Loops to Leapfrog

A research on the application of the Circularity Principles as decision making tool for European policy makers

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Master Thesis

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By

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Executive Summary

With the arrival of the Circular Economy Package presented by the European Commission in December 2015, more policies supporting the shift towards a more circular economy are to be expected. If these policies are to be successful, they have to reflect the underlying intent of a circular economy; guiding principles are a necessary and helpful tool. There is a need for an integrated assessment framework to implement circularity into government policy making, to evaluate the effects of a policy over the whole value chain.

This research puts the circular value creation principles (Circularity Principles) as defined by the Ellen MacArthur Foundation to the test to see if they are useful as a policy making tool. These Circularity Principles are critically examined through case studies from the plastic value chain. Different policy options are reviewed according to what extend they reflect the most preferred option in the light of the Circularity Principles which encompasses three conditions. First, products and materials should be kept as long as possible within the economic system. Secondly, the activity should be as high on the circularity ladder as possible. In terms of Waste Management Hierarchy this means that one should choose prevention above recycling. Third, the materials used in a product should contain as little hazardous substances as possible and should consist of little different and easy to separate materials.

The research concludes first of all that the Circularity Principles give a good insight in the difficulties which may arise and that they can reveal trade-offs whereas the policy maker has to balance the principles against each other. Secondly it concludes that the Circularity Principles provide a long term focus for policy makers to check a priori which policies will really contribute to a transition towards a more circular economy. Also future investment priorities for European funds can be identified when a most preferred outcome can be appointed according to the Circularity Principles. Hereby the possibility arises to leapfrog the linear economy and invest directly in the best circular practices.

Take home points

- Coherent coordination between several levels (European, National, regional and local) is necessary to seize the opportunities of a circular economy. A better understanding what kind of considerations have to be made on which level can be done on the basis of the Circularity Principles. By using the same Circularity Principles, the different levels of governance can collaborate determine the most preferred outcome and subsequently implement mutually supporting policies.
- The differences between the economic sectors in their transition towards a more circular economy are big, which means that policies will have to be differentiated to the sectors' specific needs. Frontrunners need to be supported with more legislative space, whereas legislation is perceived as a barrier for continued 'circular' innovation. The peloton often needs exactly the opposite, stricter policy to stimulate 'circular' action. Hereby the Circularity Principles may be arranged, or ranked, differently depending on the sector, to check upon the level of circularity of the proposed activity. A role for civil society and NGO's hereby can be to check whether the Circularity Principles are properly taken into account in the policy making process and assorted outcome.

- It seems that many plastic-related policy issues fall into what are defined as unstructured or badly structured problems. Such circumstances require a reflexive approach to brokering knowledge between industry, scientists and policymakers, and that scientists will need to be prepared to make and facilitate value judgements on the basis of best evidence.

Keywords: Circular Economy, Circularity Principles, Decision Making Tool.

Preface

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in European Governance at the Universiteit Utrecht in Utrecht and Masarykova Univerzita in Brno.

Conducting research about a rather new phenomenon is exciting but challenging. An increasing number of actors seem to become interested in the broad concept of a circular economy. Many different actors, from grass root organisations working towards an increased sharing of products among neighbours in the name of 'remunicipalisation', to multinationals companies who are increasingly aware of the valuable scarce materials they sell and never see in return. With so many different reasons to invest in a more circular economy, you get eminently different views and definitions. Despite the extensive research yet to be done, the momentum for a circular economy is here right now, at least in the Netherlands. I am very much looking forward to all the initiatives which are about to get foot on the ground, especially the work in progress from the European institutions.

Hereby I would like to thank all of the interviewees for the very interesting conversations and indispensable insights. Also I would like to like to thank my supervisors from both universities for their feedback and guidance throughout my research.

Furthermore, I would like to acknowledge my colleagues of DCMR Milieudienst Rijnmond. I am grateful for their enthusiasm to share their expertise and endorse me in my research. I owe a special word of thanks to Marc Koene for welcoming me at DCMR and giving me the opportunity to gain valuable working experiences.

Finally, I also want to thank Rik for his sharp eye and last but not least, Gerard and Charlotte for their unconditional support.

Michiel Nanninga
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List of abbreviations

ABS	Acrylonitrile butadiene styrene
C2C	Cradle to Cradle
CEP	Circular Economy Package
CEMR	Council of European Municipalities and Regions
CEWEP	Confederation of European Waste-to-Energy Plants
CO_2	Carbon Dioxide
CP	Circularity Principle
CPB	Centraal Planbureau
DNEL	Derived no-effect level
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Environmental Agency
EMF	Ellen MacArthur Foundation
EPR	Extended Producer Responsibility
EREP	European Resource Efficiency Platform
EU	European Union
FHG	Federatie Hergebruik Grondstoffen
FotE	Friends of the Earth
GAIA	Global Alliance for Incinerator Alternatives
HDPE	High-density polyethylene
HIPS	High impact polystyrene
LCA	Life Cycle Assessment
LDPE	Low-density polyethylene
MSW	Municipal Solid Waste
MWM	Municipal Waste Management
N&M	Natuur & Milieu
NGO	Non-governmental organisation
NSRR	North Sea Resource Roundabout
OECD	Organisation for Economic Cooperation and Development
PA	Polyamides
PBB	Poly-brominated biphenyls
PBL	Planbureau voor de Leefomgeving
PBDE	Polybrominated diphenyl ethers
PC	Polycarbonate
PCB	Polychlorinated biphenyls
PCT	Polychlorinated terphenyls
PE	Polyethylene
PES	Polyester
PET	Polyethylene terephthalate
POP	Persistent organic pollutants

PP	Polypropylene
PRE	Plastic Recyclers Europe
PS	Polystyrene
PSS	Product-service system
PUR	Polyurethanes
PVC	Polyvinyl-chloride
PVDC	Polyvinylidene chloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RLI	Raad voor de Leefomgeving en Infrastructuur
RoHS	Restriction of Hazardous Substances
REE	Resource Efficient Europe
SER	Sociaal Economische Raad
SPI	Society of the Plastics Industry
UKWIN	United Kingdom Without Incinerators Network
UNEP	United Nations Environment Programme
USI	Utrecht Sustainability Institute
VA	Vereniging Afvalbedrijven
VROM	Volkshuisvesting, Ruimtelijke Ordening en Milieuzaken
WEEE	Waste Electronic and Electrical Equipment
WEF	World Economic Forum
WFD	Waste Framework Directive
WMH	Waste Management Hierarchy
WRAP	Waste and Resources Action

1. Introduction

"Once there was a tiny planet.

There were rivers and forests,
a large crater with small mountains in it,
and one small inhabitant"

Maggi Giles (1980:4)

1.1 Introduction

The European Union (EU) Member States rely on energy imports for more than half (53%) of their gross energy consumption and the percentage of raw material imports is even higher (Eurostat, 2015). This dependency is a source of vulnerability for our current economic system. Growing global competition for natural resources has contributed to marked increases in price levels and volatility (EEA, 2016:6). The price of these natural resources has increased at twice the rate of wage growth over the past decade (EU Observer, 2015a). This represents a historic shift compared with the 20th century, when the price of resources would normally fall while costs of labour rose. The prices of natural resources are expected to remain high for at least the next 20 years, to meet this new resource price reality, new forms of value creation must be developed if the world is to maintain and increase prosperity (Chathamhouse, 2012:2).

But there are limits to this increase of prosperity, especially when being stuck to the use of finite resources and the unsustainable use of renewable resources like water and soil. The fact that there are limits to growth has already been said by the Club of Rome in 1972 (Meadows, 1972). We have to put the idea that the world economy can grow for two centuries with double digits out of our mind or we make sure the economy functions well by being depended on significantly less primary resources, which is the idea behind a circular economy (Tukker, 2016:5).

The institutions of the European Union have seen these developments as well and have started working on it. The first visible step was the publication of the Roadmap to a Resource Efficient Europe (REE) back in 2011 that proposes ways to increase resource productivity and decouple economic growth from resource use and its environmental impact (EC, 2011a). The publication of the second Circular Economy Package (CEP), after the first one was discarded, is the next step towards the development of a more circular economy. In the package the European Commission brought up policy action points on all the different life-cycle phases of products, from design up to the after-use management (EC, 2015). But the publication of the CEP has not gone without criticism. It seems like the REE Roadmap has already been forgotten because the CEP mainly consists of initiatives and targets aimed to reduce the landfill and incineration of waste, but there is no longer a target for an overall reduction in the total amount of resources we use (Lowe, 2015). It is not a plan to ‘go further with less’ like the original idea was in 2014 (Robert, 2014).

The World Economic Forum (WEF) states that the policy-makers should be engaged to develop a common vision of a more effective system and that they should be provided with relevant tools, data and insights (WEF, 2016:9). One specific deliverable could be a ‘plastics toolkit’ for policy-makers, giving them a structured methodology for assessing policy options in transitioning towards the ‘New Plastics Economy’, as the WEF calls a circular economy regarding plastics (Ibid). In other words, there is a need for an integrated evaluation method to implement circularity into government policy making, to evaluate the effects of a policy over the whole value chain (SER, 2016:41-44). Indeed, if a policy is to be successful, it has to reflect the underlying intent of the circular economy (RWM, 2014:8). Likewise, policy evaluations will systematically be necessary to adjust policies in time when a government is executing adaptive governance (SER, 2016:38), guiding principles are a necessary and helpful tool. This research therefore goes back to one of the first comprehensive reports about the idea of a circular economy, published by the Ellen MacArthur Foundation (EMF) in 2013, in which four “*simply principles of circular value creation that hold true*” are presented (EMF,2013:31). The idea is to put these to the test and see how these circular value creation principles - from now on called Circularity Principles (CP’s) – can be used as decision making tool for policy makers.

The overall aim of this research is to influence thinking of policy makers in developing a circular economy. Hereby the research specifically aims to get insight how the Circularity Principles can be used as a policy decision making tool and how policy makers on the European level are able to make policies according to them. Critically examining these Circularity Principles via a case study will strengthen the academic knowledge about the fundamental theories of the EMF's vision of a circular economy. The obtained insights therefore have academic as well as social relevance. The insights might be useful for policy makers on different layers of government as well. Overall, coherent coordination between several levels (European, National, regional and municipal) is necessary to seize the opportunities of a circular economy (RLI, 2015).

Next to that, the Utrecht Sustainability Institute states that it needs to be investigated for every separate product-chain on what scale, or combination of scales, it can be closed best (USI, 2013:37). Therefore, next to time and space limits, the choice has been made to focus on one particular product-chain - in this research called value chain - namely the one of plastics. Plastic is produced almost exclusively from oil and, at present, plastic production accounts for approximately 8% of world oil production, of which 4% as a raw material and 3-4% as energy for the plastic manufacturing processes (Plastics Europe, 2015:7, Hopewell et al., 2009 and UNEP, 2014:16). If there is one resource of which the use will have to be limited, it is fossil fuels. On top of that, plastics are widely used in different variations, in everyday products, of which much is used just once and then thrown away, resulting in 95% of the value of plastic packaging, worth up to 120 billion pound annually, being lost to the economy (EMF, 2016a:14). In 2014, 25.8 Million tonnes of post-consumer plastics waste ended up in the waste upstream, of which only 29,7 % was recycled (Plastics Europe, 2015), which is only the plastic waste collected at households. The durability of plastic means that uncontrolled disposal is problematic as plastic can persist in the environment for a very long time (EC, 2013:3). As a result, the generation of plastic waste is growing worldwide. Given the projected growth in consumption, by 2050 oceans are expected to contain more plastics than fish (by weight), and the entire plastics industry will consume 20% of total oil production and 15% of the annual carbon budget (WEF, 2016:14). This makes it even more urgent to have a look on the role that plastics can play in a circular economy.

The main question of this thesis is*:* How can the Circular Principles be used as a policy decision making tool for policy makers in the European Union regarding policies affecting the plastic value chain?

Corresponding sub questions to be answered are;

- What are the Circularity Principles?
- What are expected difficulties when applying the Circularity Principles as decision making tool?
- What happens if you use the Circularity Principles as decision making tool in a single demarcated policy choice?
- What happens if you use the Circularity Principles as decision making tool to determine the policies for future development?

1.2 Methodology

Besides the descriptive background parts that have a more ontological approach, this research has a rather epistemological approach. Epistemology is hereby freely understood as a field of science that tends to describe the many approaches we can choose to understand our world. The Circularity Principles are used as an approach to figure out difficulties in a decision making process and to see to what extent certain activities or applications can be classified as being 'circular' or not. The CP's hereby are used as a, rather straightforward, classification method whereby the 'level of circularity' is determined. The better a policy choice measures up to the most preferred option according to all of the three CP's, the more the policy choice should be preferred.

1.3 Interviewees

This qualitative research makes use of expert interviews. The interviews are used to gain insight in the virgin and secondary plastic market, in the processes of plastic waste handling and in the state of research and innovation around circular practises. It is thereby aimed to gain insight on the positions of government, businesses and non-governmental organizations. An overview of the interviewees and their function is presented in Annex II. Based on their background, it is expected that all stakeholders have a slightly different interest in investing in a circular economy. To gain more insight in the practices involved in a circular value chain and to get an objective view on the implications of these practices, two independent researchers are interviewed as well. One has experience in research on (creating cooperation within) value chains within the built environment and the other has experience in life cycle assessment research and product-service-systems.

1.4 Interview method

Several interview methods exist. In this case a semi-structured interview technique is used, in which more or less open-ended questions are brought to the interview situation in the form of an interview guide. The main challenge is to get the participant to expand upon their answer, give more details and add additional perspectives (Stewart, 2008). In this way, a profound insight can be gained in the different considerations in moving the plastic value chain towards a more circular economy.

1.5 Research structure

In part 2 of the research the concept of a circular economy is introduced. What does it mean? And what is the idea behind it? Herein the Circularity Principles are introduced and analysed to make them applicable as a simple policy making tool. What follows is a theoretical reflection of what happens if you use the CP's in a strict way. This is done to check the CP's upon inconsistencies. All of which is done via literature study.

In part 3 of the research the focus is narrowed down to a case study around a single demarked policy choice. This is the part where the CP's are used as decision making tool in a case study around a single demarked policy choice. Hereby background information is given about policies regarding PVC plastics, of which the knowledge is acquired via a literature study. The case study is based on a real-life example around PVC applications containing cadmium of which insights are gained via interviews with a policy maker and a NGO concerned with similar policies.

In the fourth part of the research, the CP's are used as a reflective guide through a decision making process to determine a future development path. Hereby examples and insights from interviews with academics and industry representatives are used combined with a literature study.

In the fifth and last part of the research, the focus is broadened again. This part comprises the reflection on the two analytical parts of the case study and the future development path. The aim of this part of the research is to answer the main research question and give some practical recommendations for European policy makers and future research.

1.6 Definitions

Biobased plastics
The term biobased plastics in this research refer to all plastics that are bio-based, biodegradable or compostable or a combination of them (EMF, 2016:68), as long as they are able to be brought back in the economic system via the biological cycle as represented in the butterfly model in figure 1.

Chemical Recycling
Chemical recycling converts waste polymers into feedstock for chemicals or materials (Zhuo and Levendis, 2013:1). Chemical recycling for fuel production is left outside the scope of this research.

Economic system
When referring to the 'economic system', the European common market is meant if not stated differently.

Hazardous substances
Hazardous substances in this research are all of the substances as covered by:

- Article 4.1 of Directive 2002/95/EC on the Restriction of Hazardous Substances (RoHS);
- Article 2 (a) of Directive 96/591/EC on PCB/PCT;
- Article 2 of Directive 2009/148/EC on exposure to asbestos at work.

These include, among others, lead, mercury, cadmium, hexavalent chromium, poly-brominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), Polychlorinated biphenyls (PCB), polychlorinated terphenyls (PCT) and Asbestos.

Among these substances are Persistent organic pollutants (POPs) that are chemical substances that persist in the environment, bio accumulate through the food web, and pose a risk of causing adverse effects to human health and the environment (EC, 2016a). PCBs, for example, are classified as probable human carcinogens and produce a wide spectrum of adverse effects in animals and humans, including reproductive toxicity, teratogenicity and immunotoxicity. They can be transported long distances and have been detected in the furthest corners of the globe, including places far from where they were manufactured or used (EC, 2016b).

Plastics
Plastics as referred to in this research are all the materials considered in Annex I of this research. Biobased plastics, Styrofoam and rubbers are not taken into account within the scope of this research.

Policy
Policy is in this research broadly understood as something which 'changes the rules' that govern the way in which people, businesses and other organisations behave (RWM, 2014:7).

Reconditioning
Reconditioning is the rebuilding of major components to a working condition that is generally expected to be inferior to that of the original model (King et al., 2006:261).

Recycling
Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations (Art. 3.17 of Directive 2008/98/EC on Waste).

Remanufacturing
Remanufacturing requires the total dismantling of the product and the restoration and replacement of its components. Of all the current 'secondary market' (used product) processes, remanufacturing involves the greatest degree of work content and as a result its products have superior quality and reliability (King et al., 2006:261).

Repairing
Repairing is simply the correction of specified faults in a product (King et al., 2006:260). Generally, the quality of repaired products is inferior to those of remanufactured and reconditioned alternatives.

Re-use
Re-use means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived (Art. 3.13 of Directive 2008/98/EC on Waste).

Upcycling
Upcycling is considered as a process in which waste materials are converted into something of a greater value and/or quality in their second life (Sung, 2015). Important here is the word waste, the original user must have disposed the material or product before it can be upcycled. Otherwise upcycling could also be applied on the process of manufacturing.

Waste
Waste means any substance or object which the holder discards or intends or is required to discard (Art. 3.1 of Directive 2008/98/EC on Waste).

2. Circular Economic theory

"If a businessman suggests opening a manufacturing plant to make money, it can be countered that they can make five times as much from opening a remanufacturing plant" [1]

Walter Stahel

[1] Walter Stahel, originator of the circular economy concept, said that if a businessman suggests opening a manufacturing plant to make money, it can be countered that they can make five times as much from opening a remanufacturing plant. Therefor the anti-competitiveness argument put forward by some in big business is wrong-headed (The Guardian, 2014).

2.1. Circular Economy

Is the circular economy not just a fancy word for recycling? The answer is no, because a circular economy is much more than that (Guardian, 2015a). It can be seen as an umbrella term of many economic systems and product design principles, of which most are already in use for many years[2]. With the coining of the term circular economy, it is just the first time they are used in such an inclusive way. It is important to keep in mind that the circular economy must not be seen as a goal itself, but as a mean to reach certain goals (de Man, 2016), such as sustainable use of scarce resources, generating long-term economic growth, creating jobs, and reducing environmental impacts, including carbon emissions (EMF, 2015:5).

The Ellen MacArthur Foundation (EMF) is one of the pioneers in the field of circular economy and provides the most complete -and often cited- definition for a circular economy available up to date. The circular economy is *"an economic and industrial system that is restorative and regenerative by design and which aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles"* (EMF, 2015:22).

Unlike the contemporary take-make-consume-dispose approach, a circular economy seeks to respect environmental boundaries by increasing the share of renewable or recyclable resources while reducing the consumption of raw materials and energy and using those resources more efficient (EEA, 2016 and Acceleratio 2015). A circular economy represents a new economic model which ultimately seeks to decouple global economic development from finite resource consumption. This can be done via eco-design, sharing, re-using, repairing, refurbishing and recycling existing products and materials, which all helps to main- or retain the value of products and materials (EEA, 2016). These practices are visualised in the butterfly model (figure 1) as continuous positive development cycles that preserves and enhances natural capital, optimises resource yields, and minimises system risks by managing finite stocks and renewable flows (EMF, 2012:24).

The goals of a circular economy of long-term economic growth, sustainability and zero waste can only be reached when the avoidance (or use) of waste flows is central in the design phase of the product and of systems (Bastein et al, 2013:7). The Ellen MacArthur Foundation provides three guiding thoughts here for (EMF, 2015:7).

1. Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.
2. Optimise resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles.
3. Foster system effectiveness by revealing and designing out negative externalities.

These three guiding thoughts provide the basis for the four potential sources of core economic value creation, put down in words by the four Circularity Principles which will be introduced in the next paragraph (2.1.2).

Actions towards a circular economy to date have mainly been driven by value maximization along the value chain and the interest in continually reintroducing assets to markets (Acceleratio, 2015:4). A real shift away from the linear economy towards a circular economy requires a system change (Rli,

[2] Of which the most important ones are explained in the next section.

2015:11). After all, process optimisation could block more radical changes for the purpose of a circular economy. For example the miniaturization of products and components could make it harder to repair the product and the process of making plastic packaging even more light-weight could lead to a decrease in recyclability cause of added additives. Circular economic system thinking needs to become common practice.

However, process optimisation from the design phase is not easy. That can be partly explained due to the complexity of the value chains which are iconic for our global economy, especially when design takes place somewhere else on the globe and whereby costs cannot easily be offset in a fair way (Bastein et al., 2013:10). That is even more reasons to work together with a broad set of actors. Especially economic actors like businesses and consumers are key in driving the process, alongside local, regional and national authorities to enabling the transition towards a circular economy.

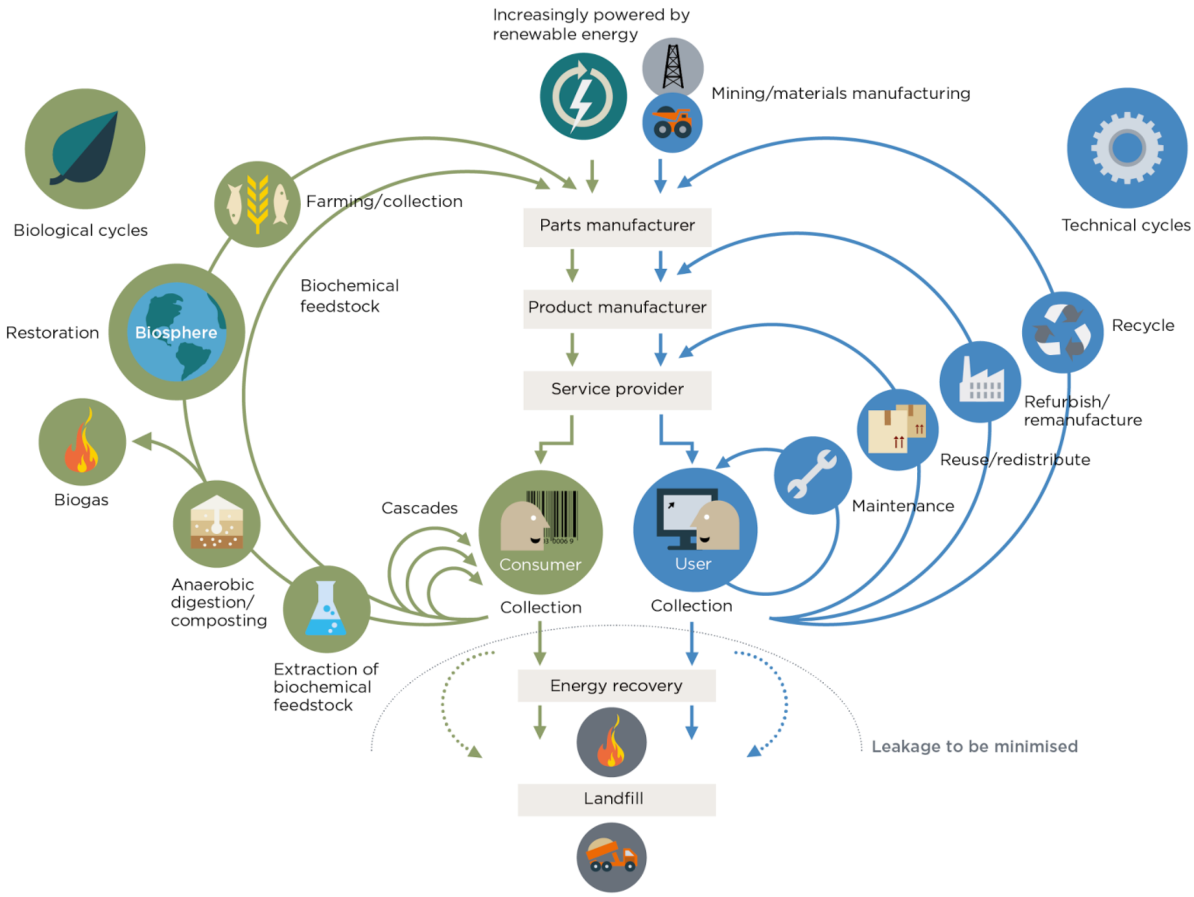

Figure 1: The Butterfly Model of a circular economy as presented by the Ellen MacArthur Foundation.

All in all there are at least three broad motives to be distinguished to invest in a circular economy (PBL, 2014). The first one is to secure raw material supply by keeping materials within the European economy. Decreasing the dependency on imports of raw resources is one way to increase the stability of one's economy against external shocks relating to geopolitical treats.

Secondly, a Circular Economy has a substantial long-term economic growth potential. Circular practices have added value or can lead to a reducing in costs and can create new business opportunities. In 2011, the Ellen MacArthur Foundation together with consultancy group McKinsey calculated that a shift towards a circular economy would save up to 1.3 trillion euro of which in a minimum scenario would result in material-saving worth 380 billion annually for the EU Member

States (EMF, 2013:10). Also the level of jobs created is considered to be large. On the European level, a shift in reusing, remanufacturing and recycling products could lead to more than half a million jobs being created in the recycling industry across Europe (Chathamhouse, 2012). Commissioned by the Dutch government, the research consultancy firm TNO calculated that a circular economy would result in a gain of 7.3 million euro for the Dutch economy and it would create 54.000 jobs (Bastein et al., 2013:3).
Third, a Circular Economy will decrease the human footprint on the natural environment. Not only by extracting fewer raw materials out of the natural environment, but also via the prohibition on the use of toxic materials and the minimisation of the waste production. In a nutshell, one of the environmental benefits is an 85% drop in energy use for remanufacturing in general compared to virgin material manufacturing (EMF, 2016).

2.1.2. Origin of Circular thought

The rationale behind the circular economy is not new. The American economist and philosopher Kenneth M. Boulding already termed the concept of a closed economic system aimed on long-term economic growth, sustainability and zero waste as 'Spaceship Earth'. "*The closed economy of the future might similarly be called the 'spaceman' economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system*" (Boulding, 1966:8). In 1989 Robert U. Ayres drew attention to the 'industrial metabolism' asking for a more systematic approach to material use. A former senior economist of the World Bank, Herman Daly, proposed in 1992 a 'steady state economy' as answer to the physical limits of economic growth. Others followed and managed to measure the resource dependency from the economic macro down to the micro level (Heck, 2006:6).

The recent phenomenon of a circular economy builds on and extends these approaches, such as the vision of Swiss architect and industrial analyst Walter Stahel of an economy in loops[3] (Reday and Stahel, 1976). Stahel is the one to come up with the notion of a 'functional service economy', the idea of selling services rather than products, now more widely subsumed into the notion of 'performance economy' or producer-service systems (PSSs)(EMF, 2016b).

Another approach is Cradle to Cradle (C2C). As put forward by the American Architect William McDonough and German chemist and visionary Michael Braungart, C2C considers, like the circular economy, that all material involved in industrial and commercial processes to be nutrients, of which there are two main categories: technical and biological. They aim to design for effectiveness in terms of products with positive impact, which fundamentally differentiates it from the traditional design focus on reducing negative impacts (McDonough and Braungart, 2002).
The processes in the biological cycle of the circular economy are also discussed within the framework of a Biobased Economy (IMSA, 2013:16). Many of these approaches refer to nature as a source of inspiration for innovation and as a metaphor for a regenerative economic model, like biomimicry or the Blue Economy as put forward by Gunter Pauli (2010). The processes in both the biocycle and

[3] This report for the Commission for the European Communities (today the European Commission) essentially put the argument of extending the service-life of buildings and such goods as cars and highlighted the waste inherent of disposing of old products Instead of repairing them. The report was published in 1982 as the book; Jobs for Tomorrow, the Potential for Substituting Manpower for Energy.

technocycle can be analysed via the principle of Industrial Ecology, which basically is the study of material and energy flows through industrial systems and seeks to quantify these flows and document the processes that shape the modern society and natural systems. As one can see, there are many related and overlapping ideas between these approaches (IMSA, 2013:16).

2.2 Introducing the Circularity Principles

The three guiding thoughts about a circular economy as described earlier, offer a description of how a circular economy should work as a whole and are the fundament for the four value creating principles, or Circularity Principles as called in this research, which are described in the following paragraph.

2.2.1. Circularity Principle one: The power of the inner circle.

This Circularity Principle is a direct result of the second guiding thought that products, components and materials should be used at the highest utility at all times. CP one states that the tighter the circle, the more valuable the strategy. In general, the tighter the circles are, the larger the savings should be in the embedded costs in terms of material, labour, energy, capital and of the associated rucksack of externalities (EMF, 2012:30). This means for example that one should opt for repairing as long as it provides higher embedded value, until the next cycle (reuse) provides a higher embedded value. With increasing resource prices and higher end-of-life treatment costs, the idea behind this rule becomes more attractive, especially in the beginning when the economies of scale and scope of the reverse cycle can benefit from higher productivity gains (because of their low starting base given that many reverse processes are still subscale today) (EMF, 2012:30). Notably, it is important to emphasize that 'embedded value' is taken as a broad concept that includes the embedded costs in terms of material, labour and capital of a product or material. The embedded energy of a product is a special case and will be discussed later on.

So how to make this Circularity Principle practical as a decision making tool? The idea behind this CP is not new. The observant reader might already have detected that the butterfly model entangles a policy principle which is already in use for a couple of decades, namely the Waste Management Hierarchy (WMH), visualised in figure 2. On the European level this policy principle was introduced back in 1996 by the European Commission (EC, 2005:9). Nowadays it can be found in Directive 2008/98/EC, the Waste Framework Directive (WFD). The WMH stresses the relative priority of the different methods of managing waste (CMS, 2013:11). It has become quite important because it influences much of the current national waste legislation and policies since Member States are required to implement the hierarchy in national law[4] (Article 4, WFD).

But there is room for improvement in the use of the Waste Management Hierarchy. Not least because the hierarchy is a very simplified version, the Dutch professor Jacqueline Cramer has come up with ten Re-s in terms of relative waste management strategies[5]. Secondly the WMH alone does not provide proper tools for policy makers to steer towards actions.

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[4] For example the 'Hierarchie způsobů nakládání s odpady' in the Czech Republic, the 'Ladder van Lansink' in the Netherlands and the 'Vlaamse prioriteitenladder' in Flanders.

[5] Refuse, Reduce, Redesign, Re-use, Repair, Refurbish, Remanufacture, Re-purpose, Recycle and Recover (energy) (Cramer, 2016).

Luckily, the Dutch Sustainability Business Association has come up with an improved version of the Waste Management Hierarchy, which they call the 'Ladder of Circularity', represented in figure 3 (De Groene Zaak, 2015:8). It presents economic activities with an increasing 'degree of circularity'. Prevention represents the highest degree of circularity and recycling represents the lowest with disposal to be avoided. Circular Principle number one therefore is; the higher on the 'Ladder of Circularity', the more preferred the action is and should prevail above the other steps under need as policy option.

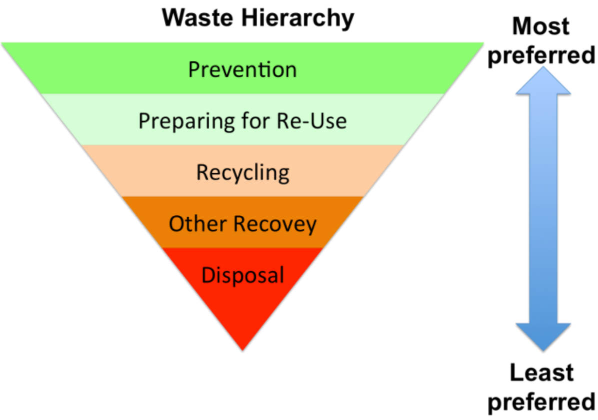

Figure 2: Waste Management Hierarchy.

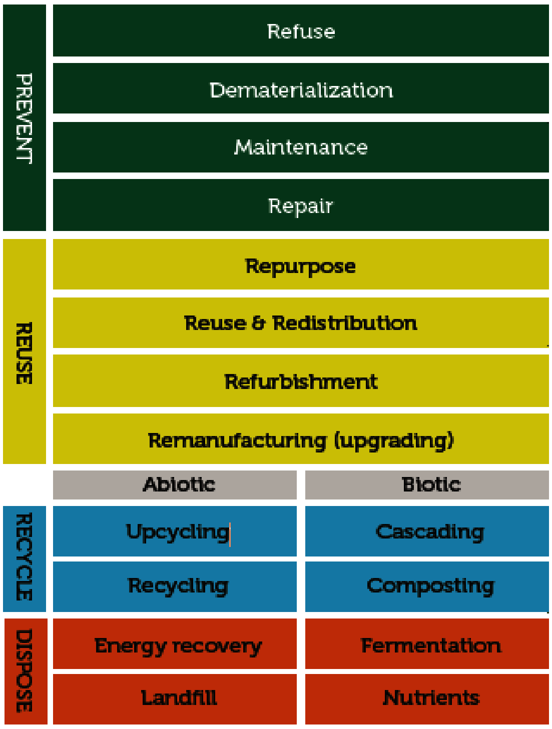

Figure 3: 'Ladder of Circularity' as presented by De Groene Zaak.

2.2.2. Circularity Principle two: The power of circling longer.

The rationale behind the second CP is to keep products, components and materials as long as possible within the economic system, which can be done by either going through more consecutive cycles or by spending more time within a cycle (EMF, 2012:30). Each prolonged cycle avoids the material, energy and labour of creating a new product or component, for example by remanufacture the plastic interior of a car more than once or extending the use of a washing machine from 1,000 to 10,000 cycles. This is something which is acknowledged by the European Commission in their Communication about the Circular Economy Package, to be precise, it is stated in the openings words; "The transition to a more circular economy, *where the value of products, materials and resources is maintained in the economy for as long as possible*, and the generation of waste minimised, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy" (emphasis added) (CE, 2015:2). From ecological perspective, long-life products perform better in all environmental impact categories than short-life products (Umweltbundesambt, 2016:5).

To go short, Circularity Principle number two aims to maximize the number of consecutive cycles and/or to prolong the time in each cycle for products. This means in practise that each policy option that aims to extend the life-time of a plastic product within the economic system the longest, either by prolonging the user-time of a product or by maximising the number of user-times of a product, is preferred above policy options that result in a shorter life-time or in less numbers of life-times of a plastic product. Here, too, rising resource prices render this value-creation lever more attractive.

2.2.3. Circularity Principle three: The power of pure inputs.

To generate maximum value, each of the above levers requires a certain purity of material and quality of products and components. That is where the third Circularity Principle is about, the power of pure, non-toxic, or at least easier-to-separate, inputs and designs, which offer a whole range of benefits.

A proven method to stimulate recycling is by increasing the recyclability of products (CPB, 2016:6). In reality products are more and more a complex mix of several different materials, closing the loops of materials can only happen after disassembly, separation of materials and thus connection of several material recycling loops (Deckmyn et. al., 2014). Scale economies and efficiency gains in the reverse cycle can be obtained through improvements in the original design of products (e.g. the ease of separation, better identification of embedded components, and material substitution) (EMF, 2012:31).These improvements to the product and the reverse cycle process translate into further reductions of the comparative costs of the reverse cycle while maintaining nutrients, especially technical ones, at higher quality throughout the cycles, which typically extends longevity and thus overall material productivity.

To make this Circularity Principle practical for policy makers, it is decided to focus on one indicator, namely the amount of hazardous substances used in the product. The rule will be that a product (and its components and materials) that is brought (again) on the market, should contain the least amount of hazardous materials as possible. The most preferred option is that hazardous substances are completely eliminated and substituted by non-hazardous substances. The second-best option is the minimization of the amount of hazardous substances used in a product.

2.2.4. The power of cascaded use. A fourth Circularity Principle.

While the second Circularity Principle is about reusing identical products and materials within the circular setup for a specific product, component or material category, there is also an opportunity in the cascading of products, components or materials across different product categories (EMF, 2012:31).

This cascading is used especially on nutrients in the biological sphere, or in other words, materials that fall within the left cycle on the butterfly model of the Ellen MacArthur Foundation. In these cascades, the arbitrage value creation potential is rooted in the lower marginal costs of reusing the cascading material as a substitute for virgin material inflows and their embedded costs (labour, energy, material) as well as externalities against the marginal costs of bringing the material back into a repurposed use (EMF, 2012:31). It is not easy to convert this Circularity Principle into a decision making tool, especially because it needs to be investigated per application if the secondary use is indeed the highest possible 'value creator' possible[6]. One way of doing this is via comprehensive Life Cycle Assessment (LCA) studies. Due to practical time and space limits it is impossible to compare all possible applications for all the different bio-plastic products. The choice is made to leave the biological cycle out of the scope of this research, which means that all bio-based plastics are not

[6] One guiding principle in the so called Bio Based Economy is the cascading pyramid in which health and lifestyle product applications (Pharmaceutical and fine chemicals) of bio based substances are the highest value creating applications and the use of biobased substances for energy-applications (fuel and fire) is considered the lowest value creating application (Virida, 2016).

taking into the scope of this research. When plastic from the technical cycle can be substituted by plastic which falls within the biological cycle, it is mentioned, but no further explanation is added.

2.2.5. Conclusion

In summary, the Circularity Principles pinpoint to a most preferred option, namely an activity which:

- Is as high as possible on the 'Ladder of Circularity';
- keeps the product (and its materials and components) as long as possible in the economic system;
- keeps hazardous materials out of the value chain by not letting it be used in products.

As decision making tool, the rule will be that a policy maker should always strive to go for the most preferred option according to all of the three Circularity Principles, fulfilling up to the underlying intend of a circular economy the best as possible. If the most preferred option is not available, one should strive for the second-most preferred option and keep the most preferred option in mind for future development. In the case study and later on in the future development part of this research, this rule will be followed and explored more in-depth.

2.3 Scrutinizing the Circularity Principles

What does the literature say about these circular added value principles? Are they valid? And what difficulties can be expected when they are used as policy evaluation tool in the way as was explained in the previous section? All three Circularity Principles will be scrutinized in this part.

2.3.1. Circularity Principle one

CP number one is based on the idea that the tighter the circles are, the larger the savings should be in the embedded costs in terms of material, labour, energy, capital and of the associated rucksack of externalities (EMF, 2012:30).

There is a broad agreement within the academic world that mechanical recycling of plastics provides the best environmental outcomes in terms of CO_2-emissions compared to other types of (chemical) recycling (NRK, 2016). This makes sense since the products are often kept in shape while mechanically recycled, keeping its kinetic energy inside the product without loss. For similar reasons, recycling of plastic waste is a better option than energy recovery or landfilling. There are at least no technical reasons why plastic should go to landfill rather than being recycled or exploited for energy recovery (EC, 2013:10). Although under a life cycle perspective not all plastic waste may be suitable for recycling. Studies that look at the entire life cycle of a particular material can shed light on this question in a particular case. The British charity Waste and Resources Action Programme (which operates as WRAP) took a broad look at this by conducting a review of 55 LCA's. The researchers then looked at more than 200 scenarios, comparing the environmental impact of recycling with that of burying or burning particular types of waste material. They found that in 83% of all scenarios that included recycling, it was indeed better for the environment (WRAP, 2010).

All in all, it makes proper sense to strive for the highest step on the 'Ladder of Circularity' as possible when looking at the embedded value of a product and its materials and components. From a technical point of view, no big difficulties are expected when applying the first Circularity Principle.

Laws of thermodynamics

Another way of understanding the issues like described above is through the first two laws of thermodynamics. The following is a shortened paragraph from King et al. (2006:263-264).

"The first law states that no energy or material can either be created or destroyed, merely transformed. This promotes the idea of closed loops to transform material back into useful products rather than into useless (and harmful) waste. However, the second law of thermodynamics shows that this transforming process itself requires additional energy. The second law states that for a closed system the entropy (disorder) will always increase. The very waste problem is a manifestation of this fact: high-energy material comes in at the start and gradually becomes more disordered to the final state of waste. However, to change this, additional energy needs to be added to the system; and more energy needs to be added to higher entropy material. Thus, recycling (using highly disordered material) requires more 'corrective' energy than remanufacturing (where the primary shape is preserved, which in turn requires more than reconditioning and repair (where most material and assembly are kept)."

Textbox 1: The Laws of Thermodynamics.

2.3.2. Circularity Principle two

The problems arise when the second Circularity Principle is brought into the game. As said, the prolongation of usage will substitute virgin material inflows to counter the dissipation of material out of the economy (EMF 2013:30). While assuming a constant demand and given the second law of thermodynamics, i.e., 'matter is decaying towards entropy', will eventually happen. So assuming a constant prolonged usage of the material, a constant input of energy is necessary to preserve the embedded energy of materials, it is therefore said that a Circular Economy is the perpetuum mobile of sustainability (de Man, 2016).

Secondly, the second Circularity Principle does not always apply on electricity consuming apparatus when taking the energy use into account. Rapid innovations in energy-efficiency make newer versions of electronic devices, such as washing machines and fridges, more energy-efficient, i.e. less energy-consumptive, than older variations of the same product (N&M, 2015). So although according to the second CP the product should be kept in the product-user-phase as long as possible, it might not be the best option when taking the energy consumption into account. In other words, a long-lasting product could be less attractive from a total cost of ownership perspective (EMF, 2013:49). Therefore one should consider going one step back on the 'Ladder of Circularity', e.g. remanufacturing the product with the newest, more energy-efficient, compartments, instead of prolonging the life-time of the product in unaltered format. This would have been problematic, were it not that via a net-present-value analysis, done by the Ellen MacArthur Foundation, it is shown that both washing machine sellers and customers can benefit from a model in which long-lasting machines are leased to customers—who then have the option of upgrading to a different lease model if a more efficient model emerges (EMF, 2013:49).

All in all, to overcome the problem of energy use and demand, two assumptions are made in this research. First – Energy demand for an activity and the energy consumption of an apparatus are left outside the scope of this research. In other words, it is considered that energy, be it in the form of electricity or gasoline, does not attribute any transaction cost to a certain economic activity and subsequently has no influence on the policy choice. Secondly, the difference in entropy or 'state of energy' is not taken into account in the embedded value of a product or material.

2.3.3. Circularity Principle three

The main point of criticism on the third Circularity Principle is the idea that one can filter out all hazardous substances in products and materials. For instance in the case when a substance classified as hazardous is a necessity for the functioning of the product and can either not be replaced by another substance at all or no replaceable substances have been found yet. A question one should ask in that case is; is it possible to ban the use of the product containing the hazardous substance? And if the use of the product or material is found necessary, one should take care that the hazardous substances are well-traceable and easy to take out of the product and handled with care after the service life of the product.
A second difficulty is the fact that there are hazardous substances that bio-accumulate and spread diffusely throughout the natural environment. Nowadays some of these substances have spread to such an extent that they can be traced in a lot of different substances. This makes it hard to guarantee that a product contains absolutely none (0%) hazardous substances. Therefore the assumption is made that if a product is said to contain no hazardous substances, it means that the amount of hazardous substances in the product is preferably non-traceable and at least far below the current safety limits[7].

[7] Take for instance the DNEL, the derived no-effect level, which is the level of exposure to a substance above which humans should not be exposed.

3. Case study of a single policy choice

"Le mieux est l'ennemi du bien"

Voiltaire (1764)

3.1 Rigid PVC containing hazardous substances

This case study is included to see what happens if you use the Circularity Principles as decision making tool in a single demarcated policy choice. First some background information regarding the case is given. Followed by an explanation of the case and a step-by-step process along the Circularity Principles is provided. At the end, a future prospect about a possible role of the CP's in the development of plastics containing hazardous substances is given.

3.1.1 Background information

Rigid Polyvinyl-chloride (PVC) is commonly used in building and construction work, for instance for plumbing or as window- and door-framing, and has a rather long life-time (NSRR, 2016). In the past, hazardous substances like lead and cadmium[8] were used as stabilizers to improve the material qualities of PVC. Without the stabilizing additives, PVC will fall apart when exposed to the ultra violet radiation of the sun. The use of cadmium has been prohibited in the EU in a number of plastic articles since 1992, but was still allowed in some rigid PVC as at that time alternatives were not available on the market (EC, 2011b). In practice this means applications which are exposed to the weather such as window frames, still contain cadmium and/or lead. It was expected that many of the exceptions would be reviewed at a future date (Cusack and Perret, 2006).

Since alternatives became available the European PVC industry decided to phase out cadmium from all PVC as part of a program called "Vinyl 2010", that started back in 2000 (EC, 2011b). From about 2006 onwards the plastic supply chain began to wake up that they need to comply with the Restriction of Hazardous Substances (RoHS) Directive (Cusack and Perret, 2006). The use of alternatives PVC stabilizers, such as calcium/zinc stearates, is growing. Organic pigments are now widely available as replacements for cadmium in low temperature applications, including many plastics (Ibid).

In 2000 the European Parliament called on the Commission to bring forward as soon as possible a draft long-term horizontal strategy on the replacement of PVC. Among other recommendations it suggested that a recycling system similar to that of end-of-life vehicles be set up and that labelling of all plastic materials be made compulsory (OECD, 2005:89). In 2012, the European Chemicals Agency (ECHA) received a request from the Commission to prepare a research to assess whether the existing restriction on cadmium and cadmium compounds could be widened to cover all plastic materials (ECHA, 2012). All in all, a trend is visible in which hazardous substances are more and more phased out of all materials[9].

For PVC recyclate (sorted, ground material) to be qualified as a 'product' ('end of waste') the WFD requires that the use of the material complies with applicable legislation. REACH[10] allows the use of PVC recyclate containing cadmium and/or lead, under certain conditions, namely that recycled PVC main contain up to 0,1 % of the products weight of cadmium[11]. However, no unequivocal

[8] Cadmium is a carcinogenic substance and is toxic for the aquatic environment.

[9] Many companies are taking steps to phase out toxic substances such as phthalates, brominated flame retardants and polyvinyl chloride as well (UNEP, 2014:46).

[10] EC 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

[11] See product 23 in Annex XVII of the REACH regulation EC 1907/2006.

interpretation of the WFD exists yet with respect to the question whether the PVC recyclate can be qualified as 'end of waste' before it has been incorporated into REACH compliant articles. If the authorities were to conclude that PVC recyclate still has a 'waste' legal status, producers of PVC articles (converters) using the recyclate would formally become 'waste handlers', which could trigger requirements for additional safety measures and administration (NSRR, 2016).

3.1.2. The case

A company invented a new business case whereby they encapsulate cadmium in such a manner that it will not be able to leak out of the PVC recyclate and is said to be no risk for the environment or human health. This PVC recyclate will be used in secondary rigid PVC applications like pipework. Their question to the policy makers of the European Commission is to grand the recyclate coming out of their new recycling method the 'end of waste' status, also known as 'product' status. The company claims that without the product status, the new business case will not be commercial viable enough to be rolled out because their clients, who are buying the secondary PVC application, would have to take obligatory safety measures and administration work because they are classified as waste handlers. Therefore the transaction costs of buying the secondary plastic will be too high and the companies will refuse to buy it. The original user of the PVC will send the PVC to an incinerator if he cannot sell the PVC to the company who invented the business case. The decision to make in this case is to either grant the recyclate coming out of this new way of processing the 'end of waste' status, or not. What should the policy makers decide when applying the Circularity Principles as decision making tool?

3.1.3. Applying the CP's

In this case, the first two steps are not possible anymore since the PVC product is already physically in use. The following question is if the product can still be maintained or repaired to expand their user phase life-time and to prevent them from becoming waste in the first place. These two steps do not conflict with the third CP, because the rigid PVC is not brought (again) on the market. Let us assume that these two steps are already applied by the original user the maximum number of times, whereby the second Circularity Principle is applied[12]. Therefore maintenance and repair is not possible anymore so the user is looking for a way to dispose the PVC pipework.

Difficulties arise when looking for the best option in the category of reuse. Considering refurbishment and remanufacturing of PVC pipes not possible, repurpose and reuse both will prolong the user-phase time of the PVC via consecutive cycles. But the PVC recyclate contains cadmium, which is considered a hazardous substance and therefore repurpose and reuse are both not the most preferred option according to Circularity Principle three.

Coming to the next step on the 'Ladder of Circularity', upcycling, might be an option if that means that the upcycled PVC application contains less hazardous substances than the PVC from before the start of the upcycle process. Applying the third Circularity Principle in the most preferable way would mean that the PVC should not contain any cadmium after the upcycle process. If the upcycled PVC can be used again, CP number two is also applied in a preferable way.

[12] It is unknown in the real life case if these options are considered in the way they are described in this research.

Recycling the PVC is the next step on the 'Ladder of Circularity' which is considered the application of the recycling method of the new business case of the company. Hereby the secondary PVC application still contains cadmium, which is considered a hazardous substance. Therefore this option does not conform to the most preferable option according to the third Circularity Principle.

What follows next is energy recovery (incineration) and landfill. Both options would mean that the plastic value chain is broken and the embedded value of the PVC product is lost outside the economic system. With a continuation of demand for PVC products, this would mean that more virgin PVC is use to supply the market. On top of that, the hazardous substances will end up in the incinerator emissions (GAIA, 2013:6). Even the best state-of-the-art plants do not filter out all the toxic air pollution (Seltenrich, 2013a). In addition, the additives such as lead and cadmium from PVC will be found both in the slag and fly ash after incineration. The bottom or slag ash can be used in stone type construction materials, resulting in a diffuse spread of the cadmium into the build environment (GAIA, 2013:6).
In the end, the suppositious options of refuse and dematerialize are already applied, which means that, the step on the 'Ladder of Circularity' in which all of the three Circularity Principles are applied in the most preferable way possible, is upcycling.

3.1.4. Conclusion

Going back to the decision to be made, one has to look what would theoretically happen with both options. Granting the 'end of waste' status to the PVC recyclate would mean that the PVC would be recycled. Not granting the 'end of waste' status to the PVC recyclate would mean that the PVC would be incinerated. Strictly applying the Circularity Principles, recycling and incineration are both not the most preferable outcomes. Can a most ideal decision be identified?
That depends on which Circularity Principle is given the most priority in the decision making process. Giving priority to the first and second CP, recycling is the most preferred option. When the third CP is given the most priority, it is not totally clear which of the two decisions is preferred over the other. That depends on what the policy makers consider as the options which retains the most 'value' within the economic system and what they consider to be the least harmful application regarding the hazardous substances.
In general, mechanical recycling is the best waste management option compared to incineration and landfill in respect of the climate change potential, depletion of natural resources and energy demand impacts. Analysis highlight that these benefits of recycling are mainly achieved by avoiding production of virgin plastics (WRAP, 2010:4). With incineration, the material is lost and the cadmium might spread through the bottom ash. On the other hand, there are also contamination issues where the, in European jargon, legacy substances of plastics are passed in an uncontrollable way and are spread through recycled products (VA, 2016:7). Although the PVC recyclate is said to be unable to leak out of the PVC and should be labelled according to REACH legislation, it is hard to guarantee that the recycled PVC will be managed carefully after their second life-time within the European market, let alone outside the European market. Policy makers have to decide whether the legacy substances contained in used PVC article remain embedded into the PVC matrix of new articles well enough to not contribute to systematic accumulation in nature. The difficulty is that policy makers hereby have to think about potential future risks and are dependent on the information from the producers.
Suppose the zero hazardous substances level of CP three is abandoned and replaced by the criteria to have as little hazardous substances within a product as possible, it will still run into some

controversies. By restricting the use of cadmium up to a certain level calculated as an x percentage of the products material, the products will indeed contain less cadmium. But in that case, the hazardous substances will be spread more diffusely through the economic system, making them harder to filter out of products later on.

Although the Circularity Principles do not provide one clear preferred policy option to choose, they give a good insight in what difficulties arise and which considerations are to be made. The reuse steps on the Circularity Ladder are not possible because they conflict with the third Circularity Principle; despite they are most preferred in the light of the first and second Circularity Principle. The most striking difficulty is that the second-most preferred step on the Circularity Ladder (upcycling) is not available as outcome of the decision making process. This might be the case in more applications of PVC, since there are no techniques to separate certain additives from PVC yet (VROM, 2010:19).

3.2 Future outlook

Two future developments are given, whereas the Circularity Principles also can be used as a future lookout framework. First of all, future efforts should continually be made in the direction of prevention, in other words, limiting the use of PVC containing cadmium. Also research on advanced recycling techniques stays important, to make the second-best step, Upcycling, possible in the future. The good thing is that this trend is already slowly going on. Dutch PVC producers have agreed to work on the application of quality recycled PVC (VROM, 2010:19). Also, as discussed during one of the interviews, there are advanced remediation technologies in development which claim to be able to break down materials back to molecules using nanotechnology. A severe problem, as sketched with this case study, is the contamination of the waste from the build environment. Either because a lot of things like PVC window frames are glued to asbestos panels or the PVC itself contains hazardous substances. Molecular break-down technologies might perfectly work for compact applications, but breaking down the volumes of waste from the build environment is simply insane, not least in amounts of required energy. Modularity of the build environment therefor stays important to be implemented further, of which later more.
Secondly, within the Circular Economy Package of the European Commission, a review of the REACH legislation and the principles of the circular economy is going to be published. Herein similar difficulties as described in the case will be reviewed. There is a call for a revision of the legislation, especially from the plastic industry. They argue that the norms were made up twenty years ago and now hinder new business models of newer, safer, applications made for secondary plastics containing hazardous substances. This might result in a counterproductive movement, because the first step on the 'Ladder of Circularity', prevention, should always be the primary goal. CHEM Trust and other NGO's argue that there is no contradiction between the aim of REACH and the aim of increased recycling – in order to do the latter in a sustainable way you have to ensure that you are not recirculating hazardous substances (Warhurst, 2015). Lahl and Zeschmar-Lahl (2013:11) even argue that REACH is the most appropriate legal instrument to address the problem of cycling of pollutants within global waste recycling streams, despite, in their opinion, it should be checked whether the waste stage - which might happen outside Europe - is described sufficiently in the available REACH registration dossiers.

4. Choosing a development path

“The crux is do we understand why the market does or doesn’t do something. And if the market doesn’t do it, do we understand what kind of governance is needed to let it happen?” [13]

Arnold Tukker

[13] Quote taken from the interview.

4.1 Introduction

The previous case was set up around a rather clear demarcated decision where the consequences of the decision could be overseen to a certain extend. Now the question arises; can the Circularity Principles also be used in a more complex decision making situation, namely one of determining a development path?

The following question is central to this: what peculiarities might show up when applying the Circularity Principles as decision making tool to determine policies for future development? Focus is hereby placed on what happens when European regulation steers towards activities higher upon the 'Ladder of Circularity', thereby trying to serve up to Circularity Principle one. The exploration is based on current developments within the European Union and is discussed during the interviews.

4.2 Landfill ban and incineration

A specific call for the Commission to encourage Member States to move to a circular economy with adequate collection and processing, high quality recycling, phasing out landfill was already given by the European Resource Efficiency Platform in 2014 when the Commission reviewed the EU waste management and prevention targets for the first circular economy package (EREP, 2014:7). Especially the proposed landfill ban seems like a proper policy choice, in line with the first Circularity Principle of moving the waste handling activities higher up the 'Ladder of Circularity'. However, for waste generation there is still no absolute delinking trend, although elasticity to income drivers appears lower than in the past, since the current landfill policies do not seem to provide backward incentives for waste prevention (Mazzanti and Zoboloi, 2008). In all MS that have municipal waste incineration, the amount sent to incineration in absolute terms was higher in 2009 than in 1995 (EC, 2012:40). This seems to suggest that waste treatment is at least moving away from landfill to incineration (with energy recovery), as a result of the progressive implementation of policies to this end (Ibid).

But there is a problem. A landfill ban generating an automatic preponderance of energy recovery over recycling would not be in line with the waste hierarchy (EC, 2013), but that is unfortunately what is happening. Recycling is harmed by incineration for various reasons, including the presence of government subsidies for incineration discouraging investment in recycling, the long-term lock-in of money and feedstock to existing and proposed incineration capacity, and the fact that the true costs[14] of incineration are not reflected in the price of treatment (Seltenrich, 2013a and UKWIN, 2016). Despite this existing incineration overcapacity (Croese, 2016:124), according to a survey made by CEWEP (Confederation of European Waste-to-Energy Plants) in 2010, the incineration capacity in Europe is expected to grow in around 13 million tonnes up to 2020 through the construction of 48 new incinerators and the increase of the capacity of some of the existing facilities (Jofra Sora, 2013).

Luckily, the European Commission acknowledges this and is now aware that further measures may be appropriate to move plastic waste recovery higher up the waste hierarchy, thereby decreasing energy recovery in favour of mechanical recycling, avoiding a 'vacuum cleaner effect' in favour of waste to energy (EC, 2013). As said by Helmut Mauer, Head of Directorate General Environment of the EC: "*Closing landfills for plastic must not lead to more incineration and statistical confusion about what is recycling and what is energy recovery must be cleared away*" (PRE, 2016b).

[14] For example the cost of environmental degradation due to incineration emissions of NOx gasses and CO_2 are often not taken into account.

4.3 Chemical Recycling

There is another trend going on which is worth taking a closer look at from the perspective of the three Circularity Principles. The plastic manufacturing and chemical industry is making a move towards chemical recycling installations of plastics. Basically, this process means that a lot of different kinds of plastics, contaminated with food residues, multi-layered, it does not matter[15], can be processed back to a Naphtha fraction, which in turn can be injected into a Naphtha cracker and subsequently can be moulded into new plastic polymers.

The advantage is an almost absent loss of quality of the secondary plastic and the incineration of – formerly impossible recyclable – plastics can be abandoned. This means that one step higher on the 'Ladder of Circularity' can be achieved for practically all plastics. Another big advantage with this type of recycling is the fact that the chemical and plastic manufacturing industry is included in the circular value chain as visualised in figure 4, providing them with a role to play in a circular economy.

The disadvantage is first of all the potential commercial risk. A large inflow of plastic waste is necessary to make the process economically viable, because one will have to adjust the crackers and subsequent infrastructure, which means a large service area is demanded to have a stable input of plastic waste[16]. Especially with the current market conditions of a low oil price and the plans to expand the incineration capacity in countries like the UK and France, making expensive investments in such recycling techniques unattractive at the moment[17]. Another disadvantage from the Circularity Principles point of view is, again, the possibility of a future lock-in situation whereas the prevention of plastic waste has become an unattractive option because large investments have been made in chemical recycling installations that operate on the inflow of substantial amounts of plastic waste.

On the one hand, chemical recycling can prolong the life time of a lot of plastics, which is the goal of the second Circularity Principle. On the other hand it can trigger a development counter to the first Circularity Principle of going for refuse and dematerialization in the first place. Besides these conflicting principles, it is yet unknown to what extend hazardous substances are allowed to be put into the chemical recycling process and what the consequences will be for the secondary plastics. When determining the direction in which they want to stimulate development, the policy decision makers will have to balance the advantages and disadvantages of chemical recycling. Is a step higher on the 'Ladder of Circularity' preferred? Or is a mature chemical recycling industry prioritized? In the end, policy makers can stimulate developments, but the real step towards chemical recycling will have to be made from the plastic industry themselves.

[15] It does not matter so long as there is no PET and PVC in it. Also most biodegradable sorts of plastics can be part of this process.

[16] According to one interviewee, an area in the size of the Netherlands would be too small for such chemical recycling installation.

[17] The price of chemically recycled plastic would be uncompetitive compared to virgin plastics made from oil and the option of chemical recycling would be uncompetitive compared to incineration of plastics.

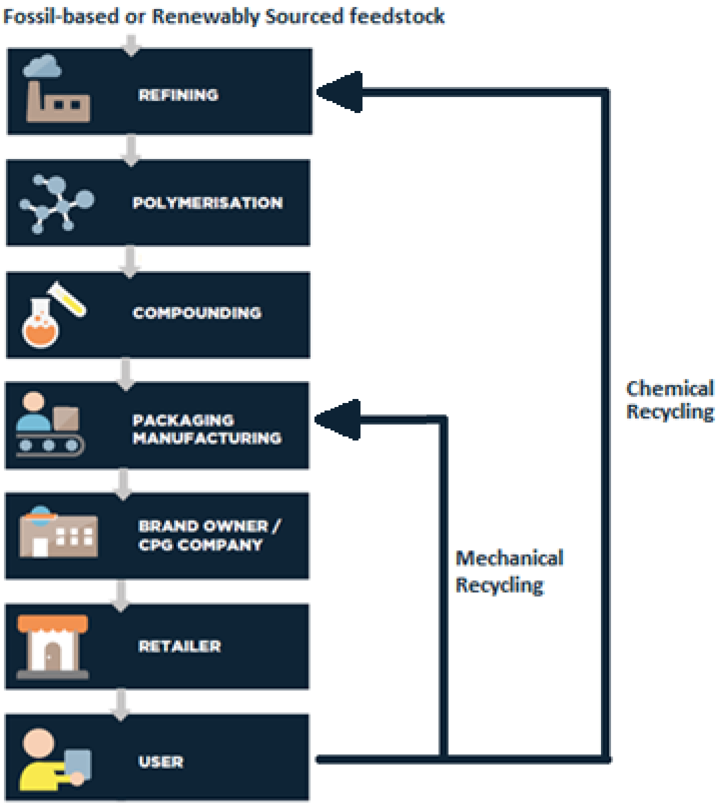

Figure 4: Visualisation on how the plastic manufacturing industry is reintegrated in the plastic value chain via the process of chemical recycling and subsequent processes of refining, polymerisation and compounding. Figure adjusted from the visualisation of the plastic packaging value chain in Ellen MacArthur Foundation (2016:26).

4.4 Recycling rates

Although recycling targets in European waste legislation may have boosted the supply of recyclable waste, as the EEA (2012:21) concludes, setting recycling targets can have some unwanted outcomes in the light of the Circularity Principles.

Take for example the extended producer responsibility regulation in the area of packaging. It mainly focusses on increasing the overall recycling rate and may have an adverse effect on the management of plastic. As plastic is lighter than metal and glass, being one of the keys to its success as material, companies prioritize the recycling of metal and glass rather than plastic to meet the percentage required to be recycled, because they need a very large volume of plastic bottles to obtain a tonne of material (UNEP, 2014:67 and The Mag, 2016). The same goes for municipal solid waste. The focus on reaching a target set on a specific tonnage of MSW can have adverse effects, as current targets are leading towards an 'over the top focus' on the weight of the collected plastic instead of the quality (Gemeente Weert, 2016:2). Municipalities increasingly focus on monitoring and reporting standards, which provides them ways to account towards the national and European institutions that they reach the recycling targets, by which they seem to be led by financial incentives[18] (FHG, 2013). Achieving high quality recycled plastic seems decreasingly used as policy goals (Ibid). European recycling targets being based around volumes (weight) instead of quality further stimulated this trend, while there

[18] Because they are often the ones accountable towards the citizens regarding the waste collection cost fees.

absolutely is a need to improve the recycling processes and quality of plastics, particularly in a context where the supply of quality-recycled plastic material does not meet demand (UNEP, 2014:48).
Secondly, there seems to be a strong economy of scale effects within the field of plastic recycling. On the one hand, due to these economies of scale, larger companies can better make use of the latest technology upgrades, such as advances in process control and automated sorting (Chimpan 2015:11). But on the other hand, these larger companies are being increasingly dependent on a continuous inflow of waste to run sorting and recycling facilities in a commercially viable way. This can have the same 'vacuum cleaner effect' as seen with incineration facilities, limiting the incentive for the vested-interests (the facility owners) to work towards waste prevention, which is the highest step on the 'Ladder of Circularity' in the first place. This might even result in a higher circling speed of materials because there is an increase demand for plastic waste to be processed, which is counter wise to the second Circularity Rule of letting materials circle longer within the economy. In addition, some authors provocatively consider the availability of recycling to be a helpful excuse for businesses to justify short product lives because recycling is perceived as a good environmental practice (Fairlie, 1992).
Thirdly, based on the targets of the Packaging and Packaging Waste Directive (PPWD), reusing packaging materials gains no recognition. So using more reusable packaging, which complies with the 'Ladder of Circularity' with regard to preventing the production of more (throw-away) packaging, makes it more difficult for Member States to achieve the recycling targets (EUROPEN, 2013:17).

All in all it seems again, that setting recycling rates may on the one hand move the handling of plastic waste one step higher upon the 'Ladder of Circularity', from incineration to recycling. But on the other hand, it may prevent any steps towards reduction of the amount of waste produced in the first place. Also, if the focus of the involved actors in the handling of plastic waste is on quantity instead of quality, is the next step on the 'Ladder of Circularity', upcycling, at all possible in such a situation? There is no use to a big pile of recycled plastic if the quality does not reflect demand and the price difference with virgin plastic is not spectacularly big enough. The World Economic Forum captures this nicely by saying that there is a need of moving the plastics industry into a positive spiral of value capture and better environmental outcomes (WEF, 2016:6).

Luckily, there seems to be a slow shift towards better quality recycling of plastics, a more professionalised recycling market for plastics and a shift in business model from supply-driven to demand-driven (QCP, 2016). Basically this means that plastic recycling companies do not take in any form of plastic waste and transforms it into - often low-value - products, but first determine the customers' needs and subsequently adjust the plastic waste into secondary plastics with the quality standards asked for. This is possible via new technologies but also via better implementation of contemporary recycling practises, like adding an extensive washing process to the recycling process.

4.5 Redesign and responsibility

The lowest steps on the 'Ladder of Circularity' have now been discussed. But what happens in the light of the Circularity Principles if policy makers aim for the highest steps? It seems that the more one wants to move towards the inner circle (the highest step on the 'Ladder of Circularity'), the more important the aspect of product design becomes. Therefore the option of setting up design principles is discussed and alternatives are presented.

First of all it is a proven method to stimulate recycling by increasing the recyclability of products, for instance via reducing the number of different materials in one product. (CPB, 2016:6 and van Beukering, 2004:307). As said by Plastic Recyclers Europe: "*Plastic packaging recycling does not begin with collection but design*" (PRE, 2016:13). What is less well known is that a proper design can take away the necessity of radical technological innovations such as advanced separation techniques (SER, 2016:38). An example can be given in the format of a desk chair of which the material represents 50% of the value of the chair[19]. A smart producer looked how it could disassemble and refurbish the chair in an easy and quick way. Via this route it could get up to 30-40% of the value of the chair back when it was resold, while still keeping the option of recycling the materials later on after a second or third life-time.

Actually, innovation in (eco) design can be more important than in end-of-life treatments and design is regarded as a base decision in life cycle thinking (Gama, 2016:11). Making products modular for example, can safe up expensive investments in a high-tech recycling facility. This counts especially for fast moving high-value products like electronics. Via modularity, new updates of the product can be implemented easily without having to throw away the whole product. Hereby second-life remanufactured products are made up to date to the market (King et al., 2006:265). Take on top of that the fact that the first useful service life of most of the electrical and electronic appliances has decreased over the last year (Umweltbundesambt, 2016:5), which increases the need for strategies against obsolescence based on requirements pertaining to product lifespans and standardization (Ibid). All in all it is advised by many[20], to make European agreements on expanding product design regulation forasmuch reparability, modularity of products and 'deconstruct-ability' as well as modularity for buildings. In other words, attention must be paid to measures at the start of the cycle, which will have a strong impact on the whole life of products (E.g. eco-design, standards for packaging and products, prevention measures, targets for producers, etc.) instead of introducing additional measures at the end of the cycle[21] (CEMR, 2013:2). This can be enhanced by proactively looking for alternative materials, for instance the application of bio based plastics.

However, as said before, process optimisation from the design phase is not easy which can be partly explained due to the complexity of the value chains (Bastein et al., 2013:10). Especially from the point of view of a European policy maker, making redesign of plastic products (or applications containing plastics) possible is not as straightforward as a landfill ban. Because how does a policy maker determine design targets? It is for example not an easy job to put up a mandatory 'level of modularity' for products, if not impossible to enforce. The same counts for putting up mandatory minimal amounts of recycled plastic input for products. In general it is questioned if regulators should interfere to such extent on the market. As said by one of the interviewees: "*a government doesn't know how to build a television*".

Despite the idea that regulating the design of products is not easy, it is the best option to strive for as a European policy maker because via proper product design one can get closer to the most preferred

[19] This example came along during one of the interviews.

[20] Among other: CEMR, 2016:3-4, Gama, 2016:11, Haas et al., 2015:765, House of Commons, 2014:27, de Man and Friege, 2016: 93, SER, 2016:115, Umweltbundesambt, 2016:5 and UNEP, 2014:73, 2014:27.

[21] Like targets for the 'preparation for re-use' and recycling of waste put upon local authorities.

outcome according to all three Circularity Principles. Consistent eco-friendly design of products (including buildings and infrastructures) can increase lifetimes, provides the same service with less material requirement, and facilitates repair and resale, product upgrades, modularity and remanufacturing, component reuse, and, finally, also end of life recycling (Haas et al., 2015:774). But why is recycling far more common than repair of remanufacture? According to Walter Stahel, the reason for this reality has been a lack of product lifetime liability (King et al., 2006:263). Before the introduction of EU Directives[22] containing the principle of Extended Producer Responsibility (EPR) ten years ago, a manufacturer had no liability (outside a short warranty period) for a product sold. Therefore, as recycling is essentially disconnected from individual manufacturers (the plastic is mixed with other plastics and waste and processed remotely), this has been the dominant return loop (King et al, 2006:263).

By introducing EPR legislation plastic manufacturers are now – financially - liable for their products through and beyond their end-of-use life[23]. Hereby the industry itself will figure out the best way to discharge the EPR. What means that the manufacturers themselves will explore if and how they will make their products modular and how they will set up the system for return logistics. It was recommended by multiple interviewees that regulators should set out the perimeters of the economy via EPR and avoid too much technical specifies.

When zooming in on the remanufacturing of products, the lack of a credible and stable demand was perceived as a fundamental barrier to initiate new remanufacturing schemes (King et al., 2006:265). The most common approach to overcome this barrier is the development of product-service systems (PSSs) (Ibid). In product-oriented business models firms have the incentive to maximize the number of products sold. However in service-oriented business models, in theory the incentive differs (Tukker, 2015: 76). Firms then make money by being paid for the service offered, and the material products and consumables that play a role in providing the service become cost factors. Hence, the firm will have an incentive to prolong the service life of products, to ensure they are used as intensively as possible, to make them as cost- and material-efficiently as possible, and to re-use parts as far as possible after the end of the product's life (Ibid), which is totally in line with the first two Circularity Principles. By putting product specific EPR legislation in place, a credible and stable demand for remanufactured goods can be ensured.

Of course in the light of the Circularity Principles, even EPR legislation may not be perfect in use, for instance in the case of 'one-time-only' plastic bags. When EPR regulation for plastic bags is installed and the costs of litter cleaning accounted for are too low, the littering of throw-away plastic bags will continue, which is in conflict with the second Circularity Principle of circling longer and is not even an option on the 'Ladder of Circularity'. In those cases, a ban on the use of or other price incentives is a proper policy option. Also the use of hazardous substances is doubtful while having EPR legislation in place. Hereby more transparency about the materials used, especially in the case of complex long-living goods (buildings, electric devices, etc.), is necessary to facilitate and reduce cost of the after-life treatment (Friege and de Man, 2016:95).

[22] Take for example the PPWD and Waste Electronic and Electrical Equipment (WEEE) Directives.

[23] Like as said before in the part about recycling, EPR legislation should not be based on setting a recycling target, but on the total lifetime cost of a product. This is interpreted in a very inclusive way, which means also litter cleaning and oceans and beach clean-ups are taken into account.

5. Results

"It's the Circular Economy stupid!"[24]

[24] Future U.S. Presidential campaign slogan.

5.1 Results

The Circularity Principles give good insight in the difficulties that may arise when making policy decisions, having a transition towards a more circular economy in mind. It can reveal a trade-off between the principles, whereas the policy maker has to balance them against each other. It can also provide a 'circular' long term focus for decision makers to see whether the policy options really contribute to a transition towards a more circular economy or at least give insight in what should be the most preferred outcome despite the possible policy options. Future investments priorities can also be identified when a most preferred outcome according to the Circularity Principles is identified. For instance if the most preferred option for a certain plastic product is repurpose which is not yet available, than the plastic industry knows where to put their research budget on and the European institutions know where to provide subsidies and support.

The differences between the economic sectors in their transition towards a more circular economy are big, which means that policies will have to be differentiated to the sector's specific needs. Frontrunners need to be supported with more legislative space, whereas legislation is perceived as a barrier for continued 'circular' innovation. The peloton often needs exactly the opposite, stricter policy to stimulate 'circular' action (SER, 2016:39). Hereby Circularity Principles may be arranged, or ranked, differently depending on the sector, to check upon the level of circularity of the proposed activity. The third Circularity Principle of 'pure' inputs, can for example be applied in a strict way regarding policy affecting (plastic) food packaging and less strict in case of plastic applications with a lower perceived risk regarding hazardous substances infection. Another example is whether to allow a mixture of materials from the techno- and biosphere to be used in a newly invented application, which in other words will result in a less 'pure' product but it significantly increases the life-time of the product, making it worth to pay the extra cost of separating the materials after the user-phase. Only with a proper explanation a policy maker should divert from aiming for the most preferred option according to all three of the Circularity Principles. A role for civil society and NGO's can be to check whether the CP's are properly taken into account in the policy making process and assorted outcome. To go short, this arrangement or ranking of the CP's will have to be examined case-by-case and could be supported by extensive Life Cycle Analysis research.

In general, the more one moves into the inner circles of the Circular Economy, the greater the need for data of higher resolution in order to understand the potential impacts of any given initiative (RWM, 2014:11). After all, policies aimed at the reparability of a product, which has everything to do with design, will have consequences on the successive loops of products and its parts and materials. This diversity of issues leads to an equally complex policy environment and these measures must therefore be considered within a framework of Life Cycle Analysis, including synthesis of the chemicals that are used in production together with usage and disposal. Overall, policy problems in relation to guiding transitions relate to the distributed nature of control over the problem and the solutions, to the fact that it is unclear how short-term steps can lead to long-term structural change, to the danger of lock-in to non-optimal solutions, and to the short-term focus of politicians and policy-makers (Kemp, Loorbach, and Rotmans 2007).

It seems that many plastic-related policy issues fall into what are defined as unstructured or badly structured problems—in essence, problems that lack consensus and clarity in the relevant policy question and in some cases lack clarity in the relevant knowledge base to inform any decision (Thompson et al., 2009). Shaxson (2009) suggests such circumstances will require a reflexive approach to brokering knowledge between industry, scientists and policymakers, and that scientists will need to be prepared to make and facilitate value judgements on the basis of best evidence. On top of that, it can be assessed what levels of cost are acceptable to the scheme only when the potential impacts are understood. Notably, the 'level of circularity' is not the only assessment criteria of public policy, which will always be judged according to its perceived cost and benefits. Shaxson (2009:5) takes it a step further and states that policy relating to plastic will have to weigh societal and economic benefits against environmental and health concerns. This will require a whole range of policies to focus at diverse issues including polymer safety, material reduction, reuse, recycling, biopolymers, biodegradable and compostable polymers, littering, dumping and industrial spillage. It has to be said that not all information on different resources is available yet, like scarcity of the resource, which should be taken into account as well (PBL, 2014:5). Indeed, a proper analysis and understanding of policies that can support radical innovation and system transformation is required before any policy (package) can be chosen (Meelen and Farla, 2013:957). For policies made on a European level, there are even more criteria on which they will be evaluated, not least on the principles of subsidiarity and proportionality. On top of that, on the European level there seems to be an increased focus on the job creating potential of European policies when conducting a cost-benefit-analysis. Recycling hereby seems to score well (FotE, 2010) and is therefore widely seen as an attractive option to promote for European institutions even if it is not the best activity possible in terms of the Circularity Principles.

5.2 Impact for different levels of governance

A transition towards a more circular economy will have an impact on the choices made by legislators on different levels of government. Coherent coordination between several levels (European, National, regional and local) is necessary to seize the opportunities of a circular economy (Rli, 2015). A better understanding of what kind of considerations have to be made on what level can be done based on the Circularity Principles. After all, the Circularity Principles can point towards a most preferred option, consequently giving insights on what level policies can be drawn. For instance, to stimulate repair services the local municipality can stimulate the arrival of repair shops and thrift shops, by collaborating with technical schools in the area or working together with municipal un- or re-employed programmes for example. The national level government can set stimulating fiscal policies towards labour-intensive activities like repairing. The European level can steer towards improved design of products that in turn make repairing and maintaining the product easier (House of Commons 2014: 27). Using the same tool, the Circularity Principles, the different levels of governance can collaborate to determine the most preferred outcome of their policy choices which will mutually support each other.

5.3 Discussion

Several recommendations can be given for further research in the field of policy decision making tools in the light of a transition towards a more circular economy. Further research could be done on different value chains, for instance on particular critical raw minerals like phosphor and lithium. Next to that, the implementation of biodegradable plastics in which the fourth Circularity Principle of cascading could be incorporated and included in further research. In this a better understanding can be obtained on the implications of using the Circularity Principles as decision making tool. A second point of critique on this research is that the choice for interviewees does not cover the full range of

actors involved in the plastic value chain. For instance the vision of plastic recyclers and municipal waste handlers is missing. Also no European policy makers are consulted. This can be taken into account in further research. A third point that can be explored more in-depth is how to incorporate the traceability of hazardous substances as factor in making policy decisions.
The fourth thing to keep in mind is the international competition position of the EU within the global economy. Will the EU have to set up trade barriers for certain products if they do not uphold to the Circularity Principles? And what will it mean for products manufactured in Europe, which are optimised according to a European economic system, built around the Circularity Principles, but are shipped abroad outside the EU? These products might not be competitive in other economies and it might mean a loss of materials when the product and its materials are not returned after use.

5.4 Conclusion

If a policy is to be successful, it has to reflect the underlying intent of the circular economy (RWM, 2014:8). The Circularity Principles eminently reflect the intentions of a circular economy. Therefore the Circularity Principles are suitable to be used as decision making tool for policy makers, to check a priori whether what policy option matches the underlying intentions of a circular economy in the best way possible. Surely, a new way of designing the economic system unavoidably needs a matching policy decision making tool. The unifying theme appears to be to avoid, as far as possible, the use of primary resources and when resources are used, they should be used as long as possible and according to the highest utility as possible. The Circularity Principles can provide a helping hand to determine if, for example, a policy did indeed prolong the life-time of a product and if the policy did make a particular waste stream more 'pure', for example through better separable product compartments that therefore are easier to be brought back in another loop again.
Likewise, policy evaluations will systematically be necessary to adjust policies in time when a government is executing adaptive governance (SER, 2016:38). Especially when applying a long-term transition agenda towards a more circular economy, consistent policy choices have to be made. The Circularity Principles can be used as consistency check and as a method to check upon flaws when making decisions while determining a development path, for instance to watch out for lock-in situations by keeping in mind that one should aim for the highest step on the 'Ladder of Circularity' and if that is not yet an option, one should keep the possibility open to step up in the near future.

Depending on the level of ambition, different policy instruments come into play. High ambitions (e.g. minimize waste by circular product design and use of renewable raw materials) come to a different approach than if the initiative is to burn as little municipal solid waste as possible. In the latter case, a bet on high-tech separation technologies could be sufficient. Unfortunately it is often forgotten to easily that a circular product design, can avoid the need for such radical technological innovations in the first place (SER, 2016:38). The Circularity Principles reflect an ambitious approach for decision makers; especially the first CP is one which should be kept in mind primarily when considering policy options. For European policy makers this means in practise that the waste hierarchy from the WFD, should be applied in a more consistent way. Practically this also means that intentions from the plastic industry to foster activities like pyrolysis and chemical recycling should be framed as a rather low step on the waste hierarchy, but with the potential to make incineration of plastics unnecessary if well executed and should therefore be considered twice when implementing policies stimulating these activities.

Ten years ago, only few countries were working on a holistic, systemic, and interdisciplinary approach for Circular Economy (Heck, 2006). Today, there is still a need for an integrated evaluation method (SER, 2016); the Circularity Principles can be the very base of the framework. In that way, the importance of the transition towards a more circular economy can be determined and insights in the trade-offs, for instance with energy use, can be provided. Because many plastic-related policy issues fall into unstructured or badly structured problems, continued information exchange between industry, academics and policy makers is necessary to facilitate the value judgement the policy maker has to make in the end.

All in all, as Walter Stahel frames it, a maturing circular economy will face three big challenges (de Wolf, 2016). The challenge of 'Re-' that is the challenge to perfect re-using, re-manufacturing, re-designing and all the other 're-' actions that need to occur to keep resources at their highest value for the longest possible time. Secondly follows the challenge of 'De', when products can no longer be re-cycled in a value-adding way: 'de-constructing', 'disassembling', 'de-taching'. The third challenge comes with a capital K – Knowledge.
Having the knowledge the current economic system will run into its physical limits sooner or later, makes it more urgent to act now. Hereby achieving a reversal of the trend of global growth in resource consumption into a dynamic of reduction, or at least a steady-state physical economy, remains the greatest challenge of all (Haas et al., 2015:774). The World Economic Forum states that actors across the plastic value chain have proven time and again their capacity to innovate (WEF, 2016:15). Now, harnessing this capability to improve the circularity of plastic could create a new engine to move towards a more circular economic system. The window of opportunity is now here to 'leap frog' the linear economy and invests directly into a more circular economy.

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Annex I

Types of Plastics

There are many types of plastics available on the market, all with their own unique characteristics. The application of plastics vary widely, from the packaging, communications and transportation industry to the sports, leisure and health sector. There are two main groups of plastics, thermoplastics and thermoset polymers. Thermoplastics are the plastics that do not undergo chemical change in their composition when heated and can be moulded again and again. Examples include polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC). Thermosets can melt and take shape only once because of an irreversible chemical reaction. After they have solidified, they stay solid. The vulcanization of rubber is an example of a thermosetting process.

Other classifications are based on qualities that are relevant for manufacturing or product design. Examples of such classes are the level of elasticity, biodegradability and electrical conductivity. Plastics can also be classified by various physical properties, such as density, tensile strength, glass transition temperature, and resistance to various chemical products. In 1988, the Society of the Plastics Industry (SPI) established a classification system to help consumers and recyclers properly recycle and dispose of each different type based on its chemical makeup (SPI, 2016). Today, manufacturers follow a coding system and place a number, or SPI code, on each plastic product, usually moulded into the bottom. Besides these six main classifications, some more types of plastics and their main purposes, falling under the seventh category of 'others' (SPI, 20126), are described under need.

PSI symbol	Name	Usage
1	Polyethylene terephthalate (PET)	Which is sometimes also known as PETE Carbonated drinks bottles, peanut butter jars, plastic film, microwavable packaging.
2	High-density polyethylene (HDPE)	Detergent bottles, milk jugs, and moulded plastic cases.
3	Polyvinyl chloride (PVC)	Plumbing pipes and guttering, shower curtains, window frames, flooring.
4	Low-density polyethylene (LDPE)	Outdoor furniture, siding, floor tiles, shower curtains, clamshell packaging.
5	Polypropylene (PP)	Bottle caps, drinking straws, yogurt containers, appliances, car fenders (bumpers), plastic pressure pipe systems.
6	Polystyrene (PS)	Packaging foam, food containers, plastic tableware, disposable cups, plates, cutlery, CD and cassette boxes.

Table 1: The six most used types of plastic.

Name	Usage
Polyurethanes (PU or PUR)	Cushioning foams, thermal insulation foams, surface coatings, printing rollers (Currently 6th or 7th most commonly used plastic material, for instance the most commonly used plastic in cars).
Polyamides (PA)	Better known as nylon. Fibbers, toothbrush bristles, tubing, fishing line, low strength machine parts: under-the-hood car engine parts or gun frames.
Polyester (PES)	Fibbers, textiles.
Polycarbonate (PC)	Compact discs, eyeglasses, riot shields, security windows, traffic lights, lenses.
Polyethylene (PE)	Wide range of inexpensive uses including supermarket bags and plastic bottles.
Acrylonitrile butadiene styrene (ABS)	Electronic equipment cases (e.g., computer monitors, printers, keyboards), drainage pipe Polyethylene/Acrylonitrile Butadiene Styrene (PE/ABS) – A slippery blend of PE and ABS used in low-duty dry bearings. Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) – A blend of PC and ABS that creates a stronger plastic. Used in car interior and exterior parts and mobile phone bodies.
Polyvinylidene chloride (PVDC)	(Saran) – Food packaging.
High impact polystyrene (HIPS)	Refrigerator liners, food packaging and vending cups.

Table 2: Other types of plastics.

Figure 5: PSI symbol of the plastic category 'others'.

Annex II

List of Interviewees

Role	Company	Person	Function
Stakeholder	Dutch Ministry of Economic Affairs	Mr. M. Müller	Project leader
	PlasticsEurope	Mr. Dr. T. Stijnen	Director the Netherlands
	Natuur & Milieu	Mr. Ir. T. Wagenaar	Director
Independent expert	Institute of Environmental Sciences (CML) Leiden University	Mr. Prof. dr. A. Tukker	Director, researcher and lecturer
	Delft University of Technology and Utrecht University of Applied Sciences.	Mr. Dr. Ir. R. Vrijhoef.	Researcher and lecturer

Table 3: Overview of the conducted interviews.