, 2011a)
Shipping to Singapore Ocean ship	403,2	(CE Delft, 2011a)
Shipping to Vietnam Feeder	1180,8	(CE Delft, 2011a)
Railing to VN	700	(CE Delft, 2011a)
	Gram CO2 emissions saved per tonne	
Incineration	-6.939.000	(CE Delft, 2011b)
Processing	-1.500.000	(Neidel & Jakobsen, 2013)

Source: see appendix V

7.1.5 Processing location

To determine if processing is in- or outside the port area if preferable, table 1 and 2 are used in combination with information from industry sources.

According to table 1, the port of Rotterdam area looks like the perfect settling place for a circular economy related company, especially for the biobased industry. Nevertheless, the area has one disadvantage, namely the lack of a cheap workforce. Thus, the port of Rotterdam area does not seem to be an ideal settling location for plastic recycling companies. As mentioned before, this is also the case in practice. Small plastic processing companies are located in the southeast of the country. Due to this reason, the plastic in case two will be processed outside the port area. The transporting distance from De Paauw recycling to the processing location is determined on 50 kilometres, since there are many similar companies in this range.

The circular economy in Vietnam has a big potential, but it is not located in the port area. This is caused by the underdeveloped port infrastructure, the concentrated industry in the suburbs and provinces around the big cities and the cheap logistics. EPR B.V. is also settled in the suburb of Ho Chi Minh City. Thus, in case 3 and 4, this location will be chosen as processing location.

7.1.6 Social circumstances

Since working circumstances in Vietnam are worse than in the Netherlands, extra costs can be taken into account for two reasons. As first, costs for improving the working environment. Second, these bad circumstances can be valued and added as costs.

Processing the plastic does not require a lot of workers and thus does not bring a lot of health and safety issues. In contrast to processing, manual sorting does. To keep this working environment safe, the following measurements are needed (Neidel & Jakobsen, 2013).

- Sufficient ventilation in the working place
- Use of protective clothes, gloves, masks etc.
- Enough intermissions of manual separation activities
- Enough variety in work
- Frequent health checks of the workers

Some industry sources with experience in Vietnam mention the big difference between recycling companies. Some work on an open grass field without any protection, others have similar facilities as in the Netherlands. Both sources mentioned that they do not do business with the first mentioned type of companies. Even if they wanted, those companies do not want to pay enough for the plastics. They process the abundant available highly polluted plastics in the country. The only companies willing to pay a good price are the ones with high standards.

Despite that EPR only does business with the high standard types of companies, it can never be sure that there will be no health and safety issues. Due to this reason, the manual sorting costs will be increased with 25% and the processing costs with 10%.

7.2 The cases

This chapter will discuss all the options in more detail. See appendix VI for the diagram.

Option 1: Incineration

Incineration is a relatively short and easy option compared to the others. The cargo is transported from Hengelo to the closest incinerator and burned there. It costs money to incinerate the plastics, but it saves CO_2 emissions since it substitutes other inputs.

Option 2: Recycling in Europe

At first sight, option 2 seems to be the most obvious of all the possibilities. Especially plastics with a low pollution rate are expected to be most profitable in the Netherlands. This path also starts with transport from Hengelo to the processing company. The 80/20 plastics have to be manual sorted first. After, both qualities are washed and extruded.

Option 3: Recycling in Vietnam via shipping

In this option, plastic will be transported from Hengelo to a recycling installation in the south of Vietnam. This path begins with the transportation of the cargo to the port of Rotterdam. After arrival, the goods have to be transferred on the deck, transported to Singapore first and after with a feeder shipped to the port of HCMC. After arrival in this port, it has to be transferred to the production location. At this location, the same process will take place as in option 2.

Option 4: Recycling in Vietnam via rail

This option is comparable to option 3. The only difference is the mode of transport to Vietnam. Recently, a rail connection between Duisburg in Germany and Vietnam has been in operation. It is claimed that this route is quicker but more expensive as shipping and a lot cheaper than airfreight (Nieuwsblad Transport, 2015). The trains will not go directly to HCMC, they first stop in Chonging and continue with a truck to Vietnam. Since Chonging is located south east of the middle of China, it still pretty far away from the Vietnamese border. Besides, after it enters Vietnam, it still has to be transported to Ho Chi Minh City. Because of the long road haulage, there is a possibility that the environmental benefit of the rail will be diminished. Besides, in comparison to shipping, the container will not be replaced by an empty one. After arrival in Vietnam, the procedure will be the same as in option 3.

7.3 Methodology

To calculate which of the four options gives the best overall outcome regarding the three P's, the income, costs and emissions have to be calculated. In this chapter, the used formulas will be determined per option. All the final answers will be given per tonne output. A full 2 TEU container of LDPE plastics weigh 25 tonnes and the container for the train has a maximum weight of 21,2 tonnes. The weight of an empty container is 3,8 tonnes. Also, the calculations have to be made for both the contamination levels of 80/20 and 98/2.

C= Total costs
I= Total income
E= Emissions in gram CO_2
P_i= Buying price for plastic type i per tonne
Pi= Price to pay for incineration per tonne

$Pt_!$= Price trucking per kilometre in country i
S= Selling price for plastic per tonne
Ca_s= Capacity sea container
Ca_r= Capacity rail container
CM= Costs manual sorting per tonne
CE= Costs extruding per tonne
C_s= Total shipping costs to Vietnam
C_r= Total railing costs to Vietnam
E_r= Emissions saved per recycled tonne of plastic

$E_{!}$= Emissions saves per incinerated tonne of plastic
Et= Emissions trucking
Es_o= Emission shipping ocean ship
Es_f= Emission shipping feeder
Er= Emissions railing
$R_{!}$= Rest weight after cleaning per i type of plastic
Nl= Netherlands
Vn= Vietnam

Option 1: Incineration

(1) $C = P_{!} + ((Pt_{!"} * \#_{!"})/Ca_{!})$

(2) $I = Pi$

(3) $E = ((\#_{!"} * Et_{!"})Ca_{!}) + E_{!}$

Option 2: Recycling in Europe

(4) C= $((P_{!} * Ca_{!}) + (Pt_{!"} * \#_{!"}) + (CM_{!"} * \#input) + (CE_{!"} * \#input) / Ca_{!})$

(5) $I = S * R_{!}$

(6) $E = ((Et_{!"} * \#_{!"})/Ca_{!}) + E_{!}$

Option 3: Recycling in Vietnam via shipping

(7) C = $((P_{!} * Ca_{!}) + (Pt_{!"} * \#_{!"}) + C_{!} + (Pt_{!"} * \#_{!!}) + (CM_{!"} * \#input * 1{,}25) + (CE_{!"} * \#input * 1{,}25))/Ca_{!}$

(8) $I = S * R_{!}$

(9) $E = ((Et_{!"} * \#_{!"}) + (Es_{!} * \#_{!"}) + (Es_{!} * \#_{!"}) + (Et_{!"} * \#_{!"}) / Ca_{!}) + E_{!}$

Option 4: Recycling in Vietnam via rail

(10) C = $((P_{!} * Ca_{!}) + (Pt_{!"} * \#_{!"}) + C_{!} + (Pt_{!"} * \#_{!"}) + (CC_{!"} * \#input * 1{,}25) + (CE_{!"} * \#\,input * 1{,}25)) / Ca_{!}$

(11) $I = S * R_{!}$

(12) $E = (((Et_{!"} * \#_{!"}) + (Er * \#_{!"}) + (Et_{!"} * \#_{!"}))/Ca_{!}) + E_{!}$

8. Results

In this chapter, the results will be analysed. First, the unmodified and modified results will be presented and discussed. After, the best options will be chosen and it will be discussed if the emissions are justifiable. Finally, a sensitivity analysis is included.

8.1 Analysis I

The final results without any modification are collected in table 6. Negative numbers in the columns I and I-C stand for a loss in money. The negative amounts in column ES and EE-ES stand for a savings in CO_2 emissions.

Table 6: Results per tonne

Recap 98/2						
	Costs and income			Emissions		
	C	I	I-C	EE	ES	EE-ES
Option 1	500	-150	-650	187	-6.939.000	-6.938.813
Option 2	862	931	69	3.110	-1.500.000	-1.496.890
Option 3	828	931	103	287.659	-1.500.000	-1.212.341
Option 4	1.022	931	-91	801.790	-1.500.000	-698.210
Recap 80/20						
	Costs and income			Emissions		
	C	I	I-C	EE	ES	EE-ES
Option 1	260	-150	-410	187	-6.939.000	-6.938.813
Option 2	1.204	760	-444	3.110	-1.500.000	-1.496.890
Option 3	680	760	80	287.659	-1.500.000	-1.212.341
Option 4	874	760	-114	801.790	-1.500.000	-698.210

In this table, EE stand for emissions expelled and ES stands for emissions saved
Cost and income are given in euros and emissions are given in grams CO_2 emissions

Option 1 gives a negative financial outcome. This is due to the reason than it costs about 150 Euro to let one tonne of LDPE plastics get incinerated. But, on the other hand it saves more than 4,5 times the CO_2 emissions as regular recycling. Nevertheless, this paper looks at sustainability. Since this term always requires a financial profit, incineration cannot be determined as a sustainable solution. Thus, it can only be sustainable for non-profit organizations, i.e. governments that collect mixed plastics and are more incentivized to lower pollution than profit.

Option 4 did not comply with the expectation. Rail transport is on average expected to be more expensive and more environmentally friendly than shipping. Nonetheless, in this study, rail transport is also more polluting than shipping. This is caused by the big distance between the end station of the train and the processing location. The train drives from Duisburg to Chonging, which is southeast to the middle of China. From here it has to be transported by truck all the way down to Ho Chi Minh City. This is a total distance of 2.913 kilometres.

The main comparison in this paper is between option 2 and 3. Here, both the qualities of plastic have higher revenue in Vietnam than in the Netherlands. Especially processing 80/20 quality LDPE in the Netherlands has a high loss. This is caused by the high cost of manual sorting. As expected, higher emissions are expelled with option 2 as with option 3. There is no difference in the saved emissions. Table 7 will compare the profit in comparison to the extra emissions.

Table 7: Expelled emissions related to benefits

Recap 98/2			
	I-C	EE	(EE)/(I-C)
Option 2	69	3.110	45
Option 3	103	287.659	2.785
Difference	34	284.549	8.300
Recap 80/20			
	I-C	EE	(EE)/(I-C)
Option 2	-444	3.110	-7
Option 3	80	287.659	3.607
Difference	524	284.549	543

In this table I-C stands for profit made in euros
EE stand for grams CO_2 emissions expelled

In table 7, (EE/I-C) stands for how much CO_2 is expelled to earn one extra euro. For example: when 98/2 plastic is processed in the Netherland, the profit is 69 euro per tonne and it expels 3.110 grams of CO_2. This concludes that per euro profit, 45 grams of CO_2 are expelled. When the difference between option 2 and 3 is calculated, (EE/I-C) gives answer to the ratio of extra earning against extra emissions between these options. For 98/2 plastics this is 8.300 grams and for 80/20 this is 543 grams. Since the amount of CO_2 is the same for both qualities, this difference it caused by the difference in profitability. The difference in margin between the two Vietnam options is only 23 Euro, thus the large difference between the extra emissions is caused by the high costs for manual sorting in the Netherlands.

8.2 Analysis II

Before, the trade surplus of China over Europe was discussed. Due to this reason, a high amount of empty containers go back to China. It can be argued that only the extra weight of the cargo has to be counted for calculating emissions. In the calculation, the whole supply chain is modified, not only the shipping part. Table 8 contains the all the modified results per tonne.

Table 8: Results per tonne with modification for empty containers

Recap 98/2						
	Costs and income			Emissions		
	C	I	I-C	EE	ES	EE-ES
Option 1	500	-150	-650	187	-6.939.000	-6.938.813
Option 2	862	931	69	3.110	-1.500.000	-1.496.890
Option 3	828	931	103	249.704	-1.500.000	-1.250.296
Option 4	1.022	931	-91	801.790	-1.500.000	-698.210
Recap 80/20						
	Costs and income			Emissions		
	C	I	I-C	EE	ES	EE-ES
Option 1	260	-150	-410	187	-6.939.000	-6.938.813
Option 2	1.204	760	-444	3.110	-1.500.000	-1.496.890
Option 3	680	760	80	249.704	-1.500.000	-1.250.296
Option 4	874	760	-114	801.790	-1.500.000	-698.210

In this table, EE stand for emissions expelled and ES stands for emissions saved
Cost and income are given in euros and emissions are given in grams CO_2 emissions

As expected, there are no changes in option 1,2 and 4. Option 1 and 4 have been discussed already in the last chapter and thus will not be included in the rest of this analysis.

Table 9: Expelled emissions related to benefits with modification for empty containers

Recap 98/2			
	I-C	EE	(EE)/(I-C)
Option 2	69	3.110	45
Option 3	103	249.704	2.418
Difference	34	246.594	7.193
Recap 80/20			
	I-C	EE	(EE)/(I-C)
Option 2	-444	3.110	-7
Option 3	80	249.704	3.131
Difference	524	246.594	471

In this table I-C stands for profit made in euros
EE stand for grams CO_2 emissions expelled

If corrected for empty containers, the extra emissions per Euro have decrease from 8.300 to 7.193 for 98/2 and from 542 to 471 for 80/20. These changes are not as large as expected because the emissions are calculated via the weight of the full container. Since the content is 25 tonne and the container is only 3,8 tonnes, it does not make a huge difference.

8.3 Discussion

Since incineration and processing both save emissions on a large scale, all the paths have a negative emission of CO_2 when compared to using virgin materials.

Nonetheless, this paper looks at sustainability, which includes the emissions, profit and people. Option 2 is profitable in both countries and option 3 is only profitable in Vietnam. Since option 3 is only profitable in Vietnam, it should always be exported from the Netherlands if possible. When exported, there is a higher profit of 34 euro per tonne. Due to transportation, this causes 7.193 grams of CO_2 extra per tonne.

To decide whether these emissions are justifiable; these costs have to be monetary valued and internalized. One way to internalize costs is the EU emissions trade system. Unfortunately, this scheme is at this moment not fully efficient due to the low price. In 2014, the highest price to pay for one tonne of emission was 7,26 Euro and the highest price ever was 32,02 euro per tonne (eex.com, 2015). The low price at the moment is caused by the high supply of emissions. This information is available, which causes the low price. Before, when this was not known, the price was more reasonable. Due to this reason, both prices are calculated.

(13) $P_{!} = \left(\frac{!,!"}{!""""""""}\right) * 7193 = 0{,}05$

(14) $P_{!} = \left(\frac{!",!"}{!""""""""}\right) * 7193 = 0{,}23$

For one extra earned Euro, EPR B.V. should play 5 cents or 23 cents according to the European emission trade system. Next, the total emissions cost will be determined. Here, the latter price will be used, since this is a better representation of the cost is should be.

(15) $P_{!} = \left(\frac{!",!"}{!""""""""}\right) * 246.594 = 7{,}90$

The total extra cost per tonne of plastic is 7,90 Euro, which would drop extra profit from 34 Euro to 26,10 Euro. Thus, it is still sustainable.

8.4 Sensitivity analysis

Finally, this research will include a sensitivity analysis. Only option 2 and 3 are taken into account because the other options are not relevant due to a high loss or high pollution. This analysis will look at the sensitivity of the profit, price per gram CO_2 and the total emissions. The modified outcome it used. For all variables the turning point for at which the outcome change will be determined.

To calculate this point, it is necessary to make a small recap at first. After, the calculations will be given.

Table 10: Recap calculations

98/2				
	P	PE	E	Total
Option 2	69,00	0,000032	3.110	68,90
Option 3	103,28	0,000032	249.704	95,29
Difference			246.594	26,39
80/20				
	P	PE	E	Total
Option 2	-444,00	0,000032	3.110	-444,10
Option 3	79,75	0,000032	249.704	71,76
Difference			246.594	515,86

In this table, P stand for the profit in euro, PE stands for price emissions per gram in euros and E stands for gram expelled CO_2 emissions per tonne. Total is calculated with the following formula: (P - (PE*E)).

8.4.1 Methodology

The sensitivity of profit stands for how much the profit has to change to make one option more profitable than the other one. This is determined with the following calculation.

(16) $SenP = (Total_{!"} - Total_{!"})$

There is no calculation for the sensitivity of the price for emissions. To find the turning point, it is necessary to change the price for emissions, but simultaneously the profit will change as well. Thus, it is only possible to approach it. Due to this reason, the sensitivity of the price for emissions is calculated by trial and error.

As last, the emissions are taken into this analysis. The tipping point for the total emissions stands for how much the expelled CO_2 should rise or fall to make another decision. This is calculated with the following formula.

(17) $Sen\ E = \left(\frac{!"\#\$\%_{!"} - !"\#\$\%_{!"}}{!"}\right)$

8.4.2 Outcome

Table 11: Outcome I sensitivity analysis

	98/2	80/20
Sen P	26,39	515,86
Sen PE	0,000139	0,002125
Sen E	824.068	16.110.455

In this table, P stand for the profit in euro, PE stands for price emissions per gram in euros and E stands for gram expelled CO_2 emissions per tonne

Table 11 states the outcome of the sensitivity analysis. The sensitivity of profit is the difference between the two final outcomes from table 10. Thus, no relevant information can be gathered from it. Since the price of emissions and the emissions itself are interrelated, one general conclusion can be drawn from these two outcomes.

To come to a better conclusion, equation 18 and 19 show how many times the price for emissions and the expelled emissions have to be multiplied in order to reach the tipping point

$$(18)\quad Sen\ PE\ II = \frac{Sen\ PE_{!}}{PE_{!}}$$

$$(19)\quad Sen\ E\ II = \frac{Sen\ E_{!}}{(E_{!"} - E_{!"})}$$

Table 12: Outcome II sensitivity analysis

	98/2	80/20
Sen PE II	4,34	66,36
Sen E II	3,34	65,33

In this table, PE stands for price emission and E stands for emission

The results for 80/20 quality plastic is high due to the big difference in profit in option 2 and 3. The outcome for 98/2 is more interesting. It states that the price for emissions should be 4,34 as high or the emissions should be 3,34 times as high to reach the tipping point. Since for these calculations, the highest price for emissions ever is used, it is a quite high number. Thus, in comparison to the profit, the expelled CO_2 there is low.

9. Conclusion and limitations

9.1 Research questions

Sub questions 1) How much is extra polluted when plastics are transported and processed in Vietnam compared to when they are only processed in the Netherlands?

Transportation by shipping from the Netherlands to Vietnam costs 246.594 grams extra CO_2 emission per tonne. Transport via rail transport costs 801.603 grams extra, but rail transport does include trucking from the middle of China to the south of Vietnam.

Sub question 2) Is it a lot more profitable to recycle in Vietnam compared to the Netherlands—including external costs?

For both types of plastics included in this paper, it is more profitable to process in Vietnam. 80/20 quality has a higher profit of 524 euro per tonne and for 98/2 it is 34 euro per tonne. This already includes costs for externalities based on high CO2-costs and social circumstances.

Sub question 3) Are there any social differences between recycling in Vietnam compared to the Netherlands?

The working conditions in Vietnam are not as optimal as in the Netherlands. Due to this reason, the costs in Vietnam have been raised with 10% for processing and 25% for manual sorting.

Sub question 4) Which other externalities occur alongside with this business? If so, how do they influence the sustainability?

Besides the expected externalities of pollution and social conditions, no other externalities have been found.

Sub question 5) Are the port area's attractive for the biobased and circular economy?

For the biobased economy, the port of Rotterdam meets all the factors from table 1. Therefore, it is perfectly suitable for these companies. It did not meet all the factors for the circular economy. It lacks the presence of related companies, which do not settle themselves here due to high costs. More detail see table 1.

The port area of Ho Chi Minh City is not suitable both economies. The biggest issue is the undeveloped logistics. This causes higher shipping and settling costs and this results in an unattractive area. More detail see table 2.

Research question: How sustainable is it to export recyclable plastics from the Netherlands to Vietnam and how does this business contribute to the circular economy cluster in ports?

It is sustainable to export recyclable plastics to Vietnam when the extra profit is higher than the costs for emissions. This is the case on both 98/2 and 80/20. They do cause extra emissions, but when the costs for emissions are valued an internalized, it is still profitable and thus sustainable.

The port of Rotterdam can benefit more from export than from non-export. Since most of the plastic recycling companies are located in the southeast of the country, without export, the plastic will not arrive in the area at all. But the circular port cluster does not benefit from the export, only the port related companies will. In Vietnam, only the port functions will benefit since they production is not located in this area.

9.2 Conclusion

The circular economy should help to reduce the usage of fossil sources and emission of greenhouse gasses. It will do so by optimizing the usage of materials from both the technosphere and biosphere.

Ports play a big role in creating circularity since it can be an ideal settling place for these companies. The port can provide a good infrastructure, synergy and proximity to the buying and selling market. Due to this reason, clusters are formed in a port area.

For the circular economy to be successful, it should not neglect profitability and social conditions. This paper looks into how this relates to the export of recyclable plastics from a western country to Asia. In this case, the plastics are recycled with a higher profit. But, there is a chance of negative externalities like bad working conditions and extra emissions by transport. To find out if this is in balance with each other, the research project investigated four cases. It calculated the costs, incomes and emissions per tonne LDPE with the quality of 98/2 and 80/20.

- Route one: incineration in the Netherland;
- Route two: recycling in the Netherlands;
- Route three: recycling in Vietnam with transport via shipping;
- Route four: recycling Vietnam with transport via railing;

All these routes save emissions at the end, but not all of them are profitable. Only route two for 98/2 and route three for both 98/2 and 80/20 was profitable. The extra costs for bad working environments are taken into account here already. Since profitability is a necessary, 80/20 should only be processed in Vietnam. For 98/2 it is both possible, but the profit is higher in Vietnam. By exporting, the profit is 34 Euro per tonne higher. To argue if the extra profit justifies the extra expelled CO_2, it has to be valued. It is valued according to the European Emission System. Per tonne of plastic, the emissions grew with 247.905 gram CO_2. According to the system, this has a value of 8 Euro, which lead to a profit of 26 Euro per tonne. Since there is still a profit after valuating the emissions, it is sustainable to export 98/2 LDPE plastics from the Netherland to Vietnam for processing.

9.3 Limitations

This study is limited in the made assumptions. All the price, income and emissions are assumed on basis of reports, paper and information from industry courses. It happened more than once that information did not completely comply with eachother. Besides, costs and prices vary by time. Especially the prices of plastics depend on demand, supply and the oil price. For calculating the different emissions, some standards are used. These standards are based on averages, but in real life, this is not the case.

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Appendix I

Contains confidential information. Available upon request.

Appendix II

Contains confidential information. Available upon request.

Appendix III

Transportation costs		USD/EURO	0,92	Oanda.com
			Source:	
Trucking in NL per km	1	EURO	Janic (2007)	
Trucking in VN per km	0,24	EURO	The Asia fondation (2008)	
Shipping	750			
Transshipment	225			
Bill of lading	45			
ED	45			
Shipping to Vietnam	1065	Quotation from Cyberfreight International B.V.		
Railing to Vietnam	5.100 USD	Quotation from Hellmann B.V.		
	4.692 EUR			

Distances

From	to	Afstanden		Source
Hengelo	Rotterdam	235	km	Google maps
Hengelo	Hengelo	3	km	Google maps
Hengelo	Duisburg	126	km	Google maps
Lai mep port Vietnam	Ho Chi Minh City	75	km	Google maps
Chonging	Ho Chi Minh City	2913	km	Google maps
Port of Rotterdam	Port of Singapore	13312	km	http://www.sea-distances.org/
Port of Singapore	Lai mep port Vietnam	1040	km	http://www.sea-distances.org/
Duisburg	Chonging	11179	km	Google maps
Hanoi	Ho Chi Minh City	1737	km	Google maps

Appendix IV

Contains confidential information. Available upon request.

Appendix V

Emissions

	Emissions g/tkm (CE Delft, 2011a)	Weight full contain	Per container
Transport in NL	54	28,8*	1555,2
Transport in VN	107	28,8*	3081,6
Shipping to Singapore Ocean ship	14	28,8*	403,2
Shipping to Vietnam Feeder	41	28,8*	1180,8
Railing to VN	28	25**	700

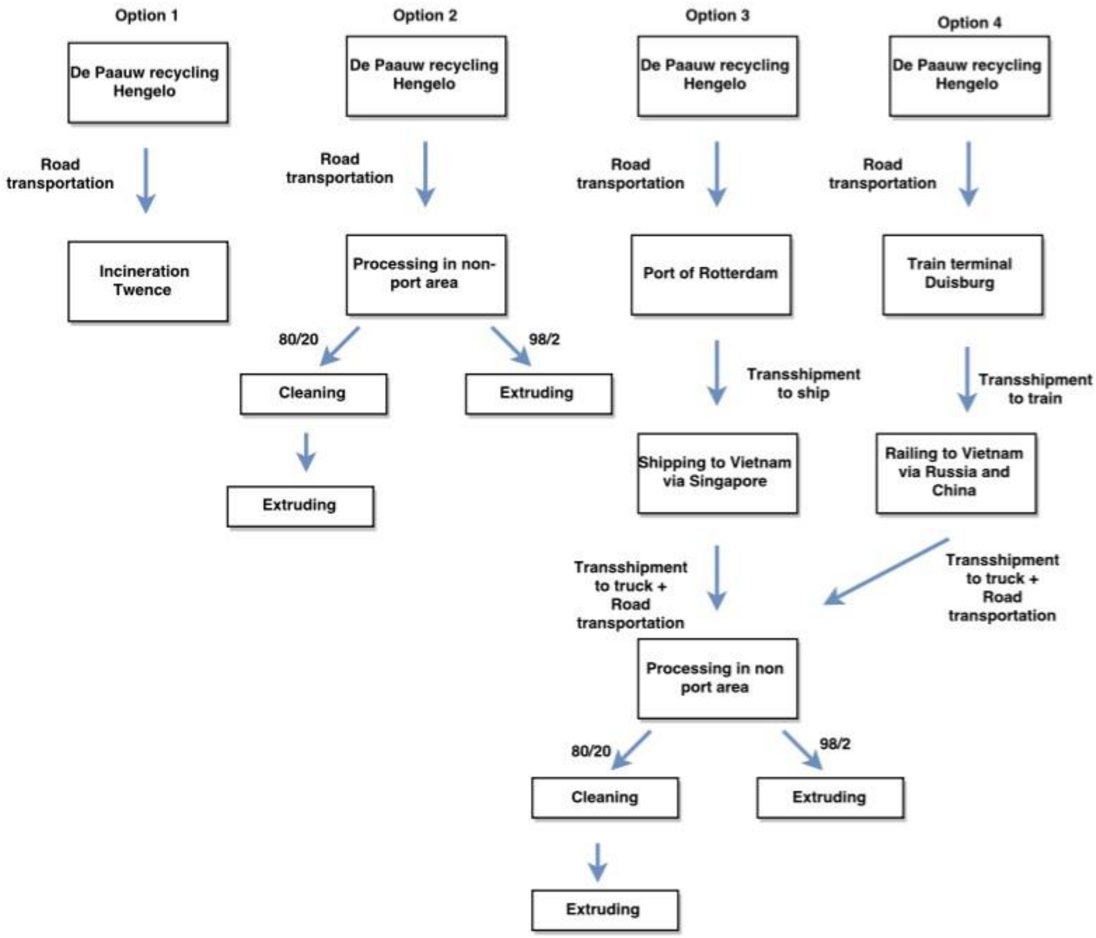
	Kg CO2/tonne plastic treated (Neidel & Jakobsen, 2013)	Content container	Kg per container
Incineration	-1.500	25	-37500

Processing	Calorific value PE	43 MJ/kg (Table 11)
	Calorific value 1 tonne of incinerate LDPE	43.000 MJ
	43.000 in kWhe	11.944 Kwh
	0,581*11.944=	6.939 kg CO2
	6.939*25	173.475 kg
	0,581 kg CO2/kWh (CE Delft, 2011b)	

* The total weight of a container is 28,8 tonne, 25 tonne for the content and 3,8 for the weight of the container.

** The total weight for the rail container is 25 tonne. The content has a maximum weight of 21,2 tonne plus the 3,8 tonne for the container

Appendix VI


Option 1
De Paauw recycling Hengelo
Road transportation
Incineration Twence
Option 2
De Paauw recycling Hengelo
Road transportation
Processing in non-port area
80/20
98/2
Cleaning
Extruding
Extruding
Option 3
De Paauw recycling Hengelo
Road transportation
Port of Rotterdam
Transshipment to ship
Shipping to Vietnam via Singapore
Transshipment to truck + Road transportation
Option 4
De Paauw recycling Hengelo
Road transportation
Train terminal Duisburg
Transshipment to train
Railing to Vietnam via Russia and China
Transshipment to truck + Road transportation
Processing in non port area
80/20
98/2
Cleaning
Extruding
Extruding