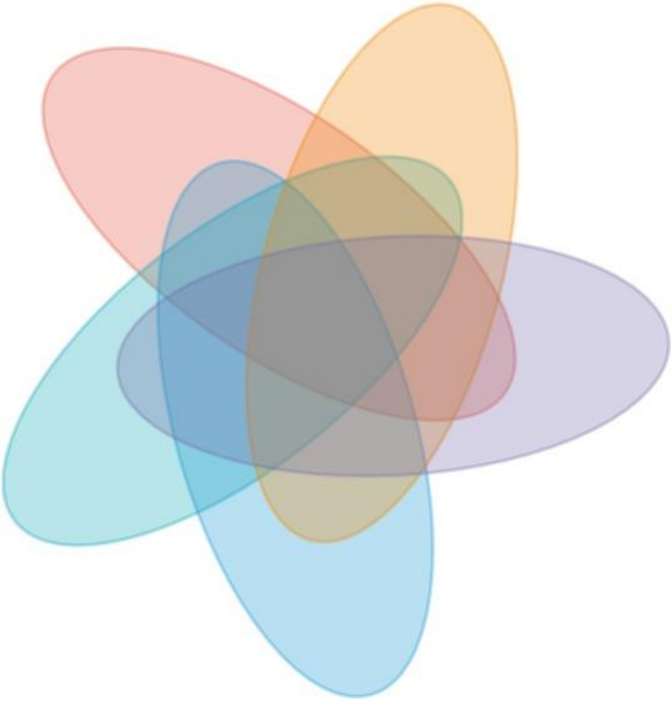
Steering towards welfare and circularity

Extended producer responsibility in the Netherlands



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Abstract

Extended producer responsibility (EPR) is a policy approach by which producers become responsible for their products after they have been used. EPR takes a central position in the waste management systems in EU-countries, including the Netherlands. This study evaluates the extent to which EPR schemes contribute to higher circularity and improved social welfare of society at large by targeting the behavior of different actors in the value chain.

A comparative study design was adopted, diving into three waste management systems in the Netherlands. Furthermore a broader exploratory study was conducted. The most important findings from semi-structured interviews, literature analysis and descriptive statistics are: 1) EPR effectively shifts the operational waste management cost burden to producers, while the total operational costs have not dropped, 2) EPR kickstarts collection and recycling and can achieve high collection and recycling rates, 3) EPR's incentives for increasing circular product design or alternative, circular business models are relatively weak, 4) post-use value or price is a key explanatory variable for collection and recycling behavior, and 5) EPR reduces environmental stress by replacing virgin material.

Challenges exist for keeping EPR a well-suiting approach to waste management that is in line with circular economy principles. Notably, environmental performance is insufficiently benchmarked due to its focus on activities, predominantly collection and recycling, rather than impact. Furthermore, financial free-riding on collective waste management efforts by producers and importers through internet sales to end-users is increasingly becoming a problem. Second-hand product exports reduce the pool for collection, which is problematic for achieving collection targets. Lastly, the inter-dependence between parties regarding collection and quality of separately collected material causes a not negligible degree of friction and conflict between the parties.

Overall, EPR is associated with robust organization of the waste management systems by producers, resulting in higher social welfare and circularity gains than before EPR was implemented, but governmental organizations still have an important role in collection and enforcement.

Keywords

Extended producer responsibility (EPR) – circular economy – social welfare economics – waste management – ecodesign

Preface

You are reading the master's thesis "Steering towards welfare and circularity: Extended producer responsibility in the Netherlands". This thesis is the capstone of almost seven years of academic studies in earth sciences, economic policy and sustainable development

The sustainable use of materials is an important challenge that societies face. Many initiatives and policies have been employed to increase the value we derive from those materials, and mitigate the potential harmful effects this might have on the environment. Some are more successful than others. When I got opportunity to write my sustainable development master's thesis on a policy approach used in the governance of materials in products and waste, I took it with both hands.

This thesis was written as part of an internship at the CPB Netherlands Bureau for Economic Policy Analysis. This study - not in any form a CPB publication - contributes to an ongoing project by the CPB and the PBL Netherlands Environmental Assessment Agency. From November 2019 to May 2020, the whole cycle of writing a research proposal, conducting the research, reporting on it and interpreting it was carried out.

Here, I present you the end result of those efforts.

Hopefully, you enjoy the reading.

Bob Vermeent

Utrecht, May 8, 2020

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1. Introduction

1.1 Sustainability problem

A widespread concern exists for the state of the environment, worldwide. Some argue that society as a whole is at risk going beyond what are called "planetary boundaries", representing " a safe operating space for humanity" (Rockström et al., 2009, p.472). Exceeding those boundaries is likely to result in profound changes in earth system functioning . Efforts are required to steer away from this scenario. Compared to thirty years before, the world economy in 2013 generated 40% more economic value per ton of raw material, while it grew by 150% resulting in a higher consumption of materials (UNIDO, 2013; Wijkman & Skånberg, 2017). Primary production of virgin resources and the disposal of waste are important pathways for environmental degradation due to their associated emissions of greenhouse gases and pollution of air, soil and water (UNEP, 2011). Furthermore, the carbon footprint from consumption grew by 78% worldwide, between 1995 and 2015 (Hertwich, 2019). In the same time period greenhouse gas emissions from material production increased from 15% to 23% (IRP, 2020). Overall, the massive increase in consumption has resulted in high rates of environmental degradation, thereby negatively affecting the health and functioning of humans, plants and animals.

1.2 Sustainability solution

1.2.1 Circular economy

The amount of waste and raw material input – and their associated harmful emissions to the environment due to processing and leakage – can be lowered by bringing (processed) waste back to the economy in the form of secondary materials or recovered energy, instead of landfilling the waste (IRP, 2020). For example, 20 times less energy is required to produce aluminum from secondary sources with respect to bauxite ore (UNEP, 2011). However, UNEP (2011) finds that 34 chemical elements have a recycling rate of less than one percent. The increased use of secondary materials is expected to result in significant environmental gains and positive socio-economic effects such as resource security, jobs and global food security (Wijkman & Skånberg, 2015; UNEP, 2011).

For the whole Dutch economy, Bastein et al. (2013) estimate that transitioning towards a circular economy represents a net value gain of 7.3 billion euros or 1.4% of GDP, per year. 5.3 billion is due to the industrial sector. Though much uncertainty surrounds the numbers, it is clear that circularity could yield significant benefits, which now fail to materialize.

1.2.2 Challenges to circularity

Landfilling in the Netherlands is negligible (1-2%) and it could be argued that some European countries already achieve 70-90% circularity for important bulk materials (European Environment Agency, 2013). The major problem is that even when waste streams are diverted from the landfill – thus being "circular" – the material is not used optimally for reducing environmental footprints. A range of different reasons is mentioned in the literature: secondary material streams are of low quality, too expensive relative to primary resources, too volatile in terms of price, imperfect substitutes for primary materials, et cetera. (e.g. see OECD, 2014). Bastein et al. (2013) mention conflicting incentives as a barrier and state – in line with IRP (2020) – that government interventions are central to realizing those benefits to society at large. Other challenges Bastein et al. (2013) mention regarding waste collection and recycling include: a focus on traditional value chains by branch organizations, a lack of cross-sectoral cooperation and a lack of interest in and capacity to capitalize on circular opportunities in the value chain by entrepreneurs.

In short, the market for secondary resources fails to function optimally whereby potentially valuable post-use ('waste') products or materials are at high risk of becoming obliterated or reduced to ashes. The result is that even if material flows are made circular, the net gains such as improved health and lower greenhouse gas emissions are relatively low (Verrips et al., 2019).

1.3 Public policy

1.3.1 Extended producer responsibility

Extended producer responsibility (EPR) policies could steer the economy towards circularity. The OECD defines EPR as *"an environmental policy approach in which a producer's responsibility, physical and/ or financial for a product is extended to the post-consumer stage of a product's life cycle"* (OECD, 2001, p.18). Considering the large diversity in EPR schemes, EPR is often not considered a policy instrument, but rather an extension of the polluter-pays-principle Massarutto (2014). Lindhqvist (2000, p. *v*) defines EPR as "*a policy principle to promote total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer of the product to various parts of the products lifecycle, and especially to the take-back, recycling and final disposal of the product"*. The idea is that when producers become responsible for their product in the post-use or waste phase, they are incentivized to minimize the amount of waste their products produce and/ or minimize the costs to manage that waste, which were Often previously incurred by municipalities and, ultimately, the taxpayers. While Lindhqvist's definition has a more logistic focus, the OECD interprets EPR more broadly. In this proposal, EPR is interpreted in its broadest form in line with the OECD to account for all the different methods by which a producer can assume or be given responsibility and be involved in waste management.

1.3.2 Circular economy and EPR in the Netherlands

Already in 1989, a piece of legislation was discussed in Dutch parliament that the designers of products and production processes ought to be aware of the effects of their product in the waste phase, and would have a certain responsibility (Tweede Kamer der Staten-Generaal, 1989). Furthermore, the consumer was recognized to have the responsibility to do something about their waste. In general, an environment test was suggested as well as a notification system for new products. Furthermore, the "delegation of responsibilities" to market parties would be researched (ibid).

In 1989, 29 different waste streams were recognized for which waste management activities were formulated (Tweede Kamer der Staten-Generaal, 1989). Goals were formulated in terms of landfilling, incineration, reuse and separate collection (ibid). Producers were recognized to not have any responsibility for their products in the waste phase later, and who was responsible was considered a key issue in waste management in 1990 (Tweede Kamer der Staten-Generaal, 1990). It was stated that producers and importers had to get the responsibility for managing their products in the post-use phase (ibid). Furthermore, it was thought that the reprocessing for secondary use would be considered in the design and production of goods due to this (ibid).

Now, the Dutch government has the ambition for the Netherlands to be circular in 2050 and have 50% less use of primary material in 2030 (Ministerie van Infrastructuur en Waterstaat [I&W], 2016). It aims for: 1) making more efficient use of resources, 2) increasing the use of renewable and secondary resources, and 3) promoting new, circular product designs and production methods (ibid). The Dutch government has the *Landelijk Afvalheerplan 3* (LAP 3) – a comprehensive national waste policy – with 85 sector plans, each governing a specific group of waste streams which steer the behavior of producers regarding products in the post-use phase to different extents (Rijkswaterstaat, n.d.-c). For five product groups, formal EPR policies have been formulated and imposed by the government (Rijkswaterstaat, n.d.-b). For two product groups, producers have assumed responsibility themselves and successfully asked the government to formalize those agreements for all the relevant producers (ibid).

1.4 Relevance, aim and research question

1.4.1 Societal relevance

The government is exploring now whether EPR schemes should and could be implemented in other sectors, in line with the EU, which considers EPR promising for reaching environmental and circularity goals (European Commission, 2019b; I&W, 2016). For this, the Dutch government has requested the CPB Netherlands Bureau for Economic Policy Analysis (CPB) and PBL Netherlands Environmental Assessment Agency (PBL) to analyze EPR practices. This study contributes to these analyses, thereby being of direct policy relevance. Furthermore, by being academically relevant, the policy-making process can be better informed about the steering potential of EPR.

1.4.2 Academic relevance

This study is of academic relevance, because based on an exploratory academic literature review (see chapter 2), it seems that EPR practices have been analyzed mostly from an environmental, socio-technical perspective on the firm level. This study takes a social welfare perspective, that focuses on cost-benefit generation and allocation in society at large due to altering incentives in value chains by implementing EPR schemes. Social welfare is the net sum of costs and benefits to a group of individuals, which is optimal (maximal) if no allocation of resources amongst those individuals can be carried out to increase the individual welfare of a person without lowering the welfare of another (Hindriks & Myles, 2013a). Social welfare analyses do not blindly seek to maximize production or consumption, but also account for costs and benefits beyond traditional economic analyses such as environmental damage and forms of inequality (Hindriks & Myles, 2013a). Thus, social welfare analyses are compatible with the sustainability imperative that value generation through production should be ecologically and socially responsible over longer time spans.

Some broader, societal-wide analyses of EPR systems and how they shape society exist. However, to what extent or how EPR systems contribute to reaching higher levels of social welfare is controversial, depending on specific design and contexts. Even theoretical models are highly sensitive to contextual changes (e.g. see Fleckinger & Glachant, 2010).

1.4.3 Aim and research question

The interplay between institutions in their broadest form – formal and informal norms shaping recurring patterns of behavior – and social welfare in the policy domain of circularity and EPR presents a knowledge gap that this study hopes to fill. More specifically, this study seeks to find the most important causal links between the problem context, EPR design and the effects on circularity and social welfare by means of a comparative case study in the Netherlands. The main research question is:

To what extent do EPR schemes contribute to increased social welfare and circularity?

Overall, the proposed study presents an empirical contribution to the functioning of EPR systems in a comprehensive, societal context by evaluating how effectively EPR can incentivize circular, social welfare-increasing practices.

1.5 Reading guide

The remainder of this thesis is structured as follows. First, an exploratory literature overview is presented for EPR specifically, followed by a theoretical literature review on the theoretical concepts central to this study. Second, the methods section is presented, including the research sub-questions, theoretical framework, research strategy, assessment criteria, data acquisition and research framework. Third, the results are presented, where a broader legal overview of EPR in the Netherlands is followed by three case studies, where the practice and experience of three waste management systems are assessed. The results section ends with an assessment of broader EPR experiences in the Netherlands, putting the case study findings in a wider context. Fourth, the limitations, academic relevance and policy implications of this study are presented in the discussion section. Finally, a conclusion is presented where the sub-research questions and main research question are answered.

2. Literature review

2.1 Chapter introduction

In this chapter, a literature review is presented. First, the academic literature regarding EPR is reviewed and key insights are presented for different academic disciplines. Second, OECD literature on EPR is discussed. Third, theoretical literature of circular economy and public economics is presented.

2.2 EPR specific literature

2.2.1 Browsing description

An exploratory academic literature review was carried out in Scopus. The term "Extended Producer Responsibility" was used and 1996 was used as the lower cut-off and 2018 as the higher cut-off. These cut-offs were chosen, because 2019 had not come to an end at the moment of the analysis and literature before 1996 was deemed relatively old and potentially outdated. In this period 549 studies were found with the term "extended producer responsibility" in the title, abstract or keyword description (609 if no upper bound was included). 19% of these 549 studies were found to be labelled as engineering or chemical engineering, 29% as environmental science and 15% as business, management and accounting or decision science (see figure 1 and 2).

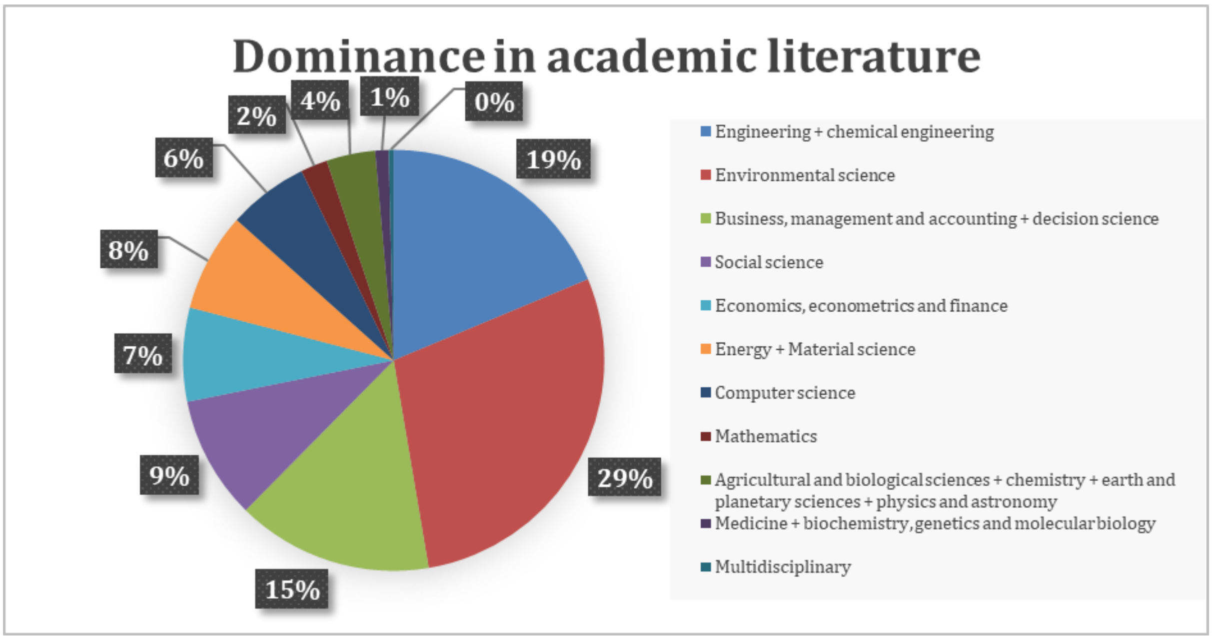

Figure 1: *Dominance of different scientific fields in EPR research.*

The scientific literature so far has focused on the technical, environmental and business sides of EPR, with waste from electric and electronic equipment (WEEA) being the dominant field of analysis based on the number of citations. Of the 10 most cited articles, 7 were categorized as part of the environmental sciences, while the other two categories both only had one of the top-10 most cited articles. For all categories, the top 5 articles were read, aside from the environmental sciences – here, the top 7 was read, to make sure none of the top 10 cited articles were left out of the analysis – and economics, econometrics and finance. Here, the top 10 was read, due to the economic perspective that is adopted in this study. None of the 609 studies was labelled as a meta-study indicating that the field can be characterized by parallel resource silos. The most relevant papers, based on their citations and the importance of EPR in the study are presented next.

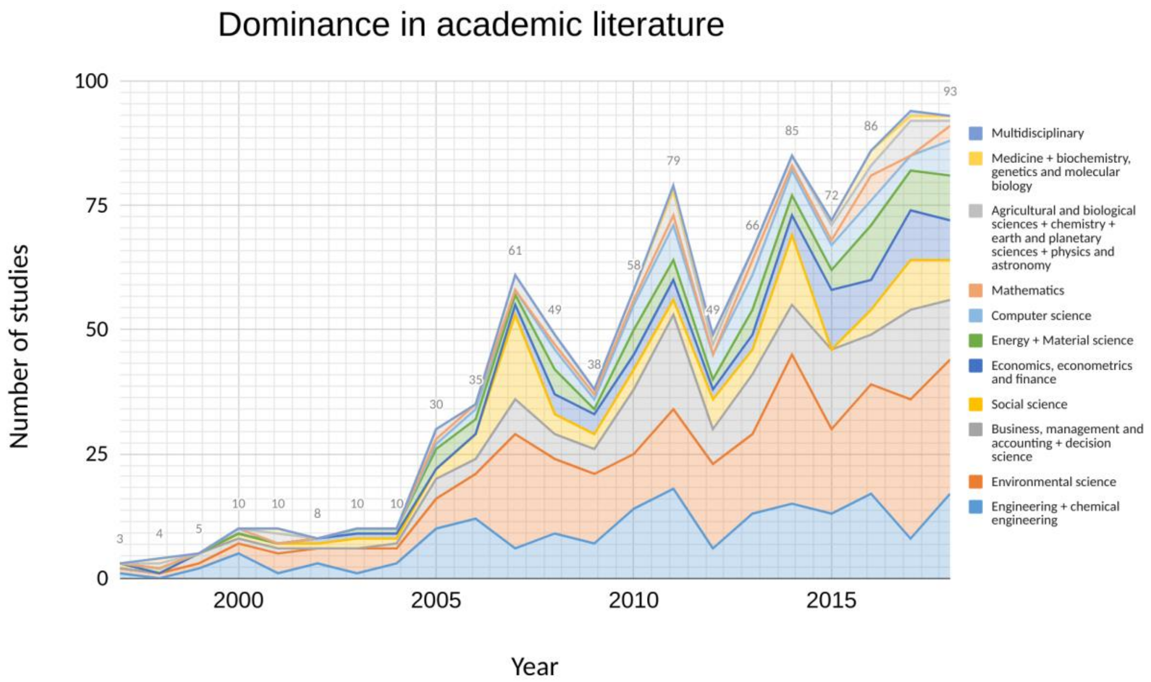

Figure 2: *Trends of publications over time regarding EPR in Scopus.*

2.2.2 Key insights

Environmental sciences

Widmer et al. (2005) is by far the most-cited study and outline five crucial design characteristics for an EPR in the field of electronic waste (p. 449):

1. Legal regulation: the scope and level of detail of legislation for operation of the EPR system.
2. System coverage: the brands and products targeted as well as the extent of EPR sub-systems and tailoring to different products or product categories.
3. System financing: who pays and to what extent are waste management prices incorporated in the product.
4. Producer responsibility: who is responsible for what and to what extent can producers allocate responsibility to collective bodies that run the waste management operations.
5. Ensuring compliance: how is free-riding mitigated.

Furthermore, they present an assessment framework for comparing EPR-like systems for electr(on)ic waste, which has three pillars. First, the structural framework is presented, which has sub-indicators reflecting: I) cultural norms and civil society, II) secondary material markets and costs of capital, III) the legislative and political environment and IV) recycling knowledge. Second, the recycling system quality is discussed, focusing on financial and material flows as well as the technological characteristics of the recycling system. Third, the impacts on the environment, health and labor are presented.

Nnorom & Osibanjo (2008) – second most-cited study – elaborate on the responsibilities that are important to EPR, drawing from Lindhqvist (2000), Langrova (2002), Milojkovic & Litovsky (2005) and Oh & Thomposon (2006). Nnorom & Osibanjo (2008) distinguish 5 different kind of responsibilities, see table 1.

Table 1: *Types of responsibilities (Nnorom & Osibanjo, 2008).*

Type	Description
Liability	The environmental damage that can be linked to a specific product and producer, depending on legislation regarding different steps in the life cycle.
Economic responsibility	The producer assumes responsibility of (part of) the expenses on waste management arising from the use of his products.
Physical responsibility	The producers assume responsibility of (part of) the physical management of his products or effects, ranging from technology development to full-fledged waste management logistics.
Ownership	When the producer owns the product in the use-phase (i.e. the consumer leases the product), then the producer can assume (part of) the economic and physical responsibility.
Informational responsibility	The producer assumed (part of) the responsibility to provide information on his products.

Business, management and accounting plus decision science & (chemical) engineering

For these two disciplinary fields, the number 1 most cited studies are different, but both number ones are specific to a certain company/ technology and do not elaborate on EPR. However, coincidentally, the number two and three most cited studies are the same for both categories and discussed here respectively.

After evaluating the end-of-life vehicle (ELV) Directive that stipulates EPR for ELV within the EU, Gerrard & Kandlikar (2007) find that the Directive had positive effects on innovation, especially regarding recycling and sorting. However, economic and consumer considerations are the most important to designing a car. Furthermore, design changes are hindered by the long lifetimes of vehicles and associated payback times, while innovations in recycling have more immediate benefits as older vehicles have to be processed as well. Overall, the Directive had impact on: 1) the use of toxic materials, 2) recyclability due to a reduced number of plastics and 3) material efficiency, while the impact on re-use and remanufacturing was low. The latter impacts were low, because the carmakers themselves are not involved in remanufacturing and thus do not receive the associated benefits. Finally, they find that some innovation types were constrained and that the ELV Directive with the economic environment leads to an emphasis in recycling and lower use of toxic materials.

Another highly cited paper falling within the engineering category had more of a focus on the economic dimension regarding EPR. Atasu, van Wassenhove & Sarvary (2009) find by means of stylized economic models that take-back mechanisms are inefficient, when they are formulated in terms of weight or mass. It would be better if they account for 1) costs and benefits of waste treatment and recycling, 2) environmental damage by the product, 3) willingness to participate in take-back schemes, and 4) the degree of competition within a market. Specifically regarding the electr(on)ic appliance waste legislation in Europe, individual producer responsibility should gain more prominence to avoid cost competition rather than improved product designs. Regarding subsidizing certain technologies, they conclude that subsidies for increasing recycling rates can actually increase the amount of environmental damage as more products are being used and produced. Subsidies for recycling technologies can be helpful for products that already have high collection rates, but also have high levels of toxic materials. Lastly, reuse of products yields higher environmental benefits than recycling.

Social science

Though the study of Widmer et al. (2005) is the most widely cited study in this category, an important contribution is also given by the number 3: Sachs (2006). Sachs (2006) is highly critical of EPR policies. According to Sachs (2006) externalities of specific products are hard to determine and internalization by letting the liable producer pay for the externalities of his products comes with high transaction costs. To overcome these high transaction costs, collectives in which producers have organized themselves – so-called producer responsibility organizations (PROs) – are operating in most European Union (EU) EPR systems. However, the presence of collectives diffuses the signals of prices and lowers incentives for individual producers. Thereby, the incentives to improve product design and manufacturing are limited. Furthermore, Sachs points out that perhaps too many objectives are pursued by EPR, stressing that "an economic maxim holds that at least as many policy instruments are needed as policy objectives" (p. 97).

In a case study, focusing on Sony Computer Entertainment Europe (SCEE) Mayers (2007) finds that organization of the post-use management through collectives is the most cost-effective for an individual company. Increased levels of competition between different producer responsibility organizations – collectives that producers can allocate EPR tasks to – reduced the take-back costs by about 50% to Sony (ibid). Mayers (2007) points out that policies should not steer towards individual responsibility but to individual financial advantage upon improvement if EPR systems are to be expanded.

Economics, econometrics and finance

Nnorom & Osibanjo (2008) is the most cited study for this category. Another widely cited study is Gupta & Palsule-Desai (2011). They find that firms subject to EPR have a multitude of strategies available to them to fulfill EPR obligations:

1. Change product design towards facilitating take-back, modulatory and reuse.
2. Rethink components and material use
3. Offer different products
4. Consider planned take-backs next to planned obsolescence for optimizing product durability
5. Adopting alternatives to selling such that decisions for replacement and maintenance are predominantly made by the producing firm.
6. Engage in different contracts in the entire supply chain, such as with distributors and suppliers to govern the (reversed) supply chain.

Furthermore, Iakovou et al. (2009) provide a methodological framework that can be used by manufacturers for making strategic decisions regarding upon end-of-life alternatives of a component. The five indicators that are present within this methodological framework are the component's: market and residual value, environmental damage, weight (incorporated because the legal environment steers on weight), quantity in a product and ease of or quality after disassembly.

Fleckinger & Glachant (2010) evaluate the efficiency of EPR based on stylized economic models. They conclude that allocating responsibility to producers does not result in efficient behavior. Pigouvian taxation leads to negligibly different outcomes then allocating responsibility individually in a competitive waste market. However, when product markets are not competitive, nor are the associated waste markets and a different extent of collusion arises as collective organization (i.e. PROs) are created. Furthermore, they find that individual EPR approaches result in higher social welfare than collusive PROs in a fully competitive waste market. If individual producers face monopolist prices in the waste market, then producer collusion results in higher social welfare. Lastly, when comparing differentiated with uniform tariffs, they show that uniform tariffs enhance social welfare if the PRO is collusive, and products are not very different regarding, for example, costs of production and waste disposal.

Brouillat & Oltra (2012) evaluate three types of instruments employed in EPR schemes – fiscal stimuli (taxes and subsidies), norms and recycling fees – on their potential to lead to innovation by means of an agent-based simulation model. The design of the EPR system is deemed highly important, because the same instrument can result in different effects due to differing levels of strictness and how incentives are allocated. Fees should be differentiated across products to achieve efficiency by accounting for the range of different technologies that producers can employ. Furthermore, they show that EPR policies emphasize certain product characteristics over others, such as recyclability over reuse or attractiveness to the consumer, thereby potentially undermining competitiveness. While fiscal stimuli lead to effects on recyclability and strict norms affect a range of or product characteristics both instruments can cause radical innovation for the respective characteristics. Fiscal stimuli provide support and thereby incentive a wide range of producers to innovate, whereas (radical) innovation from strict norms is mostly due to selection: most producers are weeded out from the market while some survive. What is more efficient is hard to say.

Massarutto (2014) discusses the economic literature and concludes that: “primary and above all, we have witnessed in the last 20 years a gigantic effort of market design, and this is the main demonstration of EPR’s success” (p. 11). The success of EPR lies not so much in solving (theoretical) market failures at the margin, but in “the superior managerial capacity of industry and the need to organize post-consumption markets that transcend the local scale and have access to the economies of scale and scope” (p. 11). In contrast, he finds that EPR policies are largely unable to spur green product innovation and that the green product innovation that is occurring is more due to individual marketing efforts.

2.2.3 OECD reports

In most of the presented papers, references are made to OECD reports, most importantly the OECD (2001). The OECD (2001) outlines four categories of EPR approaches, as presented in table 2.

Table 2: *Types of EPR approaches (OECD, 2001).*

EPR approach	Illustration
Regulatory measures	Product standards, recycling rates, material bans
Product take-back systems	Mandatory, voluntary or negotiated programs
Voluntary industry approaches	Partnerships, codes of conduct, labelling, leasing
Economic instruments	Deposit-refund systems, advance disposal or recycling fees, taxes and subsidies

Drawing lessons from over 300 EPR schemes over the world and an extensive literature overview, Kaffine & O'Reilly (2015) find that EPR schemes could effectively increase rates in collection and recycling, reduce spending of public bodies on waste management, reduce total costs of waste management and create incentives for environmentally friendly designed ("*design for environment*": DfE) innovation, depending on the context. Besides these main effects, EPR schemes can improve innovation of technologies and organizations, lead to organizational benefits in the supply chain and increase resource security by diversifying the material supply of producers.

Which steering mechanisms increase circularity and social welfare best for which product categories and position in the value chain remains unclear.

2.2 Theory

2.3.1 Theory selection & perspective

In this study, EPR as a policy sub-system of the greater policy area of circular economy is analyzed with an institutional, welfare economics perspective. The circular economy literature provides the principles that are central to a circularly operating economy, but the circular economy *an sich* is not a theory for *how* or *why* societal change is occurring. Rather, circular economy and extended producer responsibility can be approached from different academic angles.

Kirchherr, Reike & Hekkert (2017, p. 229) define the circular economy as:

"an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."

Reike, Witjes & Vermeulen (2018) distinguish a hierarchy of circular options for consumers and businesses, where lower values reflect a higher place in the hierarchy: refuse (R0), reduce (R1), resell or reuse (R2), repair (R3), refurbish (R4), remanufacture (R5), re-purpose (R6), recycle materials (R7), recover energy (R8) and re-mine (R9). R0, 1,3,4,5&7 relate to the circularity in design of products. R2 and R6 are smart applications of the product without altering its form. In R8, not the material, but only the energy within the material is brought back in the economy. R9 refers to bringing back historically used and disposed products in the economy.

Circular economy principles and operationalizations are used in this as a guide to identify where the highest potential costs and benefits are located, and help inform the institutional, welfare economics approach to EPR. This institutional, welfare economics approach is chosen here to assess how EPR schemes interact with incentives of producers and consumers by assessing costs and benefits to individuals and groups at large. In essence, economic theory is used in this study to evaluate EPR schemes for their desirability on economic grounds: higher benefits than costs.

2.3.2 Welfare economics

The welfare economics perspective is incorporated, because EPR schemes are public policies. As such, EPR schemes must solve market failures (Verrips et al., 2019). However, if poorly designed, then EPR schemes could also result in public policy failure: a negative effect on social welfare due to EPR. Social welfare is the welfare for an entire population. By analyzing EPR policies through a welfare-economics lens, their added value to a whole society can be analyzed instead of only the directly targeted actors involved in waste-management.

Central to welfare economics is the principle of allocative or Pareto efficiency: actions should be carried out so that costs are the lowest and benefits the highest, resulting in a situation in which redistribution of resources would always make someone worse off (Hindriks & Myles, 2013a). Not all costs and benefits are reflected in market prices as a result of market failures (ibid). Costs to the environment in the form of pollution, for example, are not always reflected in market prices (ibid). When market prices are wrong, goods and services are provided in excess or in short supply (ibid). This requires public policy intervention by which the government seeks to solve or mitigate the market failures, thereby improving social welfare (Teulings, Bovenberg & Van Dalen, 2003).

If markets fail to get the prices right, then prices can be directly affected by Pigouvian taxation efforts to internalize externalities, such as environmental damage (Hindriks & Myles, 2013a). However, in the presence of multiple market failures – e.g. environmental pollution with too high transaction costs due to opaque information flows, which requires costly monitoring and administration for setting prices right – Pigouvian pricing efforts alone are sometimes insufficient or undesirable from a welfare economics perspective (Hindriks & Myles, 2013b). Furthermore, Pigouvian pricing efforts can be unrealistic for legal or political reasons. Some EPR instruments can be considered Pigouvian pricing efforts, such as paying for waste disposal costs upon purchase of the product (this internalizes the waste management costs of consumption, but not necessarily the environmental externalities). Market failures and wrong prices can also be indirectly addressed, such as by labelling (overcoming information asymmetries) or banning toxic materials (to avoid unpriced health costs) (Hindriks & Myles, 2013b).

Though welfare economics analyses the effects on entire populations of groups, it draws from theory how agents behave in reaction to changes on the micro-level (Hindriks & Myles, 2013b). Therefore, institutions are important to welfare economic analyses. Institutions structure interactions by enabling and limiting the choices that agents have (Cardinale, 2018). Some institutions are formalized and adopted as laws, while others are informal and persist as static social norms. Institutions present the (dis)incentives to demand, supply, consume and produce in certain ways. Furthermore, while classical economic theory often considers a fully rational person to make choices, institutional economics favors a bounded rationality approach: not all actions derive from rational thinking, but also from non-rational behavior (Posner, 1998).

In this study, a public policy is considered a governmentally created institution to steer towards a certain goal - be it by addressing the rational or irrational part of agents – that seeks to enhance social welfare from a welfare economic perspective.

For an illustration that a policy goal can diverge from optimizing social welfare, see figure 3. A certain policy goal exists to achieve a 100% recycling rate requiring increasing efforts to achieve this. However, at one point the benefits of these efforts no longer outweigh the costs from a societal perspective.

The highest level of social welfare is then achieved for less than a 100% recycling, though this was the original policy goal. Circularity can thus be considered a means to an end, not a goal in itself.

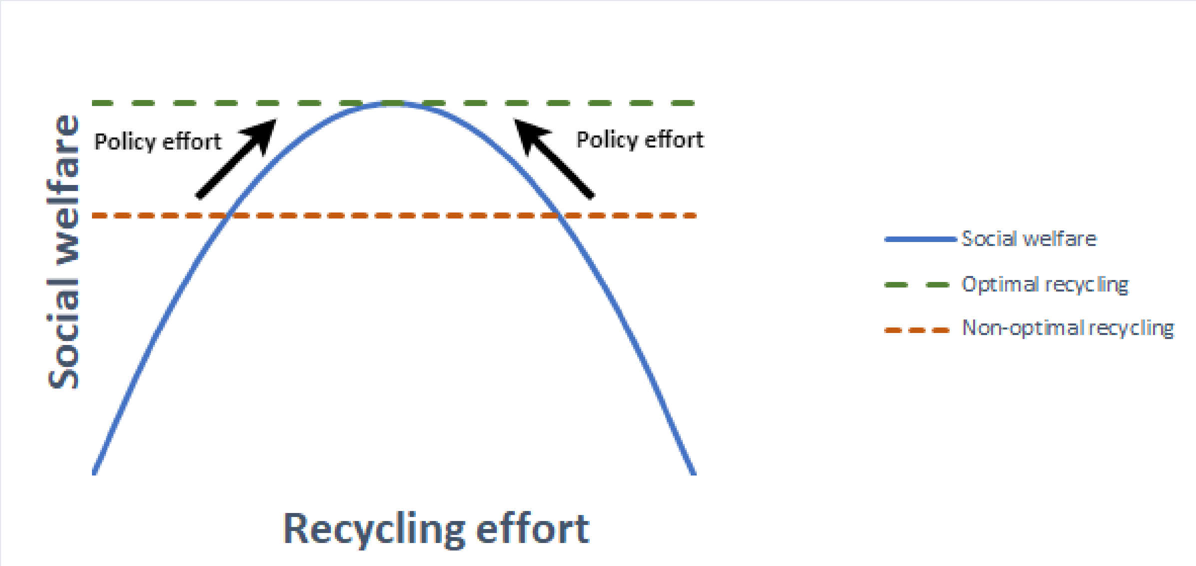

Figure 3 : *Social welfare as a function of recycling.*

2.3.3 Market failures overview

According to Teulings, Bovenberg & Van Dalen (2003), a public interest exists when free-riding leads to complex external effects, that are not solved by market parties themselves. Public intervention should occur at the level the externality is occurring (ibid). To illustrate, the construction of a theater should be evaluated for its local externalities and coordinated by a local public authority, because most externalities can be expected to be local. Overall, according to them, when a problem is characterized as of public interest the question should be: “what are the relevant complex external effects and accompanying free-riding behavior” (ibid, p. 7). The four major categories of complex external effects that justify policy intervention are listed in table 3. They state that scale advantages in combination with asymmetric information and/ or adverse selection are the most important sources for complex external effects.

Competition reduces producer surpluses, but it undermines the financing of infrastructures with economies of scales, which could result in welfare loss due to higher costs with respect to the generated benefits (Teulings, Bovenberg & Van Dalen, 2003). When no competition is present, excessive monopoly prices can prevail, thereby resulting in welfare loss (ibid). Thus, a tension exists between competition and economies of scale.

Table 3: *Complex external effects, illustrating a public interest and ground for policy intervention (Teulings, Bovenberg & Van Dalen, 2003).*

Complex external effects	**Illustration**
Collective (public) goods & externalities	Collective goods are goods that provide benefits from which nobody can be (easily) excluded. Private transactions can have negative effects on these public goods, potentially harming social welfare if the net loss of the common good cannot be compensated arising from the private transaction. Furthermore, private transactions can have external effects on other private persons.
Incomplete, asymmetric information & adverse selection	When information is missing for one or multiple parties to the transaction, it is harder to determine which choice yields the highest benefits. Parties can create and exploit an information-rich position, thereby reducing overall social welfare. The public interest is to ensure better decision-making for lower costs. This implies that disclosing more information is not necessarily the best solution, when high costs are associated with processing information for coming to a decision.
Scale advantages & market power	When scale advantages are present, average costs are higher than marginal costs. The higher the fixed costs, the more likely it is that market power is concentrated in the party that can achieve the largest scale. On the other hand, when scale advantages are achieved and the arising benefits are transferred to the consumer, the consumer benefits from the scale advantage. Establishing scale advantages and/ or redistributing benefits from these is thus a public interest, because it creates consumer and/ or producers surplus.
Uncertainty	Uncertainty - in contrast to risk - is the result of lacking or low quality information. Risk is calculable, uncertainty is not. When information is non-existent, overestimation or underestimation of benefits and costs is likely. Thus, the resulting lower social welfare would then be lower than when the information would be available.

Furthermore, Teulings, Bovenberg & Van Dalen (2003) state that income distributions matter. Those with higher incomes receive less additional utility or welfare from one extra unit of income than those with low income. Thus, redistribution efforts – though costly in operation – due to government intervention can increase social welfare. On the other hand, redistribution can lower the incentive to put effort in creating added value when the benefits of this effort are taken away. Therefore, if redistribution – by income policy or in providing goods and services – is occurring, then for each euro redistributed its return should be greater than the costs of disincentivizing value creating activities and operational costs to make the shift occurring. Overall, moving around income or other benefits results in lower average income, but – if done rightly – can result in higher social welfare, even more so if the redistribution helps to overcome more damaging market failures (ibid).

Overall, a policy intervention is only justified when it results in net benefits (Teulings, Bovenberg & Van Dalen (2003). Generally, this can be done by: 1) restructuring the market or 2) absorbing the market activity and raising revenue to fund absorbed costs (e.g. fees for public services) (ibid).

3. Methods

3.1 Chapter introduction

In this chapter, the research-sub questions, theoretical framework, assessment criteria, research framework (including the research strategy) and data acquisition are presented for this study.

3.1 Research sub-questions & theoretical framework

Drawing from the literature reviews, 5 sub-questions are formulated that are relevant to evaluating an EPR system on incentives, circularity and social welfare. Together – when answered – they enable a conclusion regarding the main research question. The sub-questions are:

1. Which market failures exist in the value chain that lead to excessive waste or low circularity?
2. Which EPR instruments are implemented to overcome these failures?
3. How do these instruments structure incentives of producers, consumers and the government?
4. Which circular practices are adopted where in the value chain due to these (re)structured incentives?
5. What are the effects in terms of costs and benefits of these practices to producers, consumers and the government?

The theoretical rationale as is follows (see figure 4). Following welfare economics, a market failure arises that can be solved with a public policy. In this study, EPR is the public policy. Due to the instruments employed in the EPR scheme incentives are restructured, after which agents change practice, leading to increased levels of welfare, ideally. It could be the case that no market failure is recognized (deleting line 1), but that market or public parties still seek to implement EPR schemes (following line 2). If this is the case, then policy failure is the result. Practices are likely to be changed due to an interplay of market conditions and incentives created by the EPR instruments (line 3). Even in the absence of EPR instruments market conditions could change such that practices are changed, leading to increased social welfare because market failures are solved. A more detailed operationalization of this theoretical framework is presented in the next section on assessment criteria.

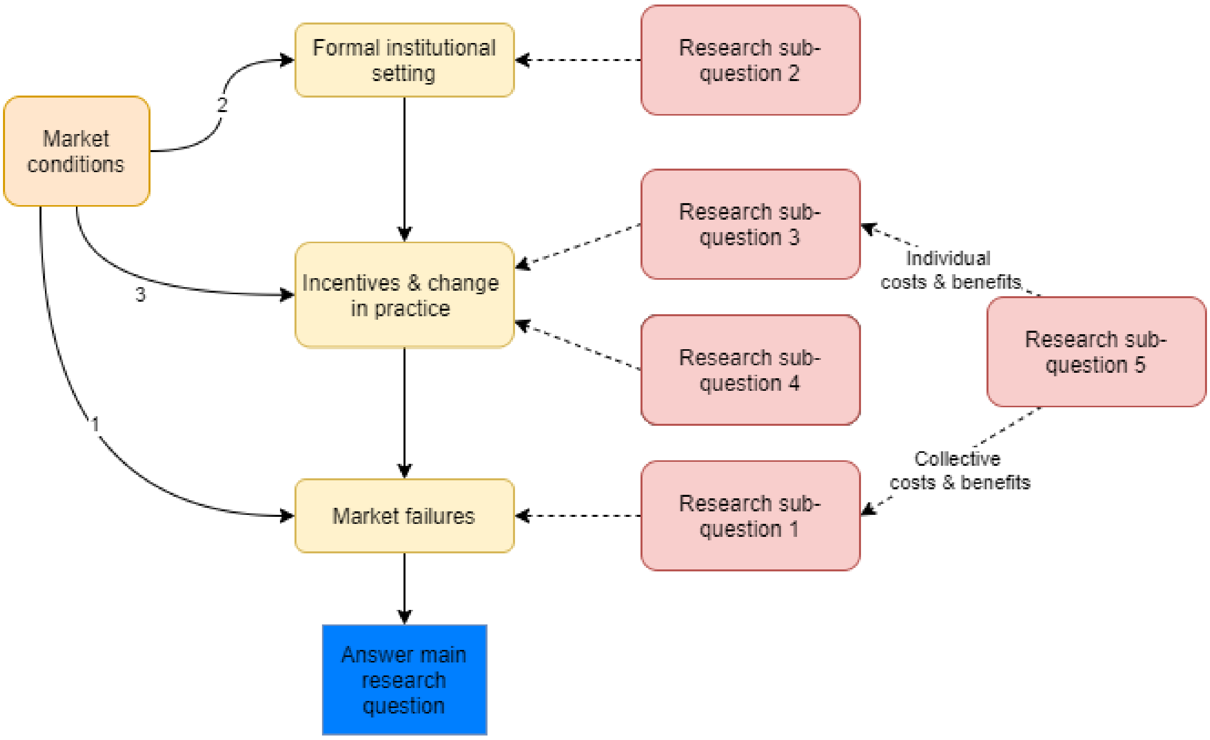

Figure 4: *Theoretical framework & connection to research questions.*

3.2 Assessment criteria

Here, the theoretical framework is operationalized such that it can be assessed through research (see figure 5 and table 4 for schematic overviews). The formal institutional setting is broken down into two indicators: 1) formal responsibilities and 2) system coverage & regulatory detail. The incentives and practical change that are due to the EPR system, are broken down into 4 indicators: 1) waste management organization, 2) waste management financing, 3) reporting, compliance & enforcement (with a focus on waste management, but also considering relevant production characteristics), and 4) circular practice beyond waste management. See table 4, for relevant sub-indicators and explanation on these sub-indicators. The market failures that are assessed are: 1) environmental externalities (throughout the value chain), 2) neglected scale advantages and 3) reduction in information asymmetries, adverse selection and uncertainty, or shortly: information issues. Based on the literature reviews, these three market failures can be expected when incentives, costs and benefits are misallocated, due to incentives by EPR, other policies or market characteristics.

It should be noted that, while conducting the research, other assessment criteria were used (see appendix 1). These other criteria were based on a more linear approach to problem-identification and problem-solving by means of public policy, while also explicitly targeting more steps in this approach. For example, the market failures were split into two temporal sub-indicators: before and after implementing EPR. However, whilst the study progressed, this sub-division became untenable, because findings on EPR could not be cleanly split into these two sub-indicators. Another problem was encountered in distinguishing between incentives for an action (called targeted choice margin in the old assessment criteria list) and the changes that occur due to EPR. Therefore, a new list of assessment criteria has been created, that is contents-wise the same and relates to the same research (sub-)questions, but clusters multiple (sub-)indicators for the sake of analysis and reporting. This new list is used in the remainder of this study.

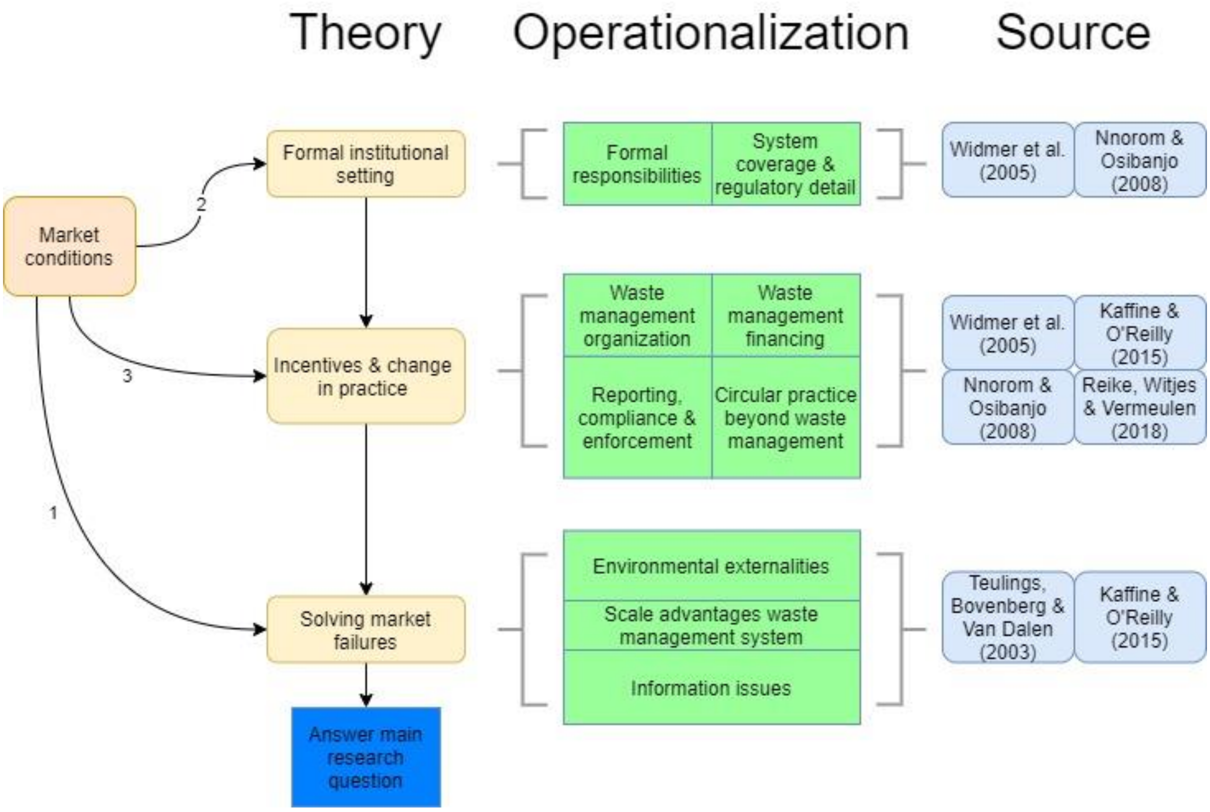

Figure 5: *Operationalization of the theoretical framework.*

Table 4: *Indicators and sub-indicators with illustration.*

Link to theory	Indicator	Sub-indicators	Illustration
Formal institutional setting (RQ 2)	Formal responsibilities	- Legal basis - Type of responsibility - Targeted and exempted products	- listing of laws - for example, organizational, financial, informative, imposed or voluntary - explicitly mentioned products in formal documents
	System coverage & regulatory detail	- Scope of the system - Type of instruments	- local, regional or national - e.g. financial, regulatory, economic, instruments in formal documents
Incentives & change in practice (RQ 3, 4 &5)	Waste management organization	- Waste management structure coordinators - Waste management structure - Number of different products and waste streams	- operational or physical characteristics of the system - relations between stakeholders in waste management - indicator for diversity of products and waste streams
	Waste management financing	- Rules and agreements on finance - Financial instruments - Fee differentiation	- allocation of financial responsibilities - type of financial instruments employed to finance waste management system (e.g. fees) - considerations for how high a fee is
	Reporting, compliance & enforcement	- Inspection & enforcement - Reporting & compliance - Quality control & certification efforts	- auditing and inspection efforts by producers and public agencies - monitoring structure and degree to which free-riding on EPR responsibilities occurs - operational and environmental performance benchmarking
	Circular practice beyond waste management	- Designing and business innovation efforts	- effect of EPR on circular design (e.g. recyclability) and new business models (e.g. leasing)
Solving market failures (RQ 1 & 5)	Reduction of environmental externalities throughout supply chain	- Environmental damage in value chain - Costs and pricing of environmental damage	- type, severity and location (in value chain) of environmental damage - degree to which environmental damage is incorporated in product prices
	Scale advantages waste management system	- Performance - Costs	- rates of collection & recycling - cost structure (e.g. costs per ton)
	Reduction in information asymmetries, adverse selection and uncertainty	- Information on separate collection - Product characteristics	- campaigning and public education efforts by producers - knowledge availability to consumers and waste processors about circularly relevant characteristics (e.g. toxicity)

3.3 Research framework

The research questions show that a more institutional, welfare economics approach to EPR schemes is adopted in this paper. The sum of all costs and benefits results in the social welfare estimation, which can be qualitative (e.g. a small or large contribution) or more quantitative (weighting of pecuniary costs and benefits). While searching for relevant EPR data the monitoring expert at the public executive agency for EPR - Rijkswaterstaat - was consulted and he emphasized the need for qualitative methods, as the quantitative data for EPR specifically is insufficient for drawing conclusions. Or, additional data sources should be found that can be used in tandem with the data Rijkswaterstaat has. By taking a multi-method approach, this study evaluates EPR systems qualitatively, and where possible quantitatively (see figure 6 for an schematic overview).

The theoretical framework and related assessment criteria are used in a comparative case study analysis for three product categories in the Netherlands: 1) batteries and accumulators, 2) non-packaging cardboard and paper, and 3) medicine. The cases are selected based on three characteristics: the type of EPR, a lack in prominence in the reviewed academic literature and timeliness. Regarding type, the cases present a continuum of governmentally imposed, self-imposed and absent post-use product responsibility for the three categories respectively. Regarding the lack in prominence in the academic literature, batteries, cardboard and paper and medicine were not explicitly researched in the reviewed literature: product focus in research is more on waste of electric and electronic appliances and to some extent end-of-life vehicles. Lastly, regarding timeliness, higher battery waste volumes can be expected due to electrification of society, cardboard and paper relate to biobased economy and options for medicine EPR are explored on the EU-level (European Commission, 2019a).

Multiple research methods are adopted to answer the research sub-questions for the three cases and broader experiences with EPR in the Netherlands, putting the case findings into wider context. The review of institutional literature contributes to answering sub-questions 2 and 3, while the semi-structured interview and evaluation document review contribute to all. In the study-design phase, it was unclear which quantitative data relevant to EPR, circularity and social welfare was available. Therefore, the interviews and evaluation reports were used to explore which quantitative data relevant to the study exists and where it can be found. The quantitative data analysis has a descriptive character, corroborating and useful to triangulating the findings resulting from the other research methods, thereby increasing reliability and validity.

Three different parts of analysis can be distinguished in this study respectively. First, the overarching formal (legal) institutional setting is assessed, operationalized with the same (sub-) indicators as in the three cases, though at a lower level of detail. This is done, because EPR legislation for certain products is embedded in a wider institutional setting, thereby being highly relevant to the cases. Second, the three cases are assessed with all assessment criteria that are in table 4. However, the incentives & change in practice indicators are assessed in two ways: practice (which activities and rules are present) and evaluation (outcomes and reasons for these activities and rules). This corresponds to a factual and valorized situation respectively. For the former, policy documents and other institutional literature are predominantly used; interviewee findings are important for the latter. The market failures are assessed with interviewee findings, evaluation reports and descriptive statistics.

After the overarching formal institutional setting and three cases are presented, broader experiences with EPR are assessed. These broader experiences are included, because of three reasons. First, some effects cannot be exclusively ascribed to the cases, though they contribute (for example, effects on municipal spending on waste management). Second, it increases the reliability and validity of the case findings. Third, it enables a wider reflection on general EPR characteristics that were not mentioned in the case studies, thereby covering extra ground and acting as an additional exploratory assessment of EPR functioning. An additional analysis for the section broader experiences of what occurs in practice by means of a thorough institutional literature is beyond the scope of this study. Interviewee information and descriptive statistics are predominantly used to evaluate practices and assess market failures.

The decision to include the broader experience section was made while acquiring data, because insights from the institutional and evaluation reports as well as from interviewees were not limited to the case studies, while being valuable to understanding EPR.

After assessing the overarching legal institutional setting, case studies and broader experiences the finding of these assessments are systematically compared. Afterwards, academic and policy implications as well as the contribution of EPR to social welfare and circularity is discussed.

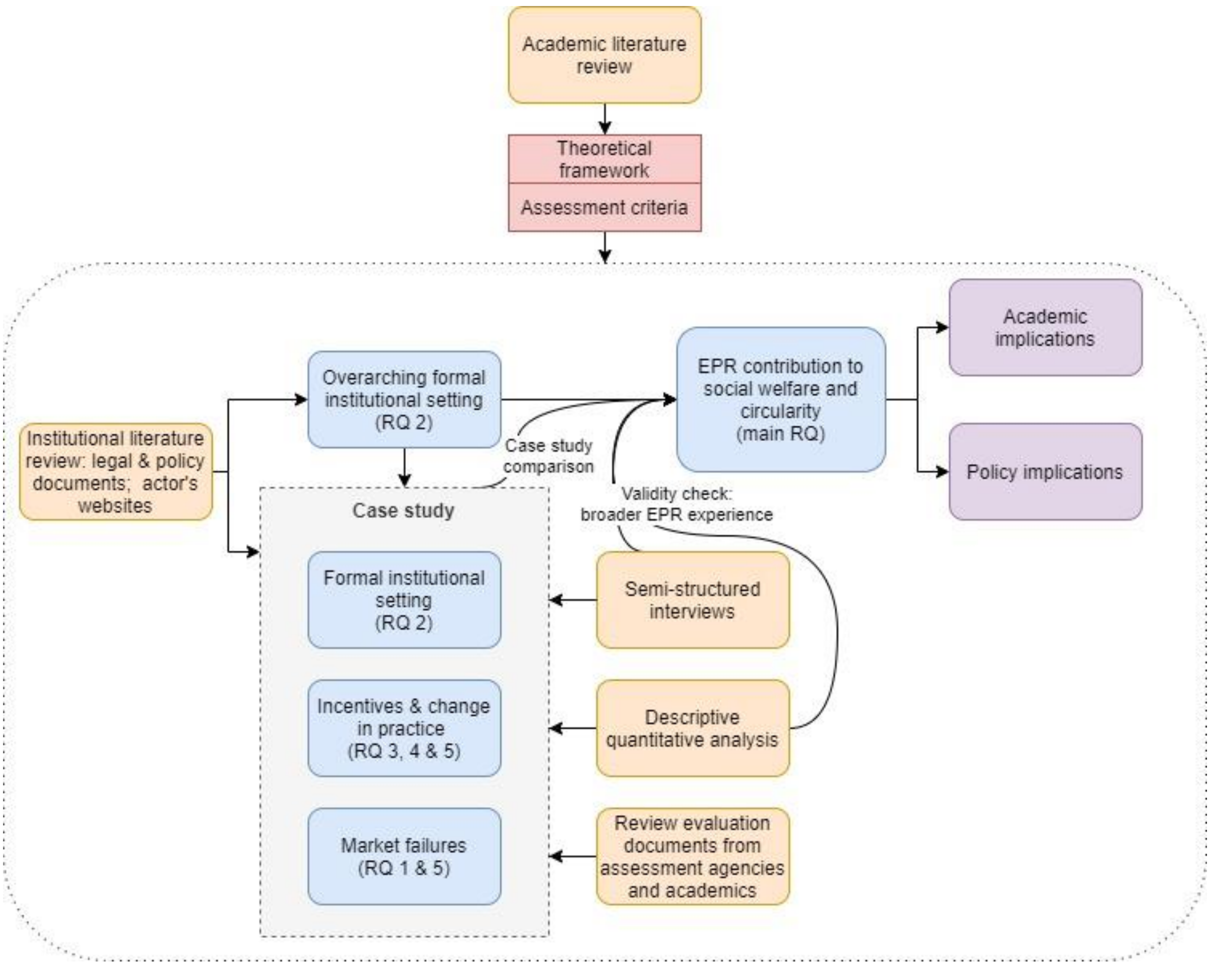

Figure 6: *Research framework of this study.*

3.4 Data acquisition

3.3.1 Literature review

Different kinds of written sources are analyzed: academic literature, policy documents, websites, and non-academic reports, such as those by assessment agencies and consultancies. Academic literature has been browsed for with Scopus and Google scholar. Policy documents are derived from governmental organizations and legal websites. Non-academic reports are obtained from browsing the databases of assessment agencies as well as by googling. Key search themes have been: EPR, waste management reverse logistics, circular economy, batteries, paper and cardboard and medicines.

3.3.2 Interviews

Staff of a range of relevant organizations has been interviewed, being PROs (Stibat, ARN), a branch organization (KNMP), an organization in which PROs cooperate (VPN) public bodies involved in operational activities for waste management (*Unie van Waterschappen (UvW),* due to its involvement in waste water management, *Vereniging van Nederlandse Gemeenten* (VNG) due to its involvement in solid waste management), a public assessment agency for environment and health (RIVM), the public executive agency (Rijkswaterstaat), inspection (*Inspectie Leefomgeving en Transport* (ILT)) and the national Ministry of Infrastructure and Water management (I&W), see table 5. Furthermore, the PRO for cardboard and paper (PRN) was contacted, but unable to respond until late in the study due to the COVID-19 outbreak. The branch organization for Innovative Medicine Producers (VIG) has also been approached, but did not respond.

The PRN was consulted by the CPB in 2019, and documentation of this report was used to identify insights for answering the sub-questions, in line with the analytical framework. Furthermore, three other interviewees commented on cardboard and paper. Though initially planned to interview, the branch organization for Innovative Medicine Producers has been excluded, because two other organizations were successfully contacted and members of three other organizations were able to comment on medicine waste management. Excluding PRN, ten organizations were consulted in a face-to-face meeting or by phone, the minimum number outlined in the proposal for this research. In a later stage, PRN was able to provide written input for and feedback on the results derived from the CPB internal documentation. Overall, eleven organizations have provided input.

The range of different organizations enables the researcher to tap from expert knowledge regarding all the indicators, but to also account for different perspectives and experiences regarding EPR. The interviewees all possessed expert knowledge for the niche that EPR is in the policy field. This enabled exploring and evaluating the finer intricacies of this complex policy approach. Public organizations were contacted by using the author's network and that of direct colleagues. The other organizations were contacted by means of the contact info on their websites. Importantly, ethical guidelines have been acknowledged by providing full-disclosure on the position of the author (a student, in the first place), asking the interviewee to what extent they wish to see their findings anonymized and asking for permission to record the interview in advance of the interview. All interview findings have been fully anonymized to account for the wishes of a few interviewees. The interviewee findings have been coded. The code P.O.n is given to the producer organizations, where n is a number that corresponds consistently with one of the producer organizations, in random order: PRN, Stibat, VPN, KNMP, ARN. The code G.O.n is given to public organizations, where n is a number that consistently corresponds in random order with Rijkswaterstaat, UvW, ILT, I&W, RIVM, VNG. It should be noted that organization names are referred as source, when the information is derived from published material by that organization (e.g. websites). See appendix 2 for the interview questions and link to the assessment criteria.

Table 5: *Categorization of organizations per product category.*

Product category	Organizations	Contact
Batteries	Stibat, ARN	Interview
Cardboard and paper	PRN	Internal documentation plus review of findings
Medicines	KNMP, UvW	Interview
Relevant to all	Rijkswaterstaat, ILT, I&W, RIVM, VNG	Interview RWS: data consultations plus qualitative questions
Relevant to all with EPR	VPN	Interview

3.3.3 Quantitative data

Quantitative data was sought for at Rijkswaterstaat, CBS, PBL and European Commission/ Eurostat as well as in PROs, individual companies and other online, publicly available data. With the information from the document and literature review, interviews and quantitative data causal mechanisms for a successful policy approach to post-use product management are explored. Quantitative data sources are mostly used to verify findings from the interviews and build on the insights, where possible. Organizations have to report on their waste streams, where each waste stream has a unique EURAL code. For some waste streams, separate codes exist for household and/ or separately collected flows. This data was obtained from Rijkswaterstaat through personal communication and used in the case studies. Other useful sources, include self-reported figures of producers publicly disclosed by Rijkswaterstaat (2020a), financial data obtained from the PRN and figures disclosed by the *Compendium voor de Leefomgeving* (CLO).

4. Results

4.1 Chapter introduction

In this chapter, the formal overarching institutional setting, batteries & accumulators case study, non-packaging paper and cardboard case study, medicine case study and broader experiences are assessed respectively. Each has a separate section. In appendices 3, 4, 5, 6 and 7 schematic overviews of all the sections are presented respectively. In the next chapter, the discussion, the findings are systematically compared.

4.2 Formal overarching institutional setting

4.2.1 Section introduction

In this section, the formal overarching institutional setting is assessed using the formal institutional setting indicators. For a schematic overview, see appendix 3. First, the legal basis and targeted products on an aggregate level are presented. Second, the type of responsibilities are presented for producers as well as public organizations are shown, also on an aggregate level. Altogether, the findings of this section can be considered a helicopter overview of the formal institutional setting of EPR, as well as a review of the basic building blocks that can infuse an EPR system for a specific product.

4.2.2 Formal institutional setting

Legal basis, targeted products

The existing, imposed Dutch EPR systems are based on specific European product directives. These EU Directives have to be implemented in national legislation, in the Dutch case with reference to the *Wet Milieubeheer*, a comprehensive law for environmental governance in the Netherlands. In table 6, the legal basis is shown for all these products. The Directive (EU) 2019/904 on the reduction of the impact of Single Use Plastics will introduce EPR responsibilities for balloons, wet wipes, tobacco product filters and fishing equipment, as well as additional responsibilities regarding the existing EPR for packaging, but specific product Directives are non-existent now. Furthermore, even if there are no specific product directives on the EU level, EPR can be implemented for other waste streams (G.O.6).

Table 6: *Current product group legislation (Rijkswaterstaat, n.d.-b; Rijkswaterstaat, n.d.-c).*

Product group	European Directive	Dutch legislation stipulating EPR responsibilities, with year of entry into force and relevant articles	Sector plan in third national waste plan (LAP 3) describing how to deal with waste
Accumulators and batteries	Directive 2006/66/EC on Batteries and Accumulators and Waste Batteries and Accumulators	- Besluit beheer batterijen en accu's 2008 (2008, art. 2) - Regeling beheer batterijen en accu's 2008 (2008, art. 2-13)	Sector plan 13
Car tires	Directive 2000/53/EC on End of Life Vehicles.	- Besluit beheer autobanden (2004, art. 2-4, 6-9) - Regeling beheer autobanden (2004, bijlage [annex] 1-3)	Sector plan 52

Car wrecks	Directive 2000/53/EC on End of Life Vehicles.	- Besluit beheer autowrakken (2002, art. 3-16) - Leidraad besluit beheer autowrakken (2002, no specific articles)	Sector plan 51
Packaging	Directive 94/62/EC on packaging and packaging waste	- Besluit beheer verpakkingen 2014 (2015, art. 2-6, 8-10) - Regeling beheer verpakkingen (2016, art. 2-5)	Sector plan 41
Waste Electric and Electronic Appliances	Directive 2012/19/EU on Waste Electrical and electronic equipment (WEEE)	- Regeling afgedankte elektrische en elektronische apparatuur (2014, art. 3-20)	Sector plan 71

The criteria that have to be fulfilled by an EPR system are stipulated in the European Waste Directive (Directive 1008/98/EC on Waste). Some main characteristics of the European Waste Directive are according to De Nederlandse Grondwet (2016)[1]:

1) The legal establishment of a hierarchy for waste management: prevention, reuse, recycling and recovery (including energy recovery).
2) A confirmation of the "polluter pays principle" such that the producer of waste carries the costs of the waste management system.
3) The introduction of the EPR concept, by which parties that put products on the market can be obliged to take them back after use.
4) A distinction between waste and by-product, where the latter is a substance from the production process that – unlike waste – has to be usable.
5) The introduction of recycling as well as recovery targets for household waste (50%) and demolition and construction waste (70%) that have to be achieved by 2020.
6) The legal stipulation that the waste management is carried out without risks to air, soil, water, as well as animals and plants, and also without nuisance due to sounds or odors.
7) A basis for good practice control as waste producers/ holders have to process it themselves or by a recognized party, while requiring permits and regular inspection.

Furthermore, when waste is separately collected, then it has to be kept separated from other waste streams according to the *Wet Milieubeheer* (Art. 51). Also, it should be noted though that a ban on most types of landfilling has been in power since 1997 for a wide range of different products (*Besluit stortplaatsen en stortverboden*, art. 1).

At the EU and national level, the Ecodesign Directive (2009/125/EC) aims to increase the environmental performance of products, by benchmarking the energy efficiency during use of the product. The Directive applies to 28 product groups, that are largely also subject to the WEEE Directive.

[1] Here, to avoid confusion 'De Nederlandse Grondwet' refers to an organization, not the Dutch Constitution, which would be the literal translation of 'De Nederlandse Grondwet'.

Relevant to EPR is also the European Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) which governs chemicals that are present on the market in the EU. It seeks to “ensure a high level of protection of human health and the environment” by governing those chemicals (REACH, 2006, article 1). Material requirements – e.g. maximum allowed concentrations – in Product Directives are linked to the Reach Directive, and hazardous chemicals are considered an option to base eco-modulation on (European Commission, 2019c).

Type of formal responsibilities and rules: producers subject to EPR

General descriptions for extended producer responsibilities are included in article 8 of the Waste Directive. Firstly, all natural and legal persons that professionally develops, manufactures, treats, processes, sells or imports can be made subject to EPR regulations in order to promote reuse, prevention, recycling and other useful applications of waste streams. These regulations can amongst others include: mandatory take-back of products and their waste, as well as the subsequent management of these material flows and financial responsibility for those activities. Also requirements can be included to make producers disclose information about the reusability and recyclability of the product. The article also makes it possible for member states to take measures that promote environmentally friendly design. Furthermore, the member states should take into account the technical as well as economic feasibility as well as the overall effects on environment, public health and functioning of the internal market. Lastly, when EPR is applied, specific legislation for waste streams and products remains in place.

Specific to Extended Producer Responsibility, the Waste Directive was amended in 2018, adding a fifth paragraph to the general prescription section on the promotion of cross-border information exchange between member states and actors involved in EPR and including an addendum (i.e. Article 8a) concerning minimum requirements to EPR systems. Article 8a is under procedure for being implemented in the Netherlands with *Besluit regeling voor uitgebreide Producentenverantwoordelijkheid (2020).* The most important general minimum requirements for an EPR system are described in the Waste Directive:

Article 8a, 1:

a. A clear description of the responsibilities and role of all the involved, relevant actors
b. Quantitative and/ or qualitative targets in line with previous legislation with additional relevant quantitative and/ or qualitative targets
c. A reporting system that monitors the products put on the market, collected waste, and treatment of waste by the producer, as well as other relevant information.
d. Equal treatment of all the producers of the product that is object to the EPR system, without disproportionately burdening producers, with explicit reference to small and medium sized enterprises and those that put only a small amount on the market.

Article 8a, 2. Member States take action to inform as well as incentive waste holders of products object to EPR systems to properly deliver waste.

Article 8a, 3. Furthermore, producers or PROs shall operate a system that has:

a. A clear geographical, product, material scope, not limited to where waste management activities are profitable
b. A decent collection system coverage
c. The means to operate the system and fulfill EPR responsibilities
d. A functional self-control method regarding budgeting and data management, with regular audits by independent third parties
e. The disclosure of information regarding reaching the objectives set for the EPR as well as of information on fees that producers in a collective pay per ton or per sold unit.

Furthermore, following article 8a, 4, the fees that are paid by a producer should cover: collection, transport, processing, information provisioning to waste holders, monitoring and reporting, and are modulated where possible, by considering a life-cycle approach. Fees should not exceed the costs for waste management. With regards to the fees, some room is left to member states to have fees cover most, but not all of the costs for waste management. According to article 8a, 5,: member states also have to implement a monitoring and enforcement scheme such that producers and PROs fulfill their obligations, and report high quality data.

In the new *Besluit regeling voor uitgebreide Producentenverantwoordelijkheid* (article 6), the PROs become the parties that are responsible for fulfilling the EPR responsibilities, not their individual members. Now, following the Dutch legislation for the five product groups in table 6, producers are individually responsible for fulfilling their EPR responsibilities in waste management though they can organize it collectively. Only in the case of packaging, the Producer Responsibility Organization (PRO), a collective, can be legally hold accountable for the responsibilities of producers in waste management (Besluit beheer verpakking 2014, article 9).

Type of formal responsibilities and rules: producers subject to AVV

Besides imposed responsibilities, as stipulated by the specific EU product directives and corresponding Dutch legislation, sector initiatives can be temporarily formalized by means of a *Algemeen Verbindind Verklaring* (AVV; in English: generally binding agreement), (*Wet milieubeheer,* art. 15.36). Such an agreement makes all parties putting a certain product on the market (including those that are not party to the agreement that is filed for becoming generally binding) subject to the obligation to pay a waste management or recycling fee to reimburse the operator of the waste management system for that specific product.

The *Regeling verzoek afvalbeheersbijdrage* is the legal document that sets out the requirements for eligbility of receiving an AVV (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer [VROM], 2000). The waste management coordinator (an PRO or PRO-like organization) that wishes to apply for an AVV has to: 1) represent an important majority of the market share in terms of turnover (rule of thumb: 75%), 2) show that it is in the interest of effective and efficient waste management, and 3) ensure the continuity of the waste management system (VROM, 2000). Furthermore, everything that is directly related to the waste management fee can be part of the agreement (ibid).For more detailed requirements to be eligible for making an agreement generally binding, see appendix 8.

Parties that do not wish to pay their dues as stipulated in the AVV, can file for exemption if they have or will create a system with minimally equal performance as the one that is operating under the AVV.

See table 7 for the products categories with an AVV. In the absence of an AVV, a producer is free to operate his own system to fulfill his own responsibilities.

The AVV instrument is applied within all product groups of which the producers have EPR obligations, except car wrecks, but also for flat glass and packaging, which do not have a Product Directive, see table 7.

Table 7: *AVVs per product category and organization (Rijkswaterstaat, n.d.-d).*

Product group	**Formalized agreement (AVV)**	**Organization AVV has been awarded to**
Separately collected paper and cardboard	*De Overeenkomst inzake de afvalbeheerbijdrage voor toepassingen van papier en karton*	Papier Recycling Nederland (PRN)
Lamps	*Afvalbeheersbijdrageovereenkomst lampen, versie 14 november 2018*	Stichting LightRec Nederland
Portable batteries	*De Afvalbeheersbijdrageovereenkomst Batterijen, including appendix A, B, C.*	Stibat
Packaging	*De Overeenkomst inzake de afvalbeheersbijdrage verpakkingen*	Stichting Afvalfonds Verpakkingen
Flat glass	*Overeenkomst inzake de afvalbeheersbijdrage voor vlakglas voor de periode 2016-2020*	Vlakglas Recycling Nederland
Car tires	*De Afvalbeheersbijdrage-overeenkomst Autobanden*	Vereniging Band en Milieu & Recybem

Regarding the history of AVV and EPR, the first EPR(-like) systems in the Netherlands, the first were established in the 1990s by means of AVVs, product directives, other regulation or covenants (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer [VROM], 2007). These were later updated (ibid). Notably, the following were implemented in 1990s, early 2000s and later updated, with the legal basis between brackets (ibid):

1. Packaging (1990, voluntary by means of covenants, no AVV; 2006, Product Directive)
2. ELV (1993, AVV; 2002, Product Directive)
3. Batteries (1995, Product Directive),
4. WEEE (1998, other regulation; 2004, Product Directive)
5. Tires (other regulation in 1995; 2004, Product Directive)
6. Old paper and cardboard (AVV, 1997)

Type of formal responsibilities and rules: governmental organizations

Rijkswaterstaat is the public national executive agency that makes sure the EPR systems operate adequately and is the organization that producers or their representing collectives have to report to (G.O.7). Producers have to report annually on their results (G.O.5; G.O.6). The *Inspection Leefomgeving en Transport (ILT)* has inspection responsibilities for the five EPR systems that have a Product Decree as their legal basis (G.O.5). The ILT can sanction by means of a *last onder dwangsom*: a producer or collective is notified that it did not comply with the performance requirements and that it will be fined for as long as the violation will continue (G.O.5). The ILT is also responsible for enforcing the energy use stipulations of the Ecodesign Directive (G.O.5). If an inspected PRO does not cooperate or is unable to provide the requested data, it can get the predicate “non-controllable”(G.O.5). For systems with only an AVV no primary enforcement task lies with the ILT (G.O.5).

According to the *Wet Milieubeheer,* municipalities have a legal duty of care in waste collection for household waste (Art. 10.21; Art. 10.22). The municipal enforcement agency can sanction waste processing companies (P.O.2).

Overall, the responsibilities for different actors are presented in table 8.

Table 8: *Actors and their responsibilities.*

Organization	**Responsibilities**
Rijkswaterstaat	Public national executive agency
ILT	National inspection
I&W	Policy-making & evaluation
Municipalities	Policy-making; waste management operation, local inspection; care duty
PROs	Execution of EPR responsibilities
Parties that put products on the Dutch market (can be either producers or importers, referred to as producers, unless explicitly mentioned otherwise)	Formally responsible for EPR
Waste collection and/ or processing operators	Responsibilities towards party (often a PRO or municipality) in the contract
Consumer	Separates household waste streams

4.3 Batteries & accumulators

4.3.1 Section introduction

In this section, the findings of the batteries and accumulators case study are presented. Batteries and accumulators are both referred to as batteries in the remainder of this document.

In 2018, about 94 kiloton of batteries were put on the Dutch market (Rijkswaterstaat, n.d.-a). Due to trends in mobility and energy supply, the total amount of batteries present in the Netherlands is increasing (Meulenkamp, van Bree & Geurts, 2019). Different battery types have different applications for which they are predominantly used, see table 9.

Table 9: *Battery types and their application (Meulenkamp, van Bree & Geurts, 2019).*

Application	Battery type
Mobility (e.g. cars, bikes)	lead-acid, lithium-ion
Power (e.g. tools and machines)	lead-acid, lithium ion
Electronics & information technology (e.g. consumer electronics)	alkaline, zinc-air, nickel-metalhydride (older: nickel-cadmium), lithium-ion
Stationary energy storage (e.g. for balancing grids)	redox-flow, (molten) salt, sodium-sulfur, lithium ion

On the EU level, batteries take a dominant position in industrial and waste policies (Meulenkamp, van Bree & Geurts, 2019). The European Commission has initiated several projects to improve the EU's position on the battery market, as batteries are important to economic functions and dependence on other regions can have geopolitical implications (Meulenkamp, van Bree & Geurts, 2019). A Strategic Action Plan aims to: "support the sustainability of the EU battery cell manufacturing industry with the lowest environmental footprint possible" (European Commission, 2018b, p. 2).

In the remainder of this section, the formal institutional setting, incentives and change in practice – practice and evaluation – and market failure evaluation are presented respectively. A schematic overview of these findings can be found in appendix 4.

4.3.2 Formal institutional setting

Legally, the *Besluit beheer batterijen 2008* and *Regeling beheer batterijen en accu's 2008* describe the EPR responsibilities regarding batteries and battery waste management, and the legal pieces are based on Directive 2006/66/EC on Batteries and Accumulators and Waste Batteries and Accumulators (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer [VROM], 2008). The Directives stipulates: 1) targets and objectives for collection and recycling, amongst others, 2) specifies norms and arrangements such as the regulations regarding harmful substances and collection schemes to be nationally implemented, and 3) activities to reach those objectives and targets, such as information-disclosure (Stahl et al., 2018). The *Besluit beheer batterijen 2008* and *regeling beheer batterijen en accu's* stipulate legal responsibility for battery design, manufacturing, collection, processing and recycling (Ministerie van Infrastructuur en Waterstaat [I&W], 2018). *Afvalbeheerplan, sector plan 13 Batterijen en accu's* stipulates what the allowed and preferred activities are for managing battery waste, following from the technical guidelines *Regeling beheer batterijen en accu's 2008*. Transport of battery waste is subject to special ADR safety regulation(I&W, 2018).

In *Besluit beheer batterijen 2008* and *Regeling beheer batterijen en accu's 2008* batteries are categorized as industrial, automotive or portable. Automotive batteries are starting-lighting-ignition (SLI) batteries. For portable batteries, producers are legally obliged to collect 45% of the batteries and achieve a certain level of recycling. A collection rate is only stipulated for portable batteries, not for industrial batteries, nor for automotive batteries. Collection rates in a year are relative to the average of the amount of batteries put on the market for that year and the previous two years. The batteries that are collected have a legal recycling target (also called recycling efficiency): 65% for lead-acid, 75% for nickel-cadmium and 50% for batteries with other chemistries. For portable batteries, a collection point should exist for every 2000 inhabitants of a municipality or at least one in a municipality.

The Battery Directive does not regulate re-using batteries or the preparation phase to make batteries suitable for reuse (Stahl et al., 2018). According to Bax & Company (2019), producer responsibility for a car batteries can be transferred from the original producer to a second producer after the product of the original producer has been used, due to an end-of-waste stipulation.

If a battery is present in an electr(on)ic appliance - which is subject to a different EPR system - the producer is responsible for coordination with compliance organizations of the EEA (I&W, 2018). Batteries that are derived from end-of-life vehicles contribute to the collection and recycling targets of the ELV Directive (P.O.4), but car producers are legally obliged to accept returned traction and SLI batteries due to the Battery Directive. All producers that put a battery on the market have to accept them when a consumer returns it to them. Thus, for all points of sale, batteries returned by the consumer should be accepted.

Lead is banned from most applications because it can be a harmful substance, but lead-acid car batteries are an exception (Stahl et al., 2018). Cadmium is also banned from application, but industrial batteries are exempted (Stahl et al., 2018).

An AVV for portable batteries is present thereby obliging all portable producers to contribute to a collective collection and recycling system that is coordinated by Stibat (I&W, 2018). Stichting Batterijen can fine non-compliant parties (I&W, 2018). Industrial and automotive batteries are not subject to this AVV. For traction batteries, for example, producers are free to do it individually or collectively (P.O.1). Stibat organizes the waste management of portable batteries and industrial batteries with a weight lower than 1 kg by means of an AVV (I&W, 2018). Though the AVV exists, producers still are individually legally responsible for fulfilling the collection and recycling targets.

4.3.3 Incentives & change in practice: practice

Waste management organization

Since the inception of the EPR system for batteries, individual parties joined the collectives and nowadays, all individual producers of portable batteries report their batteries through Stibat (I&W, 2018). No other collectives have existed for portable batteries (ibid). Stibat started out as Stichting Batterijen in the early 1990s, mostly dealing with executing the responsibilities of portable battery producers (P.O.1). Later, the producers of electric bikes also became an important group within Stibat (P.O.1). However, due to different recycling fees and different responsibilities Stichting Batterijen was split into two: Stichting Batterijen (portable batteries) and EPAC (electric bike batteries), that are the commissioning parties for the executive organization Stibat services (which is referred to as Stibat in the subsequent writings) (P.O.1). The dominant task of Stibat is to fulfill the responsibilities of the portable battery producers represented in Stichting Batterijen and electric bike batteries producers represented in EPAC (P.O.1). Besides that, Stibat is to some extent also involved in the waste management of industrial batteries of other parties that put batteries on the market (P.O.1).

Stibat takes care for providing a network of collection points, sorting, and recycling of electric bike batteries, which do not have formal collection and recycling targets (P.O.1). The responsibility for electric bike batteries involve mandatory take-back and recycling (P.O.1). For portable batteries Stibat operates a national collection network and communicates with consumers about battery recycling (P.O.1). Stibat has agreements with municipalities, schools and retails about collection close to end-users (I&W, 2018). 24,000 collection points exist (ibid). Stibat informs the consumer about separate collection and stimulates them to do so, while they also provide information to producers (P.O.1). Also municipalities take a role in informing their inhabitants about the proper disposal method of batteries (G.O.3).

After collection, the batteries are transported by wo transport companies contracted by Stibat to a dismantler (to take batteries out of appliances) and a sorting company that achieves a sorting efficiency of about 99% (I&W, 2018). This company sorts the batteries based on their chemistry (P.O.1). From there, the batteries are transported to recycling parties in surrounding countries, because there are no battery recyclers present in the Netherlands (P.O.1). Recycling facilities are concentrated in a few EU countries (Stahl et al., 2018). The transport of the battery waste in all phases is all managed by Stibat (I&W, 2018). ARN - a PRO for car recycling in the Netherlands - can be contracted for managing the entire waste management process of car batteries, but producers can also organize it themselves, or contract waste processors to do it in their name or keep ownerships while the battery is being used (Bax & Company, 2019). The ARN also has contracts with second-use processors that create stationary energy storage systems from car batteries (P.O.4). Furthermore, In the field of cars, a factory has been created by ARN to increase recycling (P.O.1; P.O.4).

Waste management financing

Producers pay an *afvalbeheersbijdrage* – a waste management fee - to Stibat for the products they put on the market and register in a web application called MyBatbase (I&W, 2018). The fees are then collected in a funds called “stichting beheer batterijen” that is at the disposal of Stibat (I&W, 2018). The fee is based on the chain deficit: the costs required to collect, transport and recycle batteries waste minus sales, and different for different categories (ibid). Also the costs for the own organization are paid from this (ibid). The dues for each producer depend on the net costs for collection and recycling of a specific battery type – not necessarily having a specific legal status in the Battery Directive – that are incurred and anticipated by Stibat, see table 10 (I&W, 2018). For example, lithium batteries are differently priced than the other battery types, while in the Directive lithium batteries are part of the container “other” category. A fee of 0 Euros is charged for lead-acid batteries, as long as the net costs are zero (ibid).

The fund is large enough to ensure continuity of the system when the revenues from the fees are insufficient for a given year, but is not allowed to be larger than 1.5 times the expected costs for collection, sorting, dismantling, processing (including recycling) and transport (ibid).

Table 10: *Waste management fee for industrial and portable batteries (I&W, 2018).*

Battery	Waste management fee lithium in euros (VAT excluded)	Waste management fee non-lithium, non-lead in euros (VAT excluded)
<51 gram, non-button	0.02	0.017
51<151 gram, non-button	0.10	0.09
151<251 gram, non-button	0.20	0.16
251<501 gram, non-button	0.36	0.33
501<701 gram, non-button	0.60	0.45
701<1000 gram, non-button	0.92	0.64
Button cell batteries	0.005	0.002
Portable batteries heavier than 1 kg.	2.37	1.23

In contrast to portable batteries, the *Besluit beheer batterijen 2008* leaves room for asking a fee when an industrial battery is returned, such as a traction battery. A pay-as-you sell system is adopted for collecting the traction battery in electric and hybrid cars by the ARN (P.O.4). In most other countries a pay-as-you collect system is adopted (P.O.4). If the parties are not involved with the ARN they do not have to pay a fee at the moment of sale to the ARN (P.O.4).

In figure 7, a schematic overview for the management of battery waste is given. It includes the formal responsibilities or obligations, while also the organizational and financial relations between the different actors are given, as discussed in the previous sections. The collection-recycling chain for ELV is depicted as one block, because ARN makes use of this network but as it is only to a limited extent influenced by the Batteries Directives, it was beyond the scope of this study to explore in great detail. The MWCF is the municipal waste collection facility, or *Milieustraat* in Dutch.

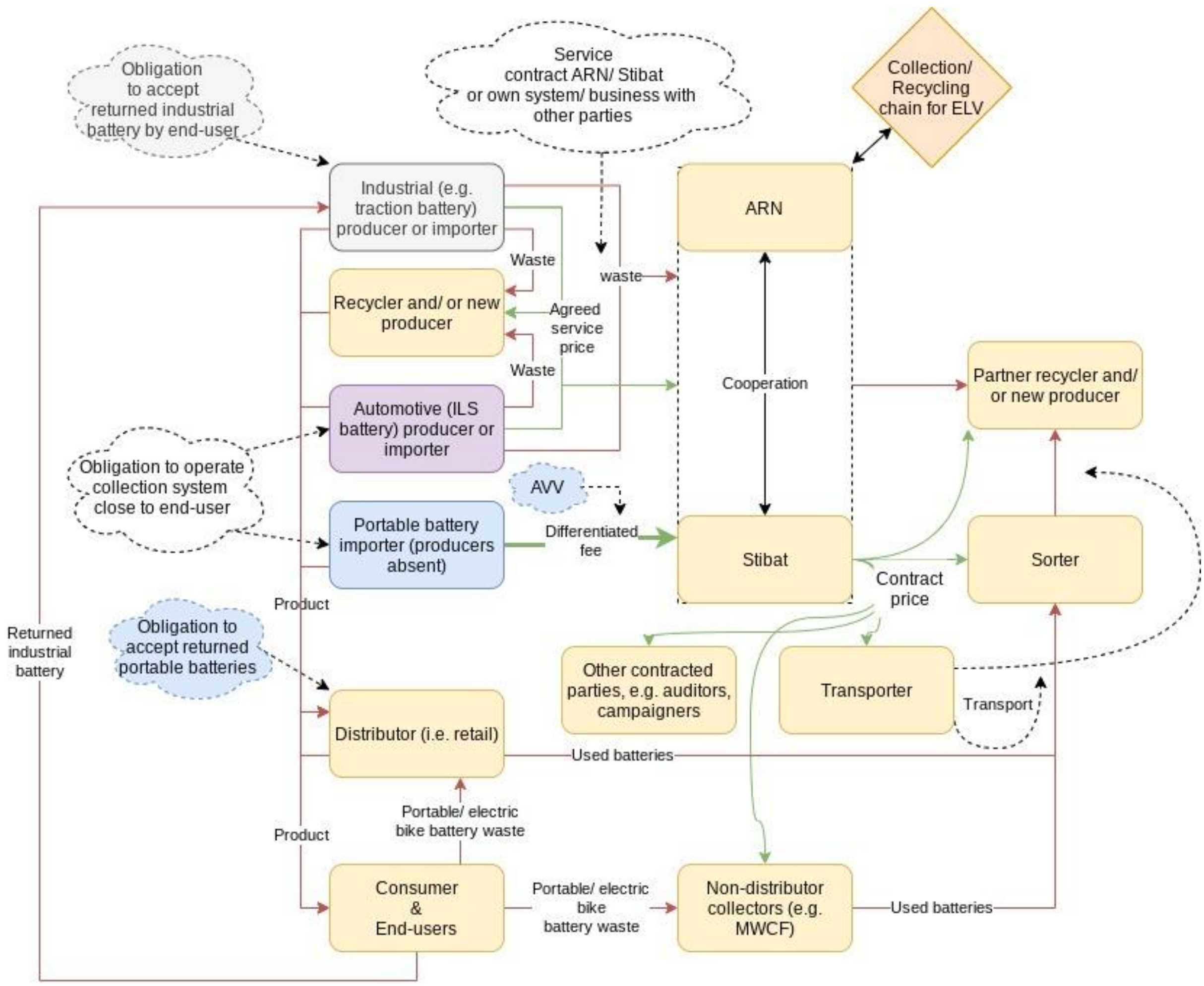

Figure 7: *Schematic overview for battery waste management (author's own).*

Reporting, compliance & enforcement

Stibat provides a collective statement for portable batteries (I&W, 2018). The collective statement can also be done for industrial batteries (ibid). Stibat reports to the government on an annual basis about what their members put on the market as well as what Stibat has taken back (ibid). Producers can report about portable batteries and industrial batteries less than 1 kg via MyBatbase (ibid). Stibat reviews the documents that are presented to them and/ or audits a producer (P.O.1). Companies that have a total annual fee of more than 10,000 euros have to hand over a statement by a certified accountant (ibid). Stibat and ARN work together on the reporting of new batteries by means of the MyBatbase and on collected batteries by means of the MyBatterybalance (P.O.4).

No certification scheme exists for battery recycling (P.O.1). However, an ecotest is employed by Stibat to assess the footprint of recyclers in terms of toxicity, material reuse, recycling (including energy recovery) and carbon emissions (P.O.1). The assessment of a recycler is carried out by an external party with which the ecotest is developed (P.O.1). Based on the assessment results Stibat decides whether it wants to do business with the recycler (P.O.1). The ecotest is carried out annually, and checks for recycling efficiencies and sustainability performances (I&W, 2018). No European certification exists either, but some other parties have adopted the ecotest as well (P.O.1).

If Stibat notices parties that do not pay the amount as stipulated in the AVV, then Stibat reaches out to these parties (P.O.1). When contact efforts by Stibat do not result in the party paying their dues, the ILT is notified and the ILT writes an "ugly" letter, though theoretically, Stibat could take these importers to court right away (P.O.1). With regards to car batteries, ARN is notified by the *Rijksdienst Wegverkeer (RDW)* when an electric vehicle is returned and the battery is subsequently tracked by the ARN (Bax & Company, 2019).

Circular practice beyond waste management

Bax & Company (2019) find that innovative companies and start-ups have recently been set up to recover critical material from disposed rechargeable batteries. On the European level, Lebedeva, Di Persio & Boon-Brett (2016) find producers and recyclers work only to a limited extent together in R&D that could result in new, cost-effective technologies for recycling.

4.3.4 Incentives & change in practice: evaluation

Waste management organization

An interviewee thinks it is good that parties have outsourced the execution of their responsibilities in the field of waste management, because producers are specialized in selling batteries (P.O.1). The PRO takes the work out of the hands of the individual producers so the only thing producers then have to do is to keep track about the number of cars they put on the market (P.O.1). Relatively few responsibilities exist for the waste management of bike batteries, compared to portable batteries for Stibat (P.O.1). An interviewee states that industrial and automotive batteries do not have collection targets, because those kind of batteries can be usefully applied elsewhere, while consumer batteries find their way easier into the waste streams (P.O.1). Increasingly, the delineation between automotive, industrial and portable becomes blurred (P.O.1), which is recognized in by Stahl et al. (2018) to be an EU-wide problem. According to this interviewee, a PRO feels the responsibility to properly act in line with the waste management task (P.O.1).

A collection rate based on put on market (PoM) of previous years is deemed problematic, because most batteries are on the market for more than three years (P.O.1). Furthermore, in a growing market like for batteries, it is hard to reach the targets (P.O.1). According to one interviewee, about a quarter of the batteries is placed on the market in electr(on)ic appliances, making the pool for collection smaller (P.O.1). The batteries within electronic appliances – such as I-phones – are hard or impossible to remove, which means that those batteries are lost in the waste processing of electric equipment and do not count towards the collection target for batteries (P.O.1).

When a battery is easily thrown away, then improper collection and subsequent recycling is more likely (P.O.1). Most industrial batteries cannot be thrown away easily, but electric bike batteries can be considered a grey area, because they are in fact a kind of industrial battery, but they are in the hands of consumers, who can through them away easily if they do not function properly anymore (P.O.1). When the waste stream is more business to business this applies to a lesser extent, such as for the batteries in electric vehicles which are large and heavy (P.O.1). The producer responsibility is well-designed there as the batteries are processed somewhere (P.O.1). Consultations with producer organizations about what is realistic and feasible to do together is called a strength of the battery EPR (P.O.1).

Collection and treatment are associated with safety risks. Fires in waste processing plants due to batteries are increasingly occurring in the Netherlands (Bax & company, 2019). Lithium-ion batteries, for example, can catch fire when they are improperly handled or damaged (ibid). Furthermore, the collection, storage and improper refurbishment of batteries increases the odds for fire (ibid).

For cars, the PRO has built a processing factory due to which higher recycling rates (95> % recovery) has increased (P.O.4). The car industry is now also putting much effort in the preparations for recycling the batteries that are going to be used in mobility and will at one point be disposed of (Bax & Company, 2019).

On the EU-level, producers or PROs that collect and recycle more than the minima stipulated in the EU Battery Directive do not benefit from this economically (Stahl et al., 2018). Incentives to perform better than the minima are absent in the EU Battery Directive (Stahl et al., 2018). However, incentives exist to compete for batteries with more profitable chemistry which can undermine resource efficiency if more than one PRO is present (ibid). In terms of innovation, the EU Directive has no effect on recycling efficiency beyond the stipulated minimum, because innovation to achieve higher recycling efficiency is not stimulated (ibid).

On the EU level, Stahl et al. (2018) find that batteries "leak" from the battery waste management systems due to 1) increasingly occurring unproper or absent removal from electr(on)ic waste, 2) export of EEE, and 3) export of ELV and used vehicles with automotive batteries. Also, the exact same type of material can have the label "recycled" in one EU-country, while it is differently labeled in another (ibid). The latter is also perceived as problematic by an interviewee (P.O.1).

When insufficiently benchmarked on the national level, the risks exist that competing PROs: 1) only operate the most profitable collection locations, and 2) only collect the most profitable type of batteries, thereby undermining the operation of the entire EPR scheme (Stahl et al., 2018).

Waste management financing

The waste management fee is incorporated in product prices – be it visible or non-visible – but for portable batteries this is in the order of cents or halve cents, being considered a minimal contribution (P.O.1). In general, there are negative costs for the waste management of batteries, but these are properly represented in the product price (P.O.1). None of the battery waste management costs are carried by municipalities (G.O.3). According to an interviewee, municipalities have never had high expenses for the waste management of batteries, also before the EPR system was in place (P.O.1).

Batteries face relatively high costs for safe logistics (collections, transport, storage), and often the costs of the waste management are higher than the revenues from selling the secondary material (P.O.1). Lead-acid batteries from cars still have a positive value (P.O.1). However, portable batteries such AA batteries have a negative value, implying that additional money is required to collect and process the batteries (P.O.1). Since 2017, profitable recycling technologies exist for recycling lithium-ion batteries (Stahl et al., 2018). However, in practice, it is more expensive to produce secondary than virgin lithium (P.O.1). Depending on the material, secondary material can compete with the virgin material (P.O.1).

Reporting, compliance and enforcement

Stibat is sometimes notified by members who notice parties that are not a member, but do import batteries (P.O.1). Right now, producers are compliant in general (P.O.1). Free-riding occurs mainly at the front in the value chain in the form of small parties that import batteries, but do who do not pay for the battery recycling system (P.O.1) . Batteries that enter the Dutch via a webshop are an example (P.O.1). If they are disposed of at a supermarket Stibat still has to process them (P.O.1). For ELV, free-riding mainly occurs in the waste management phase (P.O.1). Producers do comply with regulation for material use according to this interviewee (P.O.1). For the collection of portable batteries, collectors are highly dependent on consumers where compliance is a large issue: about 15% of all the batteries still end up in general household waste (P.O.1). All EPR systems have their own place where enforcement is required (P.O.1). To rise up against free-riding, Stibat has successfully applied for an AVV (P.O.1). Often, when in non-compliance, fee-liable parties do simply not know they have to pay a fee (P.O.1). The interviewee considers the use of an AVV to share the costs up-front a strength of the battery EPR (P.O.1).

Illegal parties are especially likely to be involved with waste streams that can have positive values, such as batteries for electric bikes but not portable batteries (P.O.1). Lead-acid batteries from cars still have a positive value, which is why nobody throws it into the environment: the economy takes care of it (P.O.1). Car deconstruction companies that are not part of the ARN network, barely have registered waste streams (P.O.1). Therefore, enforcement should occur on the material in- and outflow (P.O.1).

According to the interviewee, enforcement means are not transferred from the government to the sector, thereby still giving an important role to governments in the field of enforcement and ensuring compliance (P.O.1). The compliant companies also endorse this, because non-compliant parties operate at lower costs, thereby inducing unfair competition (P.O.1). Furthermore, the capacity of governments to deal with non-compliance is perceived to be low (P.O.1). The interviewee states an inspector is only welcome at parties that already to a great extent think they comply, while companies that mess up or do not comply might be hostile and take a longer time to audit (P.O.1). The quantitative inspection targets are considered an issue, because this could cause bias towards inspection of compliant companies which take less time to inspect (P.O.1). When scrap and recycling companies have opportunities to not comply, then money can be made quickly and also environmental damage will occur (P.O.1).

Until 2019, the ILT has had relatively few activities specific to reuse of batteries and more attention was given to collection and recycling of electr(on)ic equipment (G.O.5). In this type of products, batteries can also be present. Almost no unwanted situations exist for reporting on producer's collected and put on market numbers according to an interviewee (P.O.1). However, according to (Stahl et al., 2018) the distinction between portable and industrial can cause over-reporting of collection rates for portable batteries on the EU-level. Furthermore, they find a number of shortcomings are present in reporting now (for the EU): 1) distinguishing industrial and portable batteries, especially lead-acid, 2) an information gap for industrial batteries, 3) new trends, such as internet sales, reuse, lithium-ion, critical materials (ibid). In addition, they state that information is missing about the export of: 1) end of life automotive batteries, 2) electr(on)ic products and waste.

According to Stahl et al. (2018) enforcement of battery removal options from electr(on)ic devices is key to mitigating losing batteries through the electric and electronic appliances waste stream EU-wide. Better enforcement is required to improve the proper removal and removability of batteries (ibid). Enforcement is also deemed crucial for achieving collection and recycling efficiency targets (ibid). Additionally, recycling efficiencies are determined for countries, but the assessment is generic and does not allow for calculating the efficiency of specific recycling activities (ibid).

Regarding quality control, the ecotest is somewhat more ambitious than prescribed by the EPR and environmental legislation (P.O.1). An interviewee states that the ecotest works quite well and the interviewee is doubtful about the added value of European certification (P.O.1). He points out that, when collectives are created, these collectives come with their own norms and guidelines, such as KZW guidelines for how to deconstruct cars by ARN (P.O.1).. However, Stahl et al. (2018) find that stakeholders across Europe endorse recycler certification on the EU-level.

Circular practice beyond waste management

According to an interviewee, the post-use phase is not and cannot be considered by producers (P.O.1). EPR has relatively little influence on innovation and production methods (P.O.1). For example, batteries have to be sorted, but to ease this sorting process alkaline batteries do not get a different shape than lithium batteries (P.O.1). The legislation on which EPR is based or associated with has more influence on the production and innovation than the EPR itself (P.O.1). Companies are sensitive to appeals to their reputation, however, Bax & Company (2019) find that the image consumers have of a brand or product is more determined by safety incidents than origins of the battery.

The following findings cannot be explicitly linked to the EPR system, but take into account the whole value chain plus incentives and change in practice:

1. According to Bax & Company (2019) little incentive exists for battery producers to integrate recyclability in product design. Much research is currently done to design better (more functional) batteries and improve the recycling process of batteries (ibid). It is important to note that recyclability of a product is not the same as improving the recycling process, because former is a product design characteristic, while the latter is a post-use process that can also be improved without considering former.
2. Product innovation regarding modularity has decreased: according to Stahl et al. (2018), on the EU level increasing numbers of batteries are non-removable without destroying a device or are only removable by a professional. Batteries can also severely impact the lifetime of the products it seeks to power: appliances that have irreplaceable batteries lose function when the battery cannot store energy anymore (ibid). Furthermore, appliances are tailored to specific battery types, which makes reuse of batteries or appliances difficult due to compatibility issues (Bax & Company, 2019). This hinders important circular economic principles such as repairability of devices (ibid).
3. According to Bax & Company (2019), the European Commission is succeeding at bringing together the largest European car manufacturers, chemical industries and electronics factories to catch up on the United States and Asian countries, including Japan, China and South-Korea regarding the production of batteries. EPR is an integral part in this strategy (ibid). Furthermore, Bax & Company (2019) find that large factories specialized in one battery chemistry are being built to make use of economies of scale in battery production.

4. According to Meulenkamp, van Bree & Geurts (2019) the number of research groups at knowledge institutes dropped dramatically in the 1990s and 2000s, but increased sharply in recent years.
    a. Responsibilities for battery collection and recycling have been existing since the 1990s, but strong industrial policy (such as mentioned at bullet point three) is much more recent, suggesting that industrial policy is more important than EPR.

Innovation in battery design also leads to new hazardous substances to be incorporated in the batteries (Stahl et al., 2018).

According to Meulenkamp, van Bree & Geurts (2019), car traction batteries are likely to be replaced when the batteries are at 80% of their initial capacity. Stationary power storage can be a good application then, but large scale application of car batteries will not occur in the coming 5-10 years due to primary use in mobility (ibid). With regards to primary use and reuse, end-of-life SLI batteries & accumulators that are used as energy storage as secondary application are at risk of facing competition from energy storage systems produced in China (Bax & Company, 2019).

A material passport, increased traceability, and increased modularity are considered important for improving ecodesign in the future (Bax & Company, 2019).

4.3.5 Market failure evaluation

Scale advantages: performance

Producers in the Netherlands report on their sale and collection volumes of batteries which are made publicly available by Rijkswaterstaat (Rijkswaterstaat, n.d.-a). See figure 8 , figure 9 and figure 10. Several things can be observed from the pictures:

- The lead-acid chemistry, automotive category and total of batteries put on market evolve in tandem. Thus, lead-acid chemistry types are predominantly used in cars and constitute a large fraction of the total amount of batteries in use. In terms of weight, automotive lead-acid batteries also constitute a large fraction of the total collected battery waste.
- Nickel-cadmium batteries sales are negligible, but are still collected resulting in high collection rates.
- The industry and other chemistry types grow and converge, which could be explained by an increasing use of lithium-ion industrial batteries.
- The sales and collection of portable batteries have increased only slightly in absolute amounts, resulting in a stable collection percentage.
- Industrial battery sale and collection have increased, but the collection rate dropped and increased again.
- The apparent drop in collection rate can be explained by the calculation method of PoM, which is based on the same and two previous years.

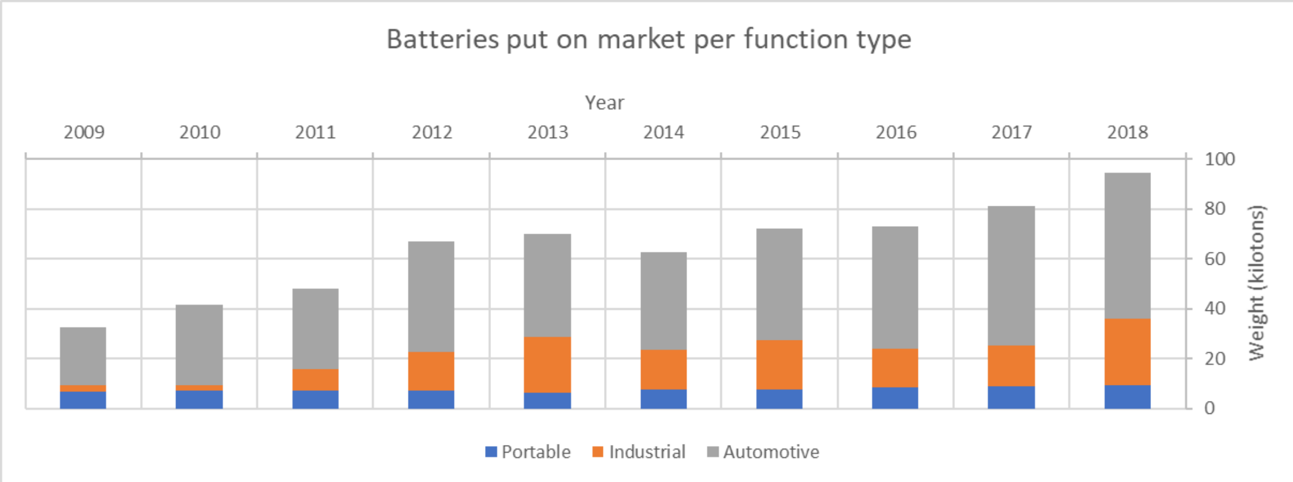

Figure 8: *Batteries that are put on the market, categorized by use (author's own, data from Rijkswaterstaat, n.d.-a)*

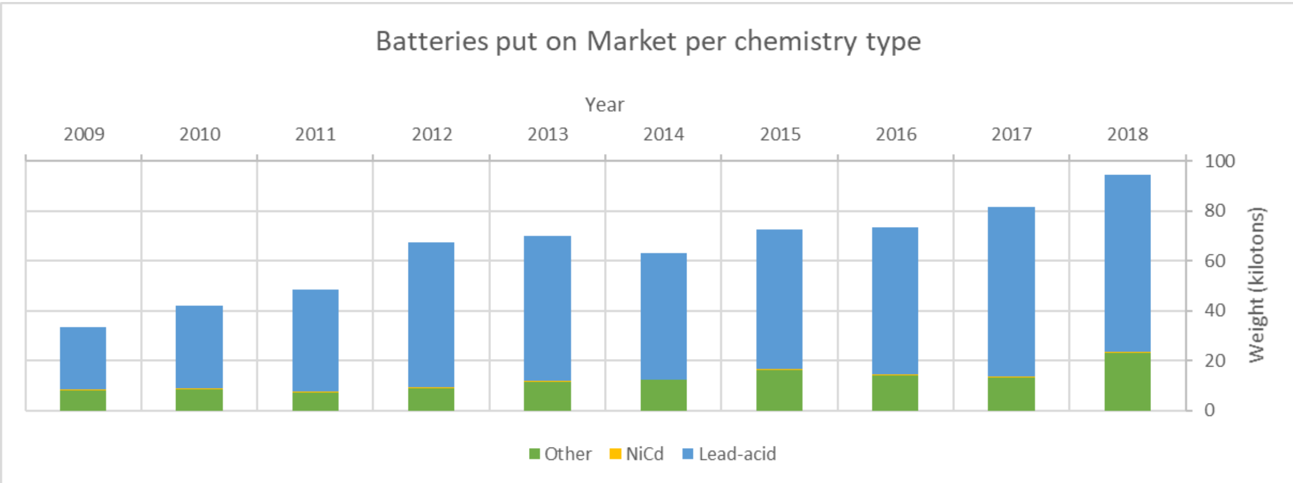

Figure 9: *Batteries that are put on the market, categorized by chemistry (author's own, data from Rijkswaterstaat, n.d.-a)*

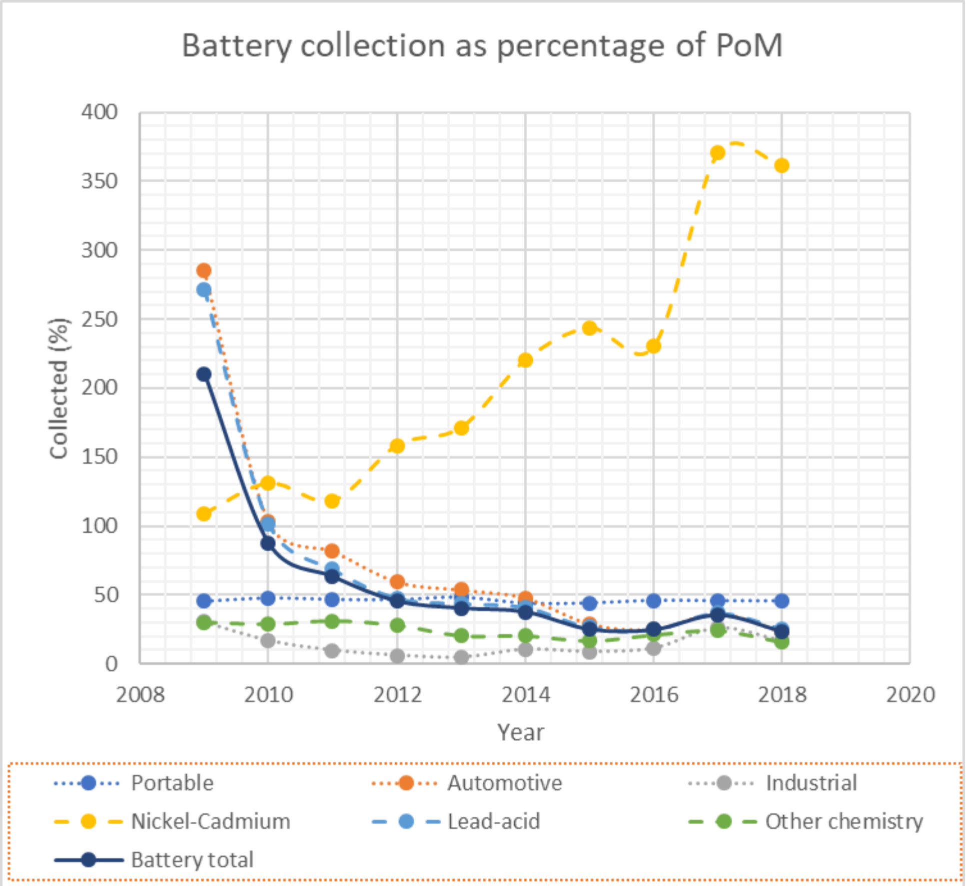

Figure 10: *Battery collection as percentage of put on market (PoM), where the battery total is the sum of all chemistry types or all application types (author's own, data from Rijkswaterstaat, n.d.-a).*

A closer look at the fraction of industrial batteries that are used in electric bikes and electric vehicles can be given. Of the bicycle batteries put on market 45% was collected in 2018 (Bax & Company, 2019). In 2016, ARN tracked 223 lithium-ion traction batteries of which 191 were recycled and 32 were reused (Bax & Company, 2018).

EURAL data, obtained from Rijkswaterstaat (2020a) differentiates between separately collected battery waste from households and other battery waste. In figure 11 and figure 12, the waste treatment (i.e. application) is presented for household battery waste and total battery waste respectively. In figure 13, the difference in percentage points between application of waste from households and non-household sources is presented. Together, the three figures show that a large fraction of the battery waste is recycled. Though not depicted, the EURAL data shows that this mostly due to the recycling of lead-acid fractions, of which 99% is recycled (Rijkswaterstaat, 2020a). Furthermore, in the figures can be observed that battery waste from households is about 20% points less recycled compared to non-household flows, while featuring higher incineration. In 2009, an unexplained amount of non-household battery waste cannot be accounted for or is discharged, illustrated, while in 2015 and 2016 household battery waste is recycled for almost a 100%. Recycling efficiency targets are met in all EU-countries, including the Netherlands (Stahl et al., 2018). In 2016, Stibat was able to achieve a recycling efficiency of 78%, 80% and 77% for lead-acid, nickel-cadmium and other chemistry respectively for a separate collection of 48.6% in total (I&W, 2018).

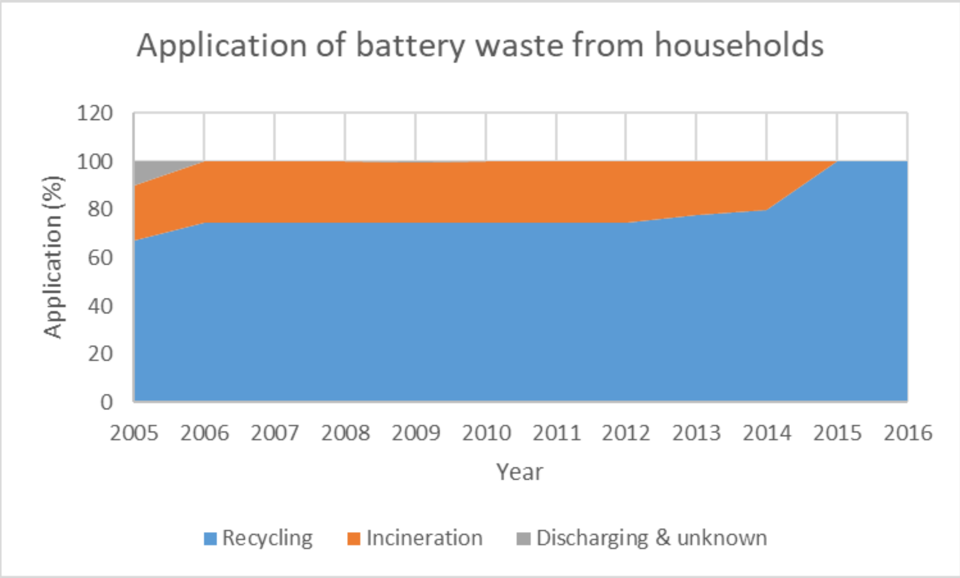

Figure 11: *Application of battery waste from households, (author's own, data from Rijkswaterstaat 2020a).*

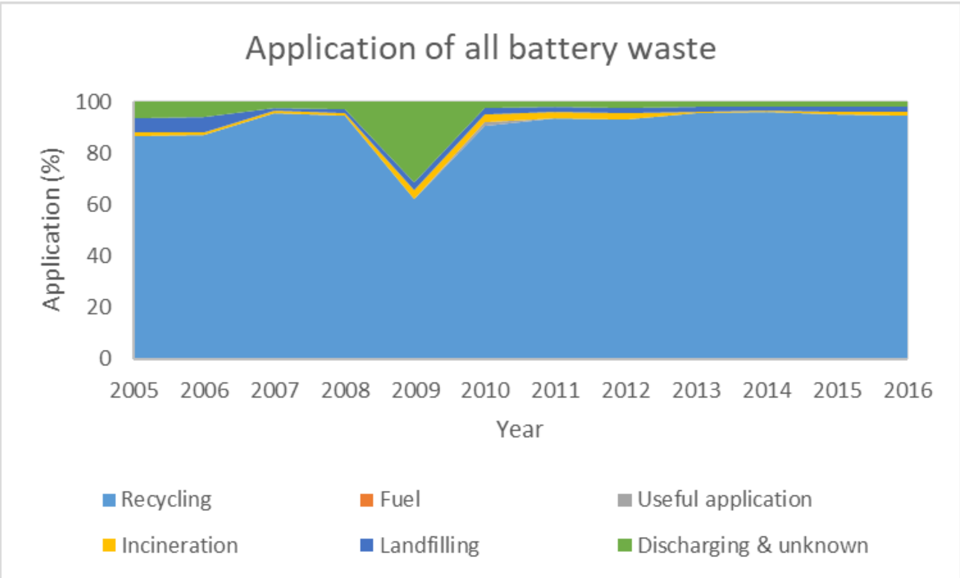

Figure 12: *Application of battery waste from households, (author's own, data from Rijkswaterstaat, 2020a).*

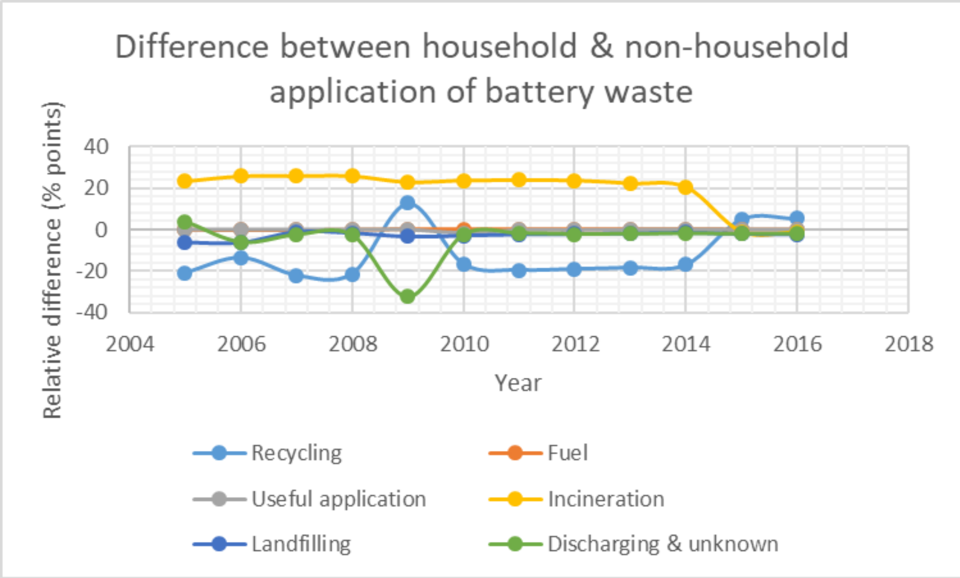

Figure 13: *Application difference of household and non-household battery waste, (author's own, data from Rijkswaterstaat, 2020).*

According to Bax & Company (2019), more than 90% of cobalt, lithium, manganese, copper and aluminium can be recovered and recycled from large batteries, though in practice the percentages are lower. Until 2017, all disposed electric vehicle batteries were processed by crushing and melting, while they are now also reused due to repair, remanufacturing or refurbishing, and sometimes they are used in another purpose by repurposing (ibid). According to an interviewee, when a metal has a positive value, then innovation for recovering that material occurs rapidly (P.O.1).

According to an interviewee, EPR can be used to get to higher levels in the R-hierarchy, especially if it supports the sorting of materials (P.O.1). Recycling legislation should leave options to deal with the non-recyclable fractions that are expected to grow when higher collection rates are achieved (P.O.1). Because, if higher collection targets are achieved, the fraction that is useless also increases (P.O.1). Overall, much room still exists to have more upcycling, instead of downcycling (P.O.1).

in 1986, 50% of the batteries were landfilled, 40 % incinerated and only 10% separately collected (Tweede Kamer der Staten-Generaal, 1989). It can be concluded that the separate collection and recycling has increased significantly since then.

Scale advantages: aggregate costs

No data about costs incurred by Stibat could be obtained, but for two years the costs are available in a study by Stahl et al. (2018). They outline some operational costs for five EU countries in 2016 and 2011, including the Netherlands. See table 11. It can be observed that the cost-burden for the management of portable battery waste differs significantly for the five different countries. Furthermore, while total cost-burden can increase, the fee per ton collected portable battery can decrease. Belgium and Switzerland perform relatively well compared to the Netherlands but face significantly higher costs.

Table 11: *Fees and collection for five countries in Europe (Stahl et al., 2018, p. 174).*

	Year	Austria	Belgium	France	Netherlands	Switzerland
Port. Batteries collected (ton)	2011	1,738	2,406	17,397	3,385	2,375
	2016		3,153	13,677	3,946	2,804
Collection rate (%)	2011	49	52	36	42	72
	2016		70.7	46.4	49.0	67.8
Collected port. batt. per inhabitant (kg/ year)	2011	0.198	0.214	0.260	0.199	0.283
	2016		0.280	0.204	0.232	0.334
Total fee (EUR millions)	2011	1.987	21.810	11.300	5.400	12.050
	2016		17.674	15.586	8.610	14.231
Fee per inhabitant (EUR/ year)	2011	0.23	1.94	0.17	0.32	1.43
	2016		1.57	0.23	0.51	1.69
Fee per ton collected port. batt. (EUR/ year)	2011	1143	9065	650	1595	5074
	2016		6917	826	1368	4297

The data from table 11 was used to explore cost differences over time, within and between countries (see table 12). For each country except Austria, the change in time in collection and costs was calculated in absolute terms and percentages in 2016 with respect to 2011. Furthermore, the presence of a scale advantage was explored, see table 13, where more ton collected would be associated with lower costs per ton.

Table 12: *Difference of 2016 compared to 2011 in collection and cost for portable battery waste, based on Stahl et al. (2018).*

	Difference total collected batteries		**Difference total collected batteries as percentage of PoM**		**Difference total fee per ton**	
	Ton	**%**	**Percentage points**	**%**	**Euro per ton per year**	**%**
Belgium	+ 747	+31.1	+ 18.7	+ 36.0	- 2148	-23.7
France	- 3720	-21.4	+ 10.4	+ 28.9	+ 176	+27.1
Netherlands	+ 561	+16.6	+ 7	+ 16.7	- 227	-14.2
Switzerland	+ 429	+18.1	- 4.2	- 5.8	- 777	-15.3

Table 13: *Comparison of battery collection and costs per year, based on Stahl et al. (2018).*

	- (Difference total collected batteries (%) / difference total fee per year(%))
Belgium	1.31
France	0.79
Netherlands	1.16
Switzerland	1.18

For Belgium, the increase in the amount of batteries collected (31.1%) is associated with a cost decrease per ton of 23.7%, thus, the amount of material change is 1.31 times the cost reduction. For the Netherlands and Switzerland this ratio is 1.16 and 1.18 respectively. In France the trend is opposite, but the interpretation the same: less is collected while the costs per ton increase.

Multiple interpretations can be given to these numbers for this range:

1. The marginal costs decreases for each unit processed, which could be due to:
   - the fixed costs have remained the same, so when more weight is processed in the system, then the costs per weight unit decrease.
   - variable cost increases (which one would assume to occur when low-hanging fruit in terms of collection and recycling) are offset by other relative cost decreases. For example, due to the reason at bullet point 1.
2. The marginal costs decrease over time, which could be due to:
   - Innovation & behavioral change: products and materials are collected and recycled for lower costs.
   - Higher revenues: the recycled material has a better price thereby lowering the net costs.

When the % as percentage of PoM is considered then for each percentage point:

3. increase, the costs per ton decreases with 115 Euros for Belgium,
4. increase, the cost per ton increases with 17 Euros for France,
5. increase, the cost per ton decreases with 32 Euros for the Netherlands,
6. decrease, the cost per ton decrease with 185 Euros for Switzerland.

The Netherlands and Belgium both have cost decreases per percentage point increase. However, when the costs per collection point would increase, then the cost decrease for the Netherlands per percentage point should be higher than Belgium's: Belgium features higher collection rates, implying that the less costly low-hanging fruit would already have been plucked. The cost reduction is greater in Belgium than in the Netherlands. However, the total costs per ton is 5-6 times a high in Belgium as in the Netherlands.

Overall, it seems that in terms of absolute numbers, more collected weight results in lower costs per unit weight and/or that over the years other efficiency gains have been made. For PoM, it is hard to distill a general picture, other than that PoM-cost trends are different in the four countries, suggesting that country specific characteristics and/ or the waste management system characteristics in these countries are important.

One interviewee states that the waste management of batteries has not become cheaper or more efficient due to EPR, because the same steps have to be carried out (P.O.1). If the responsibility was left at the municipality, the batteries would also have to be collected and processed (P.O.1). Regarding costs and targets, the costs are expected to increasingly rise with higher targets (P.O.1). One interviewee states that battery production facilities where battery waste can be used as input can benefit from scale advantages, when the supply of battery waste increases (P.O.4). Company & Bax, (2019) expect scale advantages can be gained when waste streams from small and large batteries are combined. Furthermore, according to an interviewee, EPR is suitable for creating a system for large system to overcome high investment barriers by asking a recycling fee (P.O.1.).

Environmental externalities

The production of virgin materials for batteries is generally bad for the environment: it is energy-intensive, chemical-intensive, waste-intensive and water intensive (Bax & Company, 2019). Stahl et al. (2018) find positive effects of applying R-strategies to waste batteries, though effects differ per battery chemistry. The production of secondary lead, for example, from lead-acid batteries results in about 67% less GHG emissions than primary lead production (ibid). Also, the production of secondary lead scores 18 times better in terms human toxicity potential than primary lead (ibid). On the other hand, after evaluating EPR schemes in the EU, USA and Canada, Turner and Nugent (2016) conclude that single-use batteries waste management practices are likely to yield no net environmental benefits. The environmental damage in the production and waste management phase of batteries is expected to be low by an interviewee, due to the presence of strict rules and especially when the waste processing is done by parties that have a license (P.O.1).

The same interviewee states that footprints and environmental goals are also important to consider, not only recycling percentages (P.O.1). EPR has contributed greatly to an improved environment, because batteries are diverted from the general waste (P.O.1). EU-wide, Stahl et al. (2018) find that improper disposal still occurs, considering that high amounts of battery waste still end up in municipal waste, a concern shared by the interviewee (P.O.1). When batteries are not removed from electr(on)ic waste, and are simply shredded also environmental risks can arise (Stahl et al., 2018).

Recovering metals from the batteries is energy-intensive and also requires some chemicals. Nickel, cobalt and copper can be recovered by pyrometallurgy (energy-intensive), while aluminium and lithium are recovered by hydrometallurgy (chemical intensive) (Stahl et al., 2018). Furthermore, when batteries for electric vehicles remain the same, the effects on the environment can increase dramatically, because for one ton of rare earth material, 75 tons of acidic waste are generated (Bax & Company, 2019).

Information issues

The stakeholders that Stahl et al. (2018) interviewed in an EU-wide study, pointed out that the labelling system for conveying chemistry information is insufficient. Also an interviewee states there are information issues exist in the waste management process (P.O.1). According to P.O.1 and Stahl et al. (2018), labelling can increase recycling efficiency, but also reduce safety-related risk that can also damage the waste management infrastructure. Also Bax & Company (2019) state that better chemistry reporting can improve safe handling during storage, sorting and recycling (Bax & Company, 2019).

EU-wide, insufficient information is provided to consumers regarding waste disposal and performance of batteries (Stahl et al., 2018). Capacity labeling is not required for new industrial batteries, such as for E-bikes (ibid). Information to consumers about battery capacity, battery removability and collection is generally considered to be a shortcoming (ibid).

On the EU-level, it appears that EPR schemes with only one PRO achieve higher results in raising awareness and establishing collection locations than schemes with multiple, competing PROs (Stahl et al., 2018). When insufficiently benchmarked on the national level, the risks exist that competing PROs cut spending on campaigns (ibid). According to an interviewee, the information provisioning to consumers was minimal before the EPR and due to EPR more information is provided to consumers. (P.O.1). The pressure of the collection rates helped herein (P.O.1).

Regarding secondary material market development on the EU-level, the establishment of a fair playing field between recyclers EU-wide is hindered by the absence of 1) recycling certification and monitoring, 2) lack of access to information about recyclers elsewhere in Europe and the world, and 3) non-harmonized slag accounting for recycling (Stahl et al., 2018).

4.4 Non-packaging paper and cardboard

4.4.1 Section introduction

In this section, the findings of the non-packaging paper and cardboard study are presented. Paper and cardboard waste – or old paper and cardboard – is referred to as OPC.

In the Netherlands, 1200 kiloton non-packaging cardboard and paper was put on the market in 2018 (Rijkswaterstaat, n.d.-a). The paper and cardboard industry is a dynamic, internationally oriented sector (Ministerie van Infrastructuur en Waterstaat [I&W], 2019). Globally, the demand paper is expected to be 2.4 times in 2050 as large as in 2008 (Allwood & Cullen, 2012).

In the remainder of this section, the formal institutional setting, incentives and change in practice – practice and evaluation – and market failure evaluation are presented respectively. A schematic overview of these findings can be found in appendix 5.

4.4.2 Formal institutional setting

Already in 1989, recycling of paper was on the policy agenda Tweede Kamer der Staten-Generaal, 1989). Potential measures that were considered were: to increase separate collection at companies, to increase the reusability of paper due to a lower amount of composites, change the acceptance policy of processors, and stimulate the use of secondary paper in the industry (ibid). Agreements on collection and recycling practices as well as costs were formalized by means of an AVV in 1997, 2002, 2006, 2010, 2015 (I&W, 2019). The AVVs are only valid for a maximum number of five years. The current AVV is valid until the end of 2022 (I&W, 2019).

The AVV makes all parties (*eerste* ontvangers: 'first receivers') that put non-packaging paper and cardboard products on the Dutch market liable to a *recyclingsbeheerbijdrage* (a recycling fee, the PRN-equivalent of an *afvalbeheersbijdrage*) (I&W, 2019). The fee is the financial basis for PRN to fulfill the financial, organizational and informational responsibilities that its members have assumed nationally in the sixth *Papiervezelconvenant* (I&W, 2019)*,* This is an agreement between PRN and an umbrella organization- *Vereniging Nederlandse van Gemeenten* (VNG) - in which the Dutch municipalities organized (I&W, 2019). However, municipalities are still legally responsible for collecting and processing non-packaging OPC at households (I&W, 2019).

Legal minimum requirements for how the OPC waste stream should be handled in sector plan 4 of the National Waste Management Plan (LAP3) (Rijkswaterstaat, n.d.-c). A product is considered to be a paper-cardboard product, when the paper-cardboard fraction is the largest material fraction in that product (I&W, 2019).

Overall, the two agreements aim to: 1) maximize collection and reuse/ recycling, 2) realize the reuse of material, independent of market conditions, 3) collect at least 75% of OPC and reuse it, and 4) guarantee that PRN will reuse all OPC that meets the quality standards and is separately collected (I&W, 2019). The PRN waste management system targets households and the office, retail, service and industry(*KWDI)*-sector explicitly (ibid).

4.4.3 Incentives & change in practice: practice

Waste management organization

The AVV formalizes an agreement on the recycling fee between the following the organizations present in the paper industry: *De Raad Nederlandse Detailhandel* (retail)*, De Stichting van Leveranciers van Hygiënische papierprodukten* (suppliers of hygiene paper products)*, Mediafederatie* (media companies and publishing houses), *Koninklijk Verbond van Grafische Ondernemingen* (graphic paper enterprises), *Koninklijk Verbond van Papier Groothandelaren* (paper wholesalers)*, Stichting Verwijderingsfonds* (a fund used in the waste management system) and the organization applying for the AVV: *Papier Recycling Nederland* (PRN) (I&W, 2019). 2200 first receivers were identified in 2018 (I&W, 2019). 694 of those were represented by the organizations that agreed on the recycling fee, together representing 69% of the total market share. Hereby, the PRN - who applied for the AVV - fulfilled the requirement to represent the significant majority required to apply for an AVV (ibid).

Municipalities can voluntarily choose to become a PRN member or to organize the waste management of OPC entirely by itself (I&W, 2019). Whether a PRN-member or not, municipalities have to separately collect non-packaging OPC (P.O.5). The municipalities use clubs to do this - for which they get compensation from the municipality - or they hire a professional party to do this (ibid). Municipalities operate sidewalk-pickup and central collection systems (ibid).

After collection, the municipalities offer the separately collected OPC to an OPC company (I&W, 2019). An OPC company can voluntarily choose to become a member of the PRN (ibid). A PRN-municipality is obliged to offer the separate OPC to a PRN-OPC company, which the PRN-OPC company is obliged to accept (ibid). An OPC company is allowed to sell or process the waste in a way it sees fit. Generally, the OPC-company weighs, cleans and sorts the OPC into fractions of different quality, suitable for the production of secondary paper and cardboard (ibid). These fractions are then sold to domestic or foreign paper and cardboard producers (ibid).

The paper and cardboard industry parties that are a member of the PRN network guarantee that they will take all the paper - from households and the KWDI sector - from the PRN-OPC companies (I&W, 2019). The paper producers at the *VNP* are obliged to collect paper in times of excess supply (P.O.5). In case of OPC surpluses, *Overschotmanagement Oudpapier en -Karton B.V.* makes sure that excess OPC is collected, processed and removed. Hereby, no historic supplies are created (ibid). The amount of collected OPC that cannot be processed is stored, to make sure it will be processed later. Hereby, the collected OPC still finds its way in new paper products.

The KWDI-sector is responsible for presenting separated OPC to OPC companies itself, and does this under terms stipulated in contracts between individual OPC companies and KWDI-organizations (I&W, 2019). The household and KDWI streams have to be kept separated (ibid).

Regarding information provisioning, the VNG informs municipalities about best practices, and educational material and collection methods for stimulating collection of OPW and to achieve 75% reuse/ recycling (PRN & VNG, 2018). The PRN informs companies about separate collection of OPC. Furthermore, if needed and in coordination with other parties, parties do educational campaigns to achieve the targets (PRN & VNG, 2018).

Waste management financing

Stichting Verwijderingsfonds (SVF) is the financial body of the PRN system, to which producers pay a recycling fee (I&W,2019). No fixed fee for producers exist - which is unique for the Netherlands - and fees are only charged for the quarters in which a deficit exists (P.O.5). The recycling fee covers chain deficits, transport deficits and system costs (I&W, 2019). A chain deficit arises when the market price for secondary paper drops below the costs to collect, process and recycle OPC (ibid). A transport deficit arises when a municipality has no PRN-OPC company within its municipal borders and the costs for transport cannot be covered without dropping below the 25 euro/ ton guarantee (ibid). System costs are costs that PRN and SVF make for their own organizations, as well as costs with respect to relevant research (ibid). A municipality cannot be become a PRN when a chain deficit and/ or transport deficit is occurring (PRN & VNG, 2018).

All deficits as well as the recycling fees are calculated with pre-established formulas as agreed upon by the parties that are represented in the formalized AVV (I&W, 2019). Export restitution is possible for fractions that have been paid for, but later exported (ibid). The entire system is financed by de SVF to which the recycling fees flow and in which a majority of fee-liable and a minority of compensation receivable parties are represented (ibid). Fees are charged quarterly (ibid). A minimum amount is always present in the SVF to act as buffer and account for temporal fluctuations in balance (ibid). When the AVV ends, potential fund surpluses are used to operate the PRN waste management system (ibid).

The paper industry, that makes use of the secondary paper fibres, pays a fee to the old-paper companies that in turn pay the municipality for the paper they collect (P.O.5). For OPC collection contract prices are used (P.O.5). Municipalities put the paper they collected on the market (P.O.5). However, a PRN-municipality receives at least 25 euros per ton (also referred to as the "2.5 cents guarantee") non-packaging OPC that fulfills a minimum quality standard (P.O.5). For the packaging fraction of collected OPC, a compensation from *Afvalfonds Verpakkingen* is received, the PRO for the packaging EPR system (P.O.5).

In figure 14, a schematic overview for the waste management of non-packaging paper and cardboard in the PRN system is presented. Only the prices relevant to waste management are included. The bold or thick lines are agreed upon in the AVV and *Papiervezelconvenant.* The other lines, parties are free to decide on themselves.

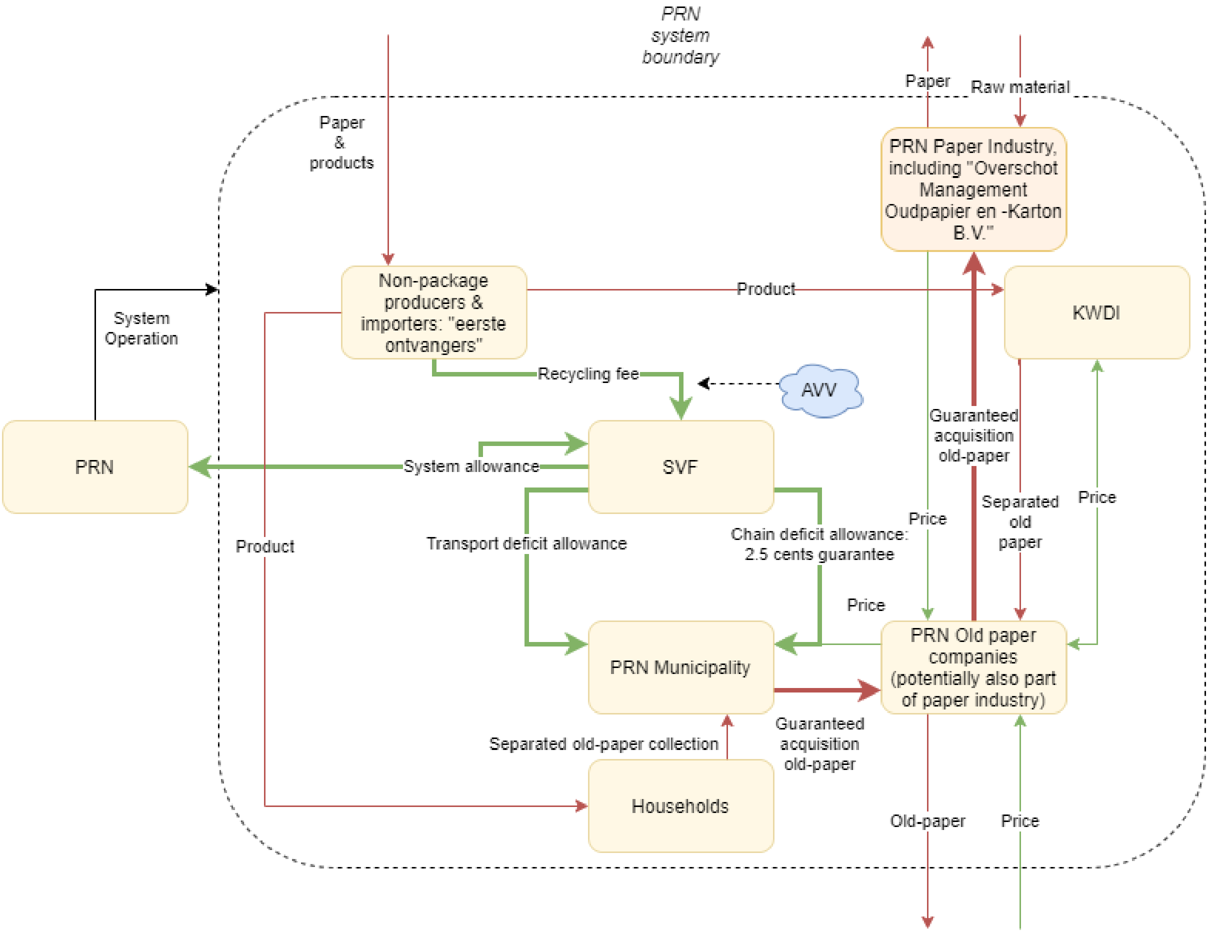

Figure 14: *Schematic overview for non-packaging paper and cardboard waste management (author's own).*

Reporting, compliance & enforcement

Eerste ontvangers have to report quarterly to PRN, that reports annually to the Ministry of Infrastructure and Water Management (I&W, 2019). PRN is allowed to verify the information send to them by the first receivers and can, for example, ask for an accountant's statement (ibid). Furthermore, those that are liable to the recycling fee, can be fined by the PRN as stipulated in the formalized agreement in case of non-compliance (ibid). PRN reports on: 1) put on market, 2) collected, non-packaging OPC, 3) processed/ recycled material, 4) method of collection, 5) overview of incomes and costs regarding the recycling fee, 6) funds development, 7) overview of organizations that are party to the agreement and those who are no longer party (ibid). If the collection and recycling targets cannot realistically be achieved, which is mutually recognized by the parties in the *Papiervezelconvenant*, then these targets can be dropped (PRN & VNG, 2018). The PRN puts effort in identifying first receivers to avoid free-riding (PRN, n.d.)

Municipalities and OPC-companies that are part of the PRN system report monthly to PRN, which are checked by PRN (PRN, n.d.). The information of municipalities and OPC companies are compared by PRN to check the quality of the data by identifying differences (ibid).

A certification system has been set up for OPC-companies (PRN, n.d.). An OPC-company can only become a PRN member, after it has received this certificate called *Erkenningsregeling OudPapier en -*

Karton (ibid). A third party called 'Kiwa Nederland' audits and monitors whether OPC companies comply with quality and operational criteria in the certification scheme (ibid). Important consideration that are mentioned are: administration and the weighting device to secure proper monitoring (ibid).

Quality of separately collected OPC is benchmarked. When quality the OPC is insufficient (above 3% contamination), weight losses can occur for which a compensation is received (P.O.5).

With regards to dispute settlement, parties to the *Papiervezelconvenant* can settle potential disputes by means of a dispute settlement commission (PRN & VNG, 2018). In this commission, three arbiters decide on the issue (ibid). One of them is appointed by the VNG, one by the PRN and one by both of them (ibid).

Circular practice beyond waste management

No forms of organization were found to increase circular practice. However, PRN deems the consideration of recycling in the design phase – design for recycling – crucial for circularly linking product value chains (PRN, n.d.).

4.4.4 Incentives & change in practice: evaluation

Waste management organization

The PRN-system was created inside the *Papiervezelconvenant* after Germany had implemented an upfront fee-system causing high amounts of OPC to be present at the old paper companies (P.O.5). Due to this, there was an excess of old paper and this became unusable (P.O.5). It was found that just collecting was not enough, also demand had to be created for the secondary paper (P.O.5). Because the paper industry makes use of fibres from the paper waste stream, these producers and old-paper companies are engaged in this system through the PRN (P.O.5). According to another interviewee, the AVVs for non-packaging OPC enables the producers to get access to resources, rather than creating resources like the other five with imposed EPR (P.O.2). Overall, OPC is an important resource for paper and cardboard producers (P.O.5). Therefore OPC companies and producers both have an interest in collecting as much paper at the highest quality possible (P.O.5).

Traditionally, a strong collection structure with many civil society clubs collecting paper exists, but collection by civil society clubs is becoming less important (P.O.5). The municipalities have had a large effect on OPC recycling, due to the *Papiervezelconvenant*, and investments in the collection infrastructure, such as by the paper collection bins (P.O.5). Furthermore, municipalities have started to cooperate much more, resulting in efficiency gains (P.O.5). Collection remains difficult in municipalities with many high buildings (P.O.5). Overall, 349 municipalities – 92% of all municipalities – were a member of the PRN in 2018 (VNG, 2018).

Over the past 15 years, manual sorting has been replaced by mechanical sorting (P.O.5). Most of the sorting is done at the source, after which the collected material undergoes further sorting, also to filter out the packaging fraction (P.O.5). After mechanical sorting, a final manual sorting is done to meet the industrial norm (P.O.5). Filtering into different qualities of paper occurred 15-20 years ago at the OPC-companies, but now most of the contamination is being filtered out at the paper producers (P.O.5). Now, infrared innovations are likely to enable better paper sorting (P.O.5). Overall, 63 types of OPC are distinguished in European legislation (P.O.5), while an actor in the sector differentiates over 200 types of OPC (Jonkers, 2012).

Some products are not suited for recycling, including toilet paper (P.O.5). Especially the plastic packaging around magazines is problematic for recycling (P.O.5). Fibers that cannot be used anymore, as they become shorter over time, are burned for energy recovery (P.O.5). Paper products with a plastic coating cannot be recycled, but drinking packaging can be and should be kept apart from non-packaging OPC (P.O.5). Informing the consumer about the value of waste streams is deemed important by an interviewee (P.O.5).

An excess supply of old paper and cardboard exists in the EU, of about 11 megaton (P.O.5). Though processing capacity has increased over the years, much of the surplus was exported to Asian countries (P.O.5). Due to source separation – in households/ companies rather than after collection of waste – the Netherlands faces less negative consequences arising from the import ban in China than other countries (P.O.5).

Other policies, furthermore, have an effect, such as the *Afvalstoffenbelasting* (P.O.5), which is a tax on waste that is incinerated or landfilled. This makes sorting more expensive and can cause an incentive to contaminate more of the OPC waste stream (P.O.5). An incentive to have less residual household waste, can result in contamination of other waste streams according to this interviewee (P.O.5). Coordination is required for streams that are similar to the consumer and get mixed, such as non-packaging OPC and packaging OPC for which PRN and *Afvalfonds Verpakkingen* take responsibility respectively (G.O.3).

According to one interviewee, the PRN system offers stability, continuity and clarity to the involved parties (P.O.5). The system works as an insurance (P.O.5). When a chain deficit occurred in 2009, the OPC continued to be collected and municipalities did not get stuck with a whole lot of paper (P.O.5). The agreements underlying the current PRN system are similar to previous agreements (I&W, 2019).

Waste management financing

Generally, the use of primary material is much more expensive than secondary materials in paper production (P.O.5). Though often positively priced, OPC has high price volatility, caused by demand-supply dynamics on the global paper market (NDP Nieuwsmedia, 2011). Quality of the collected paper has an influence on the market price (P.O.5). When the quality becomes lower, the municipally collected paper is for lower prices by market parties (P.O.5). Contract freedom of OPC-companies and municipalities is considered an important PRN characteristics (P.O.5).

Normally, due to the positive market price of secondary paper, municipalities are able to pay collectors, such as schools (P.O.2; G.O.3). Sorting of waste streams after collection by municipalities can be lucrative, such as plastic packaging removal and presenting it to *Afvalfonds Verpakkingen* (P.O.5). Overall, all costs are covered by the market (P.O.5).

Reporting, compliance and enforcement

Mostly, the financial free-riding that occurs is due to new, small enterprises that do not register with the PRN and thus do not comply with the AVV (PRN, n.d.). Furthermore, companies that include manuals with their product regularly do not register with the PRN as they do not realize that is required (ibid). In 2016 and 2017, 75 and 141 free-riders were identified and subsequently registered with the PRN system (ibid). Between 2012-2017, on average 17 (1-2% of total PoM) kiloton of new paper and cardboard (products) is put on market by non-PRN first receivers (ibid). The PRN recognizes that 100% compliance of all first receivers is not possible and to correct for this, they add twice the average weight put on the market by free-riders in the past five years to the total PoM by compliant first receivers (ibid).

PRN also checks the level of free-riding through internet sales (PRN, n.d.). In a study, the number of online-sale-packages for 3300 households were monitored, while for 2 months a fraction of the households weighted the product packaging, product itself (when it was a paper product) and transport packaging (ibid). The conclusion was that almost 4 kilotons non-packaging were put on the Dutch market, falling outside the scope of the PRN system (ibid).

Regarding collection and quality, the average degree of contamination in OPC seems to be increasing, due to tariff differentiation systems imposed by the municipality to reduce residual household waste (P.O.5). In retail, organic contamination is a problem (P.O.5). In distribution this is less the case (P.O.5).

Circular practice beyond waste management

There are almost no incentives to improve design for recycling, nor can the PRN or *Stichting Afvalfonds* do such a thing according to an interviewee (P.O.5). Switching from resource input is considerd hard, because a specific recipe is required for a certain paper or cardboard product (P.O.5). Some products can only be made from primary fibers for sanitation and quality requirements (P.O.5). The collected Dutch mix is not completely in line with the mix required for Dutch paper industry, thereby requiring paper from international markets (P.O.5). According to the VNP (n.d.), 77% of the input for Dutch paper mills was derived from OPC in 2017.

4.4.5 Market failure evaluation

Scale advantages: performance

Figure 15 shows the PoM weight of the paper and cardboard products within the scope of the PRN system between 1998 and 2019 (PRN, 2020). Before 2006, paper packaging products were also reported as part of the PRN system, but after 2005 these products are reported by *Afvalfonds Verpakkingen* (PRN, 2020). This explains the sudden drop in PoM between 2005 and 2006. The market volume of non-packaging paper and cardboard products dropped from about 1900 kilotons to about 1200 kilotons between 2006 and 2018. Now, most OPC comes from companies (P.O.5). Over the years, the share of packaging in the OPC waste stream has increased (P.O.5), but about 72% of all paper waste from households are non-packaging OPC products (VNG, 2018).

Figure 15: *Product weight put on the market in the PRN system (author's own, data from PRN, 2020).*

The PRN also reports on their collection and recycling rates relative to the PoM, showing that these two are similar most of the time, see figure 16 (Rijkswaterstaat, n.d.-a). Only in 2016, it appears that more is recycled than recycled, but the recycling percentage is calculated as the fraction of collected over PoM (PRN, n.d.) Thus, this is likely a mistake in reporting. The recycling rates are considered close to the maximum optimum (P.O.5; Jonkers, 2012). The recycling target is 75% of PoM (I&W, 2019).

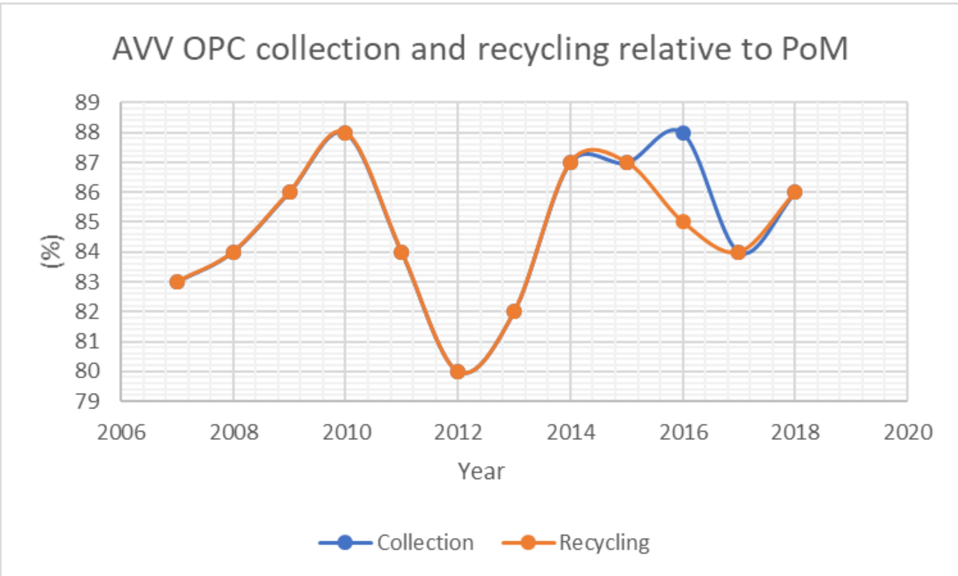

Figure 16: *Collection and recycling of non-packaging OPC (author's own, data from Rijkswaterstaat n.d.-a).*

Figure 17 shows the application of all separately collected non-packaging OPC, based on EURAL data (Rijkswaterstaat, 2020a). This is non-packaging OPC from households and companies. The EURAL code system does not differentiate between the two sources. Almost all separately collected non-packaging OPC is recycled.

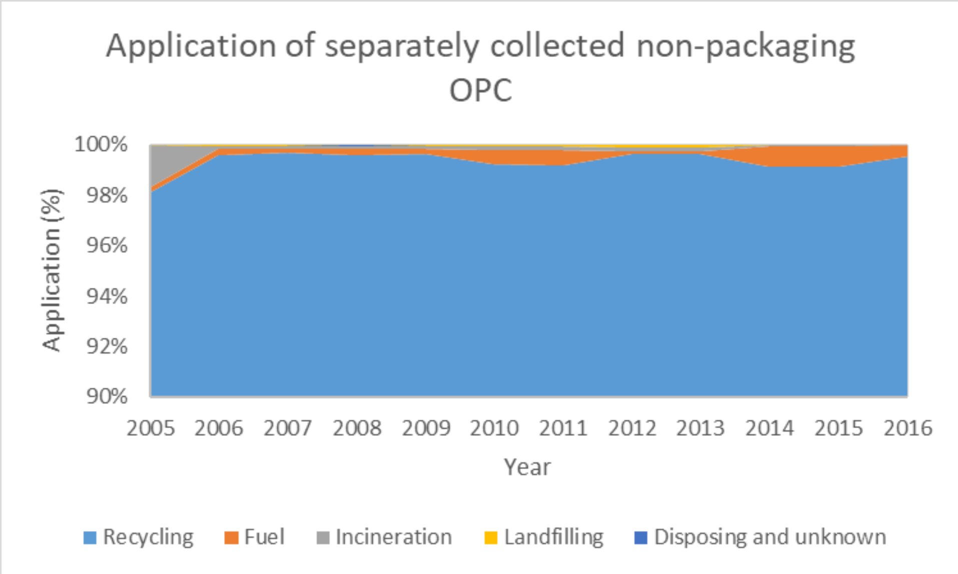

Figure 17: *Application of separately collected non-packaging OPC (author's own, data from Rijkswaterstaat, 2020a).*

In 1986, 1200 kilotons of paper were reused (including recycling), while 400 kilotons were incinerated and 600 kilotons landfilled (Tweede Kamer der Staten-Generaal, 1989). It is not clear what fraction of this was packaging and non-packaging. The reuse (including recycling) rate was 55% and considered very high (ibid). Thus, considering the performance in the recent years, the recycling of non-packaging cardboard and paper waste has increased significantly.

Scale advantages: aggregate costs

Figure 18 shows the total costs required from first receivers to let the PRN system function. In 2003 – when packaging was still part of the PRN system – and in 2009 two relatively high peaks can be observed in total costs. The peak for 2009 reflects the only chain-deficit that has occurred in the PRN-system since it covers non-packaging OPC (P.O.5).

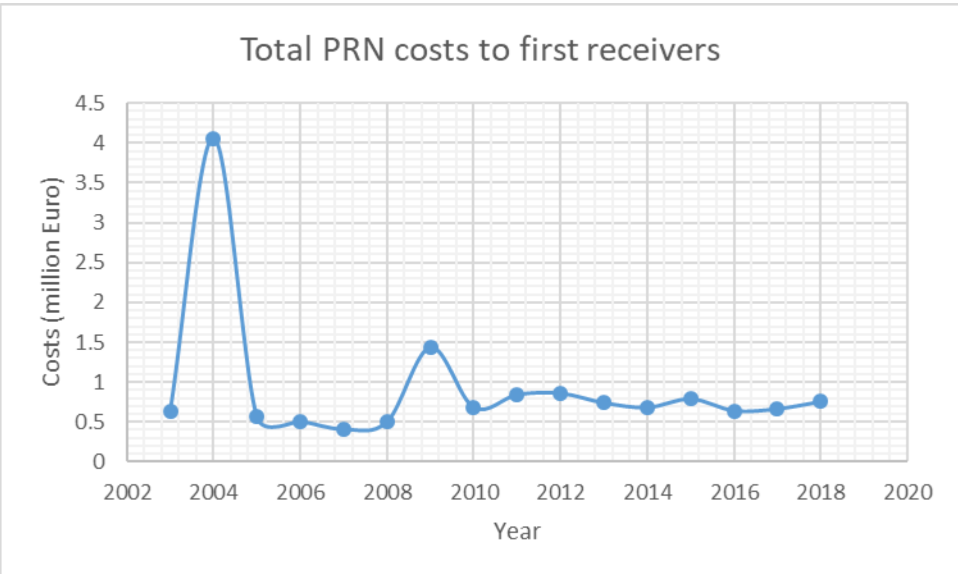

Figure 18: *Total costs of the PRN system to first receivers (author's own, data from PRN, 2020).*

Figure 19 shows the costs that first receivers had per ton PoM or per ton collected follow similar trends, though the costs per collected ton are slightly higher. In 2012 and 2013 relatively low collection rates were obtained, which can explain this gap. In recent years, the costs per ton seem to be increasing, while the total costs are more stable.

Besides good pricing of secondary paper, another reason that the PRN-system works cheaply is, because there are no permanent payments to municipalities (P.O.5). Now, the dropping secondary paper price is an issue to PRN (P.O.2). When compared to other countries, the costs to operate the system are relatively low, according to an interviewee (P.O.5). On average, the costs per ton PoM are about twice as high as in France (I&W, 2019).

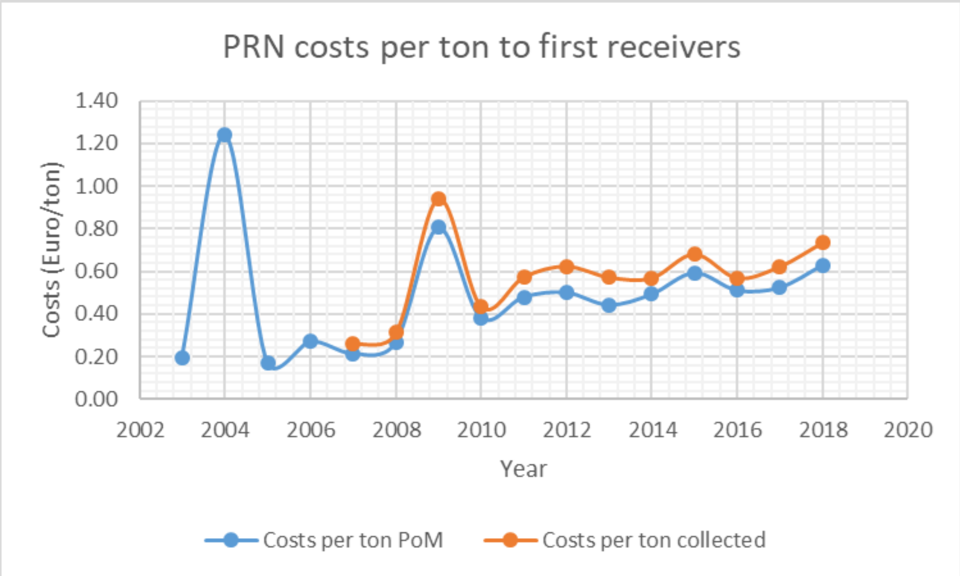

Figure 19: *Costs per ton to parties that put non-packaging and/ or packaging (before 2006) products on the market (author's own, data from Rijkswaterstaat, 2020a; PRN, 2020).*

Environmental externalities

Life cycle analysis (LCA) data is available for paper that is produced and sold in the Netherlands. A LCA for a magazine in the Netherlands shows that the environmental stress caused by primary paper reduction is about twice that of recycled paper (Jonkers, 2012). Recycled paper is slightly more energy intensive, but the positive effects on land use and forestry outweigh this negative effect (ibid). When only the carbon footprint is considered, the researcher find that secondary paper is 20% more carbon intensive (ibid). Also according to Sevenster & Bijleveld (2010) - evaluating all paper and cardboard in the Netherlands - OPC is preferred over virgin material from an environmental perspective. The incineration of drink container packaging is 60% more harmful to the environment than full recycling, also mostly due to land use effects (ibid).

Information issues

For product information disclosure, no particular issues or added benefit of the AVV for non-packaging OPC were found. Regarding investments, the PRN system was mentioned to remove uncertainty by providing stability in the OPC market, thereby being beneficial to the investment environment (P.O.5).

4.5 Medicines

4.5.1 Section introduction

In this section, the findings of the medicines case study are presented. The terms 'medicine' and 'pharmaceutical' are used interchangeably.

The total weight of the medicines used in the Netherlands is about 3.5 million kilograms according to *Ketenaanpak medicijnresten uit wate*r, a policy note describing a chain approach for reducing pharmaceutical residues in water (Ministerie van Infrastructuur en Waterstaat [I&W] & Ministerie van Volksgezondheid, Welzijn en Sport Health, Welfare and Sport [VWS], 2019). The term *'Ketenaanpak'* refers to this document. The consumption of medicines is expected to increase due to an aging population (I&W & VWS, 2019).

In the remainder of this section, the formal institutional setting, incentives and change in practice – practice and evaluation – and market failure evaluation are presented respectively. In the final part of the market evaluation, also EPR-specific comments by interviewees are considered. A schematic overview of the medicine case study findings can be found in appendix 6.

4.5.2 Formal institutional setting

No legal extended producer responsibility is imposed by the government, nor does a system exist for which an AVV has been requested. In 2000, no national waste collection policies were in place to coordinate take-back of unused medicines by pharmacists, but it was already mentioned as good alternative to the MWCF (IPA, 2000). Legally, municipalities are responsible for the collection and proper processing of medicine waste from households as stipulated in the *Wet Milieubeheer.* The use of medicines is governed by the Dutch Medicine Act. Pharmacists and producers are subject to company waste regulation, following *Wet Milieubeheer*.

The European Commission published the European Union Strategic Approach to Pharmaceuticals in the Environment in 2019 (European Commission, 2019a). It combines, amongst others, the commitments to the water and sanitation SDG (6), European health and circular economy principles (ibid). It is based on the life cycle of a pharmaceutical, both for veterinary and human purposes (ibid). Six areas of action are distinguished in it (OECD, 2019):

1. Increasing the awareness about and appropriate use of medicines
2. Helping in the process of designing pharmaceuticals that put lower stress on the environment, as well as promoting green production
3. Enhancing the assessment of environmental risks
4. Reduction and improved handling of waste
5. Increasing the scope of monitoring in the environment
6. Filling knowledge gaps not considered in the above.

The approach does not have a legally binding nature, but it is considered to be a relevant piece of policy as it can steer the direction of EU legislation and directives related to the subject, notably: "the Industrial Emissions Directive, Directive for Medicinal Products for Human Use, Directive for Veterinary Medicinal Products, Codes of Good Agriculture practice, Water Framework Directive and the Urban Wastewater Treatment Directive" (OECD, 2019, p. 131).

On the Dutch level, a chain approach is taken to address the issue of medicines entering the aquatic environment by means of the *Ketenaanpak*. Actors from different steps in the pharmaceutical lifecycle are involved. Four imperatives are central to the *Ketenaanpak*: 1) medicines must remain accessible to patients in need of that medicine, 2) actions must be pragmatic and not for window-dressing, 3) all actors act where possible, if costs are acceptable, and 4) actors ought not to be waiting for others for initiating action.

According to Moermond et al. (2016) about 2000 different active ingredients used in pharmaceuticals are present on the Dutch market. Specific to managing the waste of medicines, the *Ketenaanpak* stresses the importance of proper waste disposal of all medicines, but it is explicit about: 1) X-ray contrast liquids, 2) psychiatric medicines, 3) cytostatica (a type of medicine used in cancer treatment), 4) liquid medicine (I&W & VWS, 2019).

Five so-called intervention points in the *Ketenaanpak* are distinguished "environmental effects", "development & authorization", "prescription & use", "waste & sewage treatment" and "cross cutting issues" (Tweede Kamer der Staten-Generaal, 2018, no page or paragraph numbers). See a list of responsibilities per sector in table 14 that are being considered or have already been adopted (ibid). Responsibilities are outlined for ten different organizations and ten of them are shared responsibilities. Responsibilities are shared amongst private and public organizations. The responsibilities are diverse, ranging from waste treatment, to prevention of waste and disclosure on ecotoxicity characteristics.

Table 14: *Ketenaanpak responsibility allocation per measure (Tweede Kamer der Staten-Generaal, 2018).*

Actor	Potential measures
Waterboards	1) Identification of environmentally harmful medicines 2) Identification of intervention points in prescription and use phase 3) Increase treatment capacity of WWTP and identify costs 4) Do pilots with better treatment at WWTP 5) Identification of waste water treatments plants (WWTPs) that affect ecology and sources of drinking water most.
Drinking water companies	1) Identification of environmentally harmful medicines 2) Identification of intervention points in prescription and use phase
Pharmaceutical companies	6) Development of more environmentally benign medicines 7) System for managing risks to environment by medicines, e.g. by using Eco Pharmaco Stewardship tool 8) Active ingredients data access
Knowledge institutions	6) Development of more environmentally benign medicines 3) Increase treatment capacity of WWTP and identify costs 4) Do pilots with better treatment at WWTP
Authorization parties	10) Active ingredients data access 10
Ministry of Health	11) Proper use and prevention of use of pharmaceuticals
Health care sector	2) Identification of intervention points in prescription and use phase
Municipalities	12) Collection of unused medicines 13) Promoting proper waste disposal of medicines
Ministry of Infrastructure and Water Management	14) Creation of a tool for communicating how the medicine chain looks like *Leads stakeholder group in:* 15) identification of with medicines with medically similar but environmentally different effects 16) creation and execution of a strategy for communication 17) gaining insights from practices in other countries 18) international agenda-setting.
Pharmacists	12) Collection of unused medicines 13) Promoting proper waste disposal of medicines

4.5.3 Incentives & change in practice: practice

Waste management organization

Two relevant waste management pathways for medicine exist. Firstly, after consumption and passing through the body, medicine residues end up in the sewage system (I&W & VWS, 2019). The sewage is treated in waste water treatment plants after which the treated water is released onto the surface water (ibid). The second pathway is in the form of unused medicines, which is considered a separate waste stream “Small chemical waste” (*Klein chemisch afval* in Dutch) and should be kept apart from general household waste as they can provide health dangers to those involved in waste management (IPA, 2000; I&W & VWS, 2019).

The waste system for unused medicines is differently organized in different municipalities (P.O.3; G.O.3; G.O.4)'. Unused medicines can be brought to a MWCF, often also to a pharmacist and sometimes medicines are collected at home (P.O.3; G.O.4). Waste from a pharmacy includes the waste arising from preparing medicines, but also of medicines with an expired shelf-life that have never been sold (P.O.3). The role of pharmacists focuses primarily on the collection of pharmaceuticals, while the KNMP also seeks to raise awareness for proper disposal of unused and expired medicines by their members and clients (P.O.3). Overseeing the entire value chain, wholesalers provide pharmacists with medicines that give them to patients and have a form of extended responsibility regarding the quality of the medicine (P.O.3). In waste management, producers do not have a role (P.O.3; G.O.4).

One producer of medicines, TEVA, though not involved with the waste management of the medicines themselves, has arranged with Recycle to take back the blisters in which medicines are packaged (P.O.3). The pharmacist removes the remaining pills and potential privacy-sensitive information from the packaging, after which the blister is put in a TEVA box in the pharmacy and taken care of by a waste company (P.O.3).

Experiments occur with urine bags, to reduce contrast media emission to the sewage (G.O.4). WWTP have planned pilot projects (G.O.4). Furthermore, clients of pharmacies are now provided with information about how to dispose of medicines (G.O.4). Also, campaigns are created in cooperation with the ministry to assure proper disposal by clients (P.O.3).

Waste management financing

Pharmacists take on the responsibility of collecting unused medicines and presenting them to municipal(ly contracted) parties for further waste processing, but want to be financially compensated for this by the municipality (P.O.3). On a local level, agreements between pharmacists and municipalities can be made about who pays for which activities (P.O.3). Waterboards levy a tax for waste water treatment per household (G.O.4). Two interviewees acknowledge that no fee to waste water treatment plants is paid by those who put medicine on the market nor to subsequent drinking water companies (P.O.3; G.O.4). In figure 20, a schematic overview of the waste management system for medicine is presented. Though insurers are not involved in the waste management itself, they have an indirect effect through their role in purchasing and compensation. Green lines are financial flows; red lines are material flows. The role of insurers and a new tool for inter-pharmacy supply management are discussed in the 'circular practice beyond waste management' sections.

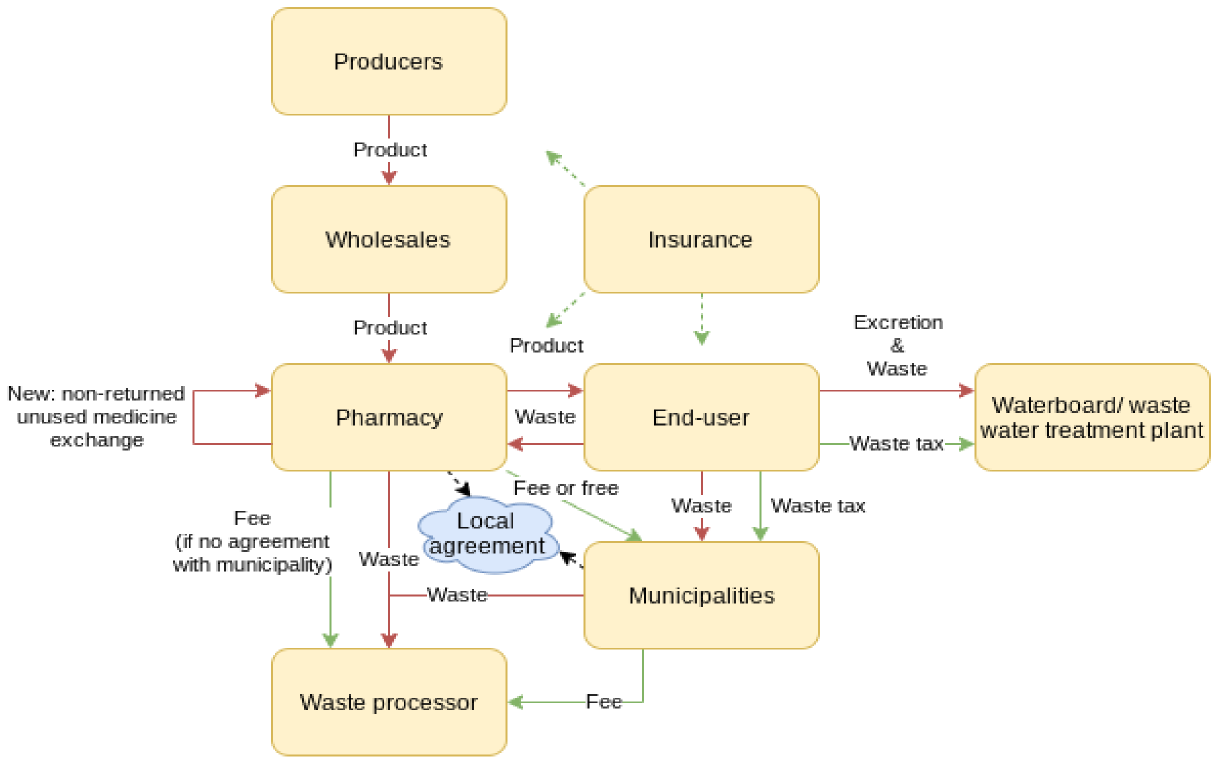

Figure 20: *Schematic overview of the waste management system for medicines (author's own).*

Reporting, compliance & enforcement

No legal obligations exist for producers for the waste management of pharmaceuticals after they have been used by consumers. Few relevant forms of non-compliance can be considered. When asked about free-riding in the value chain, one interviewee stated the pharmaceutical industry is free-riding in some form, because it does not financially contribute to handling medicine waste (G.O.4).

Organizations report on medicine waste by means of EARAL coding (European Commission, 2018a). For human medicines - in contrast to veterinary medicines - four relevant EURAL categories with corresponding codes exist, see table 15 (ibid). The coding system differentiates between two different origins: 1) the humane health care sector, and 2) separately collected from households and companies (ibid).

Table 15: *Relevant EURAL codes for medicine waste* (European Commission, 2018a).

Eural Code	Description	Waste origin
180108	Cytotoxic and cytostatic medicines	Humane health care sector
180109	Non-180108 medicines	Humane health care sector
200131	Cytotoxic and cytostatic medicines	Separately collected from households and companies
200132	Non-200131 medicines	Separately collected from households and companies

Circular practice beyond waste management

Prevention of the use of pharmaceuticals is amongst others promoted by the Ministry of Health, Welfare and Sports (VWS), which has many programs aimed at the promotion of overall health to reduce health care costs, such as by promoting healthy lifestyles (G.O.4). Regarding innovation, the KNMP and Association Innovative Medicines co-finance a policy employ working on sustainability in the innovative medicine industry (P.O.3). Furthermore, a demand-supply management tool called 'PharmaSwap' has been created by pharmacists (P.O.3). With this tool, pharmacists that have oversupply and pharmacists with undersupply can seek contact, and a certified company – healthcare alliance – then transports a medicine from one to the other (P.O.3).

4.5.4 Incentives & change in practice: evaluation

Waste management organization

Regarding the background of the chain approach, the waterboards - responsible for the treatment of waste water - initiated the chain approach by requesting the Ministry of Infrastructure and Water Management (I&W) and Ministry of Health, Welfare and Sport (VWS) to coordinate action on reducing the amount of pharmaceuticals entering the environment in the entire value chain (G.O.4). The waterboards felt unable to do this themselves and stressed the importance of engaging the pharmaceutical industry, hospitals, pharmacists and general practitioners (G.O.4). They did not perceive themselves as the party to really go into dialogue with, for example, the pharmacists (G.O.4). Though the waterboards are at the end of the chain, they want to exert pressure on the front of the chain to come up with action (G.O.4). By this, they also attempt to signal that the limitless use of medication can have negative effects on the environment (G.O.4). Drinking water companies lobby for increased removal of medicines at the WWTP, so that they do not have to implement additional treatment installations and their water sources do not become contaminated (G.O.4). The KNMP – a branch organization for pharmacists – steers strongly on the role of municipalities in the collection process of medicines (P.O.3).

According to an interviewee, tangible change has not occurred in the management of pharmaceutical waste, but awareness has increased a lot in recent years (G.O.4). Furthermore, activities have centered around research, awareness and determining stances on the matter by the relevant parties (G.O.4). According to radio commercials were broadcasted that reached 500,000 people (I&W & VWS, 2019.). Furthermore, all pharmacies were provided with information posters and a social media campaign was carried out (ibid).

An interviewee states that as soon as pharmacists collect medicines, it becomes company waste and the responsibility of the pharmacy to dispose of it properly (G.O.3). Another interviewee describes municipalities as taking a cooperative role in general, with only 30 municipalities being "unconstructive" who perceive medicines returned to the pharmacy as company waste and thus not their responsibility (P.O.3). The same interviewee states that municipalities have a wide range of policies, but are not willing to have national guidance, especially when it concerns their own waste management policies (P.O.3).

Returned medicines by clients are not given to other clients due to uncertainty about the storage conditions (P.O.3). On the household level some level of medicine sharing might occur, but on a larger scale, the supply of unused medicines that have already been into household, is non-existent (G.O.4).

On the involvement of the pharmaceutical industry one interviewee comments that the industry does not participate because it has to, but because it values a good reputation which, might be threatened if they do not participate in the chain approach (G.O.4).

Waste management financing

According to the KNMP (n.d.) the costs to individual pharmacies were up to 7500 Euros in 2016. An interviewee considers the waste management costs to individual producers significant (P.O.3). An issue was that costs increased to pharmacists, when consumers brought back their medicines to a pharmacist (P.O.3). Pharmacists would have to pay more to their contracted party – a municipality or company – to deal with the extra, returned medicines (P.O.3). When consumers would bring their medicines to the MWCF, they could return it for free, and the municipalities would carry the waste management costs (P.O.3).

Now, in most of the municipalities, returned medicines are taken back from pharmacists by municipalities at no cost (G.O.4; P.O.3) According to another interviewee, most municipalities compensate pharmacists for the collection and recycling efforts and/ or collect the unused medicines from households at the pharmacy (G.O.3). It is then the case that a large group of consumers - i.e. taxpayers - pays the bill of waste that is produced for a small number of people (G.O.3).

Reporting, compliance and enforcement

According to one interviewee, legislation is the largest barrier to increased collection and reuse of medicines (P.O.3). The inspection tolerates intermittent supply of medicines, but this is strictly forbidden by law (P.O.3). Regarding disposal behavior, less medicines are flushed by pharmacists, now they have knowledge about the consequences for the environment according to an interviewee (G.O.4). Non-compliance with regards to how waste should be handled legally is considered to be low for the entire pharmaceutical chain (G.O.4). On the other hand, reporting efforts in the chain is considered to be low (G.O.4). Certification for practices of pharmacists or general practitioners is considered to have no added value, because little non-compliance is expected there (G.O.4).

The EURAL data from Rijkswaterstaat (2020a) shows that recycling of pharmaceutical waste stream occurs due to separate collection at households and companies. However, this is impossible in practice, because metabolites, medicine residues and left-over medicines ending up in WWTP sludge or when separately collected are destroyed in the waste management process by incineration in the end (G.O.4). Also, legally it is odd, because these waste streams have to be incinerated following the National Waste Management Plant (LAP)3, sector plan 18 & 19. The EURAL data seems of low quality.

Circular practice beyond waste management

According to one interviewee no incentive exists for producers to consider the post-use phase of the product whatsoever (G.O.4). Furthermore, product innovation towards lower ecotoxicity is often difficult or impossible, because this would lower the effectiveness of the medicine in the human body (G.O.4). However, other innovations could prove useful, such as precision application, reducing the dose (G.O.4; P.O.3). Recently, a thermo-lock has been developed that monitors storage conditions of a medicine (P.O.3). The degree to which medicines are susceptible to non-optimal storage conditions differs greatly per medicine (P.O.3). Innovation in product design does not really occur according to an interviewee (P.O.3). Medicines that are based on protein-structures are expected to be more biodegradable than non-organic medicines, but no activity is observed there (P.O.3).

Regarding use of medicine, general practitioners and pharmacists are discussing how they can reduce the amount of medicines that are prescribed (G.O.4). Prescription behavior is not based on environmental considerations (P.O.3). Though prescribing behavior can be aimed at reducing stockpiling and expiring of medicines in households, the system can be influenced best upstream at the level of wholesalers and medicine producers, which should be considered at the EU-level as well (P.O.3).

Insurance companies and pharmacists often have long-term contracts to keep costs for medicines low, however, but due to changing circumstances – for example, passing away of patient – medicine stocks can become redundant and prone to expiring (P.O.3). Oversupply of patients with their medicines can also result in expiry (P.O.3). Oversupply is likely to occur when the price of the product is relatively low with respect to the logistic and packaging costs (P.O.3). The option to have annual delivery is considered a tension point (P.O.3).

Pharma-swap has improved demand-supply management amongst pharmacists themselves (P.O.3). Providing other pharmacies with one's own spare medicines was first not accepted by the inspection, because providing pharmacies with medicines was first deemed to be a responsibility of wholesalers exclusively, but now it does (P.O.3). Unlike medicines that have been in a household, the medicines that were stored in a pharmacy are known to be stored under the right conditions (P.O.3). Pharma-swap reduces the size of the redundant stocks at pharmacists due to inter-pharmacy trading, which lowers overall spending (P.O.3).

To have more grip on production, the pharmaceutical industry should be relocated back to Europe again, according to one interviewee (P.O.3). A large part of the pharmaceutical production is located outside the EU (P.O.3). For the production that still occurs in the Netherlands, it is easier to implement measures (P.O.3). Concerning circularity, the moment production disappears from a country where the specific medicine is consumed, it becomes hard to exert control according to this interviewee (P.O.3).

4.5.5 Market failure evaluation

Scale advantages: performance

About 140 tons of medicine residue are discharged on surface water in the Netherlands per year (Moermond et al., 2016). These are the medicines that have not been removed during the waste water treatment process. Assuming a removal rate of 50-80% in waste water treatments plants (G.O.4), about 280 – 700 tons of medicine residue enter the sewage system each year. In addition to those 140 tons, 30 tons of X-ray contrast media enter the sewage system each year (I&W & VWS, 2019). 95% of the medicines found in sewage water is from human excretion, the other 5% is by flushing medicines directly through the drain by clients, pharmacists and doctors (ibid). About 90% of the medicine residues that end up in the sewage system are from households (ibid).

More is collected is now due to the *Ketenaanpak* (G.O.4). Most of the medicines that are returned are handed in at the pharmacy; less medicines are returned to the MWCF (I&W & VWS, 2019). The returned medicines make up the bulk of the medicine waste that is collected at a pharmacy (P.O.3).

Due to the quality of the EURAL data, only at the aggregate level some insights can be given about recycling. As noted previously, recycling or giving out unused pharmaceuticals after entering a household is not allowed, but in figure 21 and figure 22 can be seen some pharmaceutical waste is registered as recycled. Pharmaceutical waste arising outside the health care sector is even more likely to be recycled than within the health care sector as illustrated by the percentage points differences in application in figure 22. Most of the pharmaceutical waste is burned now.

No data could be found on the reported separately collected material from households, therefore a rough approximation is presented. According to Bekker (2018), drawing from Bouvy et al. (2006), at least 100 million Euros worth of medicine is thrown away in the Netherlands each year. Annually, the total spending is 5.3 billion Euros (VIG, 2019). Assuming that weight is one-on-one correlated with medicine value, at least 66 ton (0.1*3.5*1000/ 5.3) or 1.9% of the total medicine in terms of weight becomes waste, without having been used.

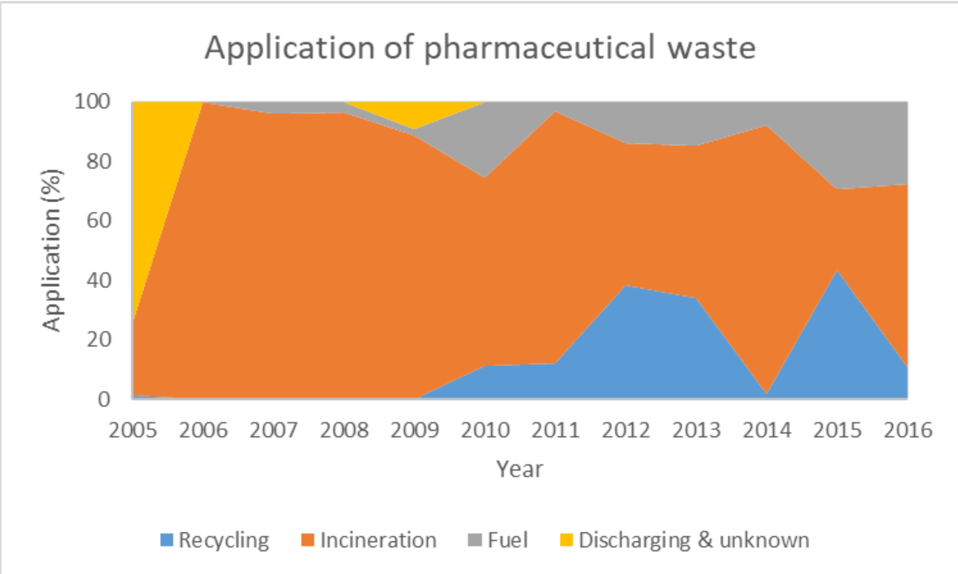

Figure 21: *Waste processing of all medicine EURAL codes (author's own, data from Rijkswaterstaat, 2020a).*

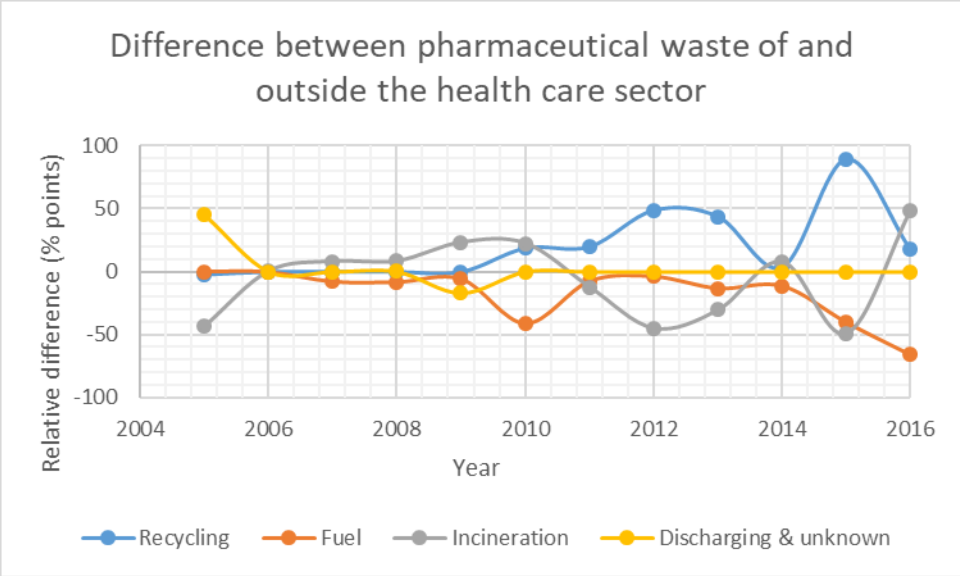

Figure 22: *The difference in percentage points of pharmaceutical waste from within and outside the health care sector (author's own, data from Rijkswaterstaat, 2020a).*

Scale advantages: aggregate costs

No data was found on the total of medicine-specific costs, nor per ton for the separate collection. Also the interviewees did not know about these costs. In Box 1, a rough approximation of the costs for separately collection is provided firstly. In Box 2, a rough approximation is given for the costs that waste water treatments plants would incur, if they increase the removal capacity of pharmaceutical waste ending up in waste water. Lastly, a reflection is given how these costs compare to the expenses on pharmaceuticals in the Netherlands.

Box 1: *A simple cost calculation for separate collection by pharmacies*

KNMP

According to KNMP (n.d.) the costs for pharmaceutical waste management to an individual pharmacy without compensation by a municipality can be up to 7500 Euros. No average or total costs are provided, but the highest costs for individual are provided per province. Only 10 out of 12 provinces have individual pharmacies paying more than 3000 Euros. The 4 nationally highest individual expenses are: 7500, 6000, 3600 and 3600 Euros per year. Based on this numbers, a relatively high waste management cost of 3,000 Euros is assumed for all pharmacies, with or without compensation or operational help by the municipality. In the Netherlands, the total amount of pharmacies is stable at about 2000 (De Staat van Volksgezondheid en Zorg, n.d.). Thus, overall costs for waste management would be 3000 x 2000, is about 6 million Euros per year. Considering a total use of medicine of 3.5 million kilograms, this would be 1,700 Euros for each ton medicine used in the Netherlands. As the bulk of the separate collection of pharmaceutical waste occurs at pharmacies, these costs reflect a large fraction of the total costs for separate collection.

Checking for the costs per ton separately collected with an assumed low separate collection rate of only 10% of the calculated 66 ton disposed medicine, the total costs per ton collected waste would be 909 thousand Euros per ton collected (6 million Euros/ (0.1*66 ton)).

CE Delft
The costs of waste management (collection and processing) of the entire group of *Klein Chemisch Afval (*KCA) has been estimated to be 1,946 euros per ton waste (CE Delft, 2017). The costs per ton put on market or used can be expected to be lower, because probably not all chemical materials end up in *Klein Chemisch Afval.* Compared to the costs of general waste (166 euros per ton) these costs are relatively high, because the toxicity of the KCA stream requires additional safety measures (CE Delft, 2017).

Thus, based on these assumptions it seems that separately collected pharmaceutical waste is more expensive than other KCA waste.

Interviewees
On the other hand, the amount of medicine or even KCA waste that a household produces is only a fraction of the general waste stream (G.O.4). According to one interviewee, stricter norms are increasingly leading to higher incineration costs (P.O.3).

Box 2: *A simple cost calculation for additional treatment by waste water treatment plants*

Interviewees
50-80% of the medicine residues that enter the sewage system are removed at this moment by general treatment steps that have been installed already (G.O.4). Depending on local conditions, technology, concentration targets would cost an inhabitant between 8 and 25 Euros per year, on top of the prevailing tax rates for waste water treatment (G.O.4). This is a cost increase of a few percent (G.O.4). Doing a rough, simple calculation, assuming the lower amount (8 Euros), multiplied with the number of Dutch inhabitants, 17.4 million (CBS, 2020), this results in a total cost increase of 139.2 million Euros per year. The costs per ton pharmaceutical used would be: 39 thousand Euros. Per ton entering the sewage system, assuming the higher end of total emission to the sewage system (700 ton), this would be 199 thousand Euros.

Knowledge institute
According to the Stowa (2017), the additional costs are between 0.10 and 0.25 Euros per cubic meter for a WWTP that processes the waste water of 100,000 inhabitants. Scale advantages for larger installations are small, and the costs for plants processing the wastewater of 10,000 – 75,000 inhabitants per cubic meter are 1.5 – 1.1 times higher (ibid). Again, doing a rough, simple calculation, assuming that all of the waste water in the Netherlands is processed in a 100,000 inhabitant equivalent WWTP at the cost of 0.10 euros/M^3 for a total of 1.9 billion M^3 waste water that was processed in the Netherlands in 2017 (CBS, 2020), the additional cost is about 190 million euros per year. The costs per ton pharmaceutical used would be: 54 thousand Euros; per ton entering the sewage system, assuming the higher end of total emission to the sewage system (700 ton), this would be 271 thousand Euros.

Thus, data from the literature and interviewee result in different numbers, but of the same order: 190 vs. 139.2 million euros per year.

The total expenditure was about EUR 5.3 billion in 2017, similar to the years before (VIG, 2019). The waste management costs (6 million) for separate collection are only a fraction: 0.11%. The annual, additional waste water treatments costs equal 2.6- 3.6%. Regarding the waste management costs per ton, the costs of separate collection at pharmacies seem to be 4.5 times higher (without treatment costs), for the given assumptions (when separate collection of the totally disposed medicine is assumed to be about 45% instead of 10% the waste management costs are about equal). On the other hand, about 4-10 times as much medicine waste is processed in WWTPs. Concluding, though shrouded in uncertainty and with several assumptions made, the operational costs for WWTP and separate collection seem to be similar in terms of order of magnitude per ton waste.

Environmental externalities

Most of the production of pharmaceuticals occurs outside the EU, mostly China and India, where environmental issues arise (P.O.3; G.O.4). Especially resistance to antibiotics in water bodies is a problem (P.O.3; G.O.4). Production occurs in a controlled environment to meet product quality requirements and avoid contamination of pharmaceuticals with unwanted substances (P.O.3). Most of these companies also fulfill international good manufacturing principles that secure product quality (P.O.3). On the other hand, company waste management is considered to be of low quality at these production sites (P.O.3). Awareness in India and China is growing, but those countries have to come from far to meet the standards that prevail, for example, in the Ruhr area in Germany (P.O.3).

The production of pharmaceuticals that is still occurring in the Netherlands are subject to strict norms and those production facilities have their own treatment processes (G.O.4; P.O.3). Waste from Dutch production sites is therefore not considered to be of high environmental concern (G.O.4; P.O.3). The environmental damage that is occurring in the Netherlands, is mostly related to the aquatic environment (G.O.4). Furthermore, with increasing levels of consumption of medicines as well as climate change, environmental risks increase (I&W & VWS, 2019). Half of the water flowing through the Meuse river can be treated wastewater in the summer already (G.O.4).

For 80 of the 2000 pharmaceutical substances, water managers have identified whether and to what extent they occur in the surface water (Moermond et al., 2016). Five of those can be found in concentrations higher than the norm under which water organisms are deemed safe. These five are comprised of one painkiller (diclofenac), three antibiotics (azythromycine, clarithromycine and sulfamethoxazole) and one anti-epileptic (carbamezipine) (ibid). X-ray contrast media are highly persistent and are only to a small degree removed in waste water treatment processes (I&W & VWS, 2019). Medicine residues have been shown to have negative effects on fish, including tissue damage by painkillers, sexual change in fish by contraceptives and altered behavior of crustaceans and fish by anti-depressants (ibid). Furthermore, antibiotics are present in surface water, thereby potentially contributing to resistance of bacteria against antibiotics (ibid).

The environmental impact of medicine, medicine residues and metabolites is still considered to be unclear, though concern is growing also at the environmental health agency (G.O.4; P.O.3). Furthermore, the effects of mixes of medicines, also in combination with other micro-pollution, like microplastics, are unclear (P.O.3). Even when individually undetectably, mixes of different substances might still carry risk (G.O.4). Though uncertain about the importance, one interviewee states that medicines can enter the food-chain, when contaminated surface water is used for agriculture or when fish are consumed that have medicines in their tissue (P.O.3). Diclofenac is mentioned as a medicine of relatively high concern (P.O.3; G.O.4). Diclofenac passes through the body unaltered and is also widely used, thereby having a relatively high impact on the environment

(P.O.3). People are exposed to very low concentrations of medicine residues in drinking water (P.O.4). No health effects occur due to this, but it is still perceived as undesirable by I&W & VWS (2019) and interviewees (G.O.4; P.O.3). The contamination of surface water is considered to be only a minor issue, especially if one compares it to the large problems that existed with regards to eutrophication and industrial pollution (G.O.4).

Now, sludge is incinerated, while in other countries it is applied in forestry or agriculture (G.O.4). In these countries, quality criteria are developed to manage potential risks due to useful application (G.O.4). The sludge can be a good fertilizer, when micro contamination concentrations are low enough (G.O.4). Here, the perception is that application of waste is risky, while in Sweden it is applied (G.O.4). Safe application is both a political and technical issue, depending on the degree of precaution one wishes to take according to this interviewee (G.O.4). Virgin sources are not necessarily less contaminated, illustrated by the cadmium contents in imported phosphate (G.O.4).

Furthermore, health and environmental risks exist in the management of returned or expired pharmaceuticals, as some medicines can be very toxic. Cytostatica – medicines used in cancer treatment – are an example of this (P.O.3). Cytostatica are increasingly consumed in households, as treatment at home instead of in a hospital becomes more frequent (P.O.3). The health risks due to exposure of pharmacists and consumers to medicines with high toxicity can complicate the reuse of blisters in which medicines are packaged, though it can be desirable from a materials perspective (P.O.3).

The environmental benefits of additional treatment are unclear: much uncertainty exists about the harmful effects that medicines have on the environment, while the techniques to remove medicines from waste water are costly, but also resource and energy intensive (G.O.4) The additional energy requirement for WWTP is considered significant (G.O.4). On the other hand, when the effects are uncertain, no limits on use tend to be imposed, which was the case for pesticides (G.O.4). When the environmental risks become clearer, the additional costs to WWTP become less problematic (G.O.4).

Despite the aim to improve the environment, affordable healthcare for everyone is considered paramount by the interviewees (P.O.3; G.O.4).

Information issues

A lack in transparency about the environmental and toxic effects medicines might have is considered an important issue (G.O.4). With better information, the water boards can come to a more informed opinion about what the problem might exactly be (G.O.4). Increasingly, information is shared by producers about the eco-toxicity of products (G.O.4). For new products this has to be reported (G.O.4). However, overall one interviewee describe the overall degree of information sharing “shockingly low” (P.O.2). Though pharmaceuticals for human use have to be tested for environmental risks, the authorization agency cannot deny market access if such an environmental risk exists (Deloitte, In Extenso & EurEau, 2019).

Interviewees’ views on EPR

Some evaluations were directly related to a hypothetical EPR system for pharmaceutical waste and are discussed here.

One interviewee suggests to create a fund that is filled by pharmaceutical producers and from which waterboards can draw to carry out additional treatment (G.O.4). According to this interviewee, this would convey the message to producers, that everything they create will have to be cleaned up in the end (G.O.4). A fund increases the salience of medicines in waste water and surface waters, because each year the costs are discussed again (G.O.4). EPR could be used as a tool for creating normative change regarding attitudes to production-consumption-wasting, without considering the environment (G.O.4). The interviewee states that it should be a relatively simple funding system, that companies have to contribute to in correspondence with their turnover (G.O.4). If it is levied on the product level, then it becomes more challenging (G.O.4.). Another interviewee suggests a pricing component based on environmental considerations could be a method, for example, to promote medicines that have environmentally friendly alternatives such as for diclofenac (G.O.3).

The considered capital-strong large manufacturers should pay up at least part of the waste management costs according to multiple interviewees (P.O.3; G.O.4; G.O.3). One interviewee states that without EPR, one keeps searching where to put the bill (G.O.3).

One interviewee is explicit about the role of the producers in the organization of waste water treatment: producers should not be given organizational responsibilities, because they have little knowledge about waste water treatment, nor about collection (G.O.4). Regarding separate collection, another interviewee explicitly stated to not know an organization that could fulfill a PRO-similar role (P.O.3.).

Some more critical notes were also given by interviewees. According to one interviewee, wholesalers of medicines already have an extended responsibility regarding the quality of the medicines, but that fulfilling this responsibility is complicated by the fact that most of the production of pharmaceuticals takes place outside Europe (P.O.3). Two other weaknesses are identified by another interviewee for a potential EPR system: 1) the additional bureaucracy, and 2) increasing tax rates would also solve the funding issue (G.O.4).

The issue of medicine waste management is also acknowledged by another interviewee who states that some pharmacies complain about the lack of a collection structure and organization for returned medicines (G.O.6). However, a role for the national government (e.g. setting standards or introducing EPR) is only desirable when the costs to the environment are great enough and the sector is unable to organize the waste themselves (G.O.6).

4.6 Broader experiences

4.6.1 Section introduction

In this section, the findings of the broader experiences regarding EPR are presented. The formal institutional setting is not presented, though section 4.2 can be considered a factual overview of this. In this section, the focus is on evaluation from interviewees and quantitative data source, not factual descriptions of rules, activities and interactions.

In the remainder of this section, the incentives and change in practice are evaluated, followed by an evaluation of the marker failures. A schematic overview of these findings can be found in appendix 7.

4.6.2 Incentives and change in practice: evaluation

Waste management organization

In the early 1990s before EPR, the sentiment amongst producers was: sell products, but due to EPR putting products on market and taking them back intertwined (P.O.2). Often EPR responsibilities involve a collection target with respect to the amount that has been put on the market, and can also involve an additional recycling target to make sure that a sizable fraction gets recycled even though other waste processing activities are legally allowed (P.O.1; P.O.2; P.O.5; G.O.1; G.O. 3G.O.5; G.O.6) Due to EPR, things have been done that otherwise would never have been done (P.O.2). Upon implementation of EPR, first, who is all subject to EPR and who sells what products were identified (P.O.2). Overlap in value chains with EPR and similar challenges (e.g. financing and data collection) are mentioned reasons that producer organizations started to cooperate (P.O.2). The formal EPR systems and systems subject to AVV, are considered to target substantial waste streams, with clearly delineated interest groups (G.O.6).

For the five product groups with imposed EPR, collective organizations (PROs) that organize the activities required to fulfill the responsibilities have been created (G.O.5). This is also the case for product groups subject to AVV (G.O.5). The producer or PRO will produce a waste and recycling chain to fulfill their responsibilities (G.O.6). Firms outsource the execution of their responsibilities to PROs to keep costs low (P.O.2). In the Netherlands, the regulatory pressure of EPR is considered minimal by one interviewee: producers have to find a way to achieve the targets in a way they see fit (P.O.2). Often, a PRO needs cooperation of other parties such as retail and municipalities for collection, transport, recycling, campaigning, et cetera (P.O.2; P.O.5; G.O.1; G.O.3; G.O.5; G.O.6).

Municipalities offer their (non-free) waste management services to producers with EPR responsibilities (G.O.6). Municipalities collect, but also inform consumers and engage with local companies to improve waste management (G.O.3). Municipalities prefer to have a say or be involved with the management of product groups subject to EPR (G.O.3).

Waste management policy is fragmented on the municipal level according to an interviewee (P.O.2). All municipalities have the mandate to organize waste collection management as they see fit (P.O.2). This causes difficulties for coordination: without a central focal point for discussion and making agreements, PROs have to engage with municipalities directly, which is difficult due to the high number of municipalities (P.O.2). Furthermore, due to the politicized nature of the functioning municipalities, every four years a different waste policy can be in place according to this interviewee (P.O.2). The interviewee also thinks that the existence of different systems that municipalities operate has a negative effect on inhabitants (P.O.2). Overall, according to this interviewee, municipalities do not perform well: they do not inform their inhabitants well, do not collect much and barely sort out the waste (P.O.2).

Products that are subject to different waste management regimes can look similar to consumers, thereby requiring coordination by the organizations that have responsibilities (G.O.3.). This can be PRO-PRO but also PRO-municipality coordination, for example, about financial compensation for different product fractions after sorting a waste stream mix (G.O.3). This interviewee also states that multiple take-back systems can have overlap regarding targeted products, with different cost and collection rates (G.O.3). The interviewee experienced that for this reason, firms argued to abolish one system, because as soon as the consumer is used to making use of the other system, the former would become redundant (G.O.3).

Campaigns help to engage consumers, and these kind of activities need continual attention (G.O.6). Campaigning activities are mostly carried out by PROs individually as each of them has to reach their own targets or at least show that they have put in effort (P.O.2). According to an interviewee, information provisioning should be more a collective effort of all the PROs (P.O.2). The public organization *Milieucentraal* provides information on the national level (G.O.6). An interviewee stresses that knowledge by itself is often not enough to ensure desired consumer behavior, such as proper disposal of products (P.O.2). Social norms play a role: people may find it embarrassing to throw away stuff in nature or hand-in some products (P.O.2).

Critique exists that EPR steers too much on collection and recycling rates, but EPR is considered to be a good tool for developing a recycling practice and learn from each other while doing so (G.O.6). Regarding potential future EPR systems, comprehensive EPR systems with additional responsibilities should be implemented over time gradually (G.O.6).

Waste management financing

Tariff differentiation is employed to induce behavior that results in lower costs in the post-use phase on environmental or operational grounds by making environmentally and/ or operationally more costly products more expensive with respect to alternatives (P.O.2; G.O.3; G.O.6). In the Netherlands, tariff differentiation based on environmental considerations only applies to packaging as an experiment (G.O.6). Normally, fees are modulated based on how costly the collection and recycle process is in the EPR system (G.O.1; G.O.5). Only products with EPR have the costs for waste management represented in the market price (P.O.2). For collective execution, a PRO calculates the total costs, then translates this into volume and allocates costs to the producers in accordance to their volume (P.O.2).

For non-EPR waste streams from households, the municipal *Afvalstoffenheffing* (waste management fee paid per household) covers most costs. According to Rijkswaterstaat the cost-coverage of municipal waste management activities by *Afvalstoffenheffing* is about 97.5% (Rijkswaterstaat, 2019). The other 2.5% is not paid for by producers through EPR, but through other municipal income. The average costs per household were 252 euros in 2019 (ibid). However, variation is present: the *afvalstoffenheffing* is more than 377 euros and less than 120 euros for the five most expensive and least expensive municipalities respectively (ibid). Municipalities benefit when streams with relatively high processing costs ending up in residual household waste are separately collected (G.O.3). This saves them money for residual household waste (G.O.3).

EPR brings about a sense of fairness because the consumer and producer pay the price, not an inhabitant through the waste management fee (G.O.3; G.O.6). An interviewee states that according to municipalities and environmental organizations, a fee should be asked for products that are not returned and disposed of, but that have high risk for littering, for example, a bag with fries (G.O.3). According to one interviewee, there is conflict between actors about the degree of purity of waste streams and who pays what (P.O.2).

Reporting, compliance and enforcement

Often, PROs check the put-on-market volumes reporting by individual producers by means of auditing by accountants (G.O.3; G.O.5). Once in every few years the completeness and correctness of producer reports are checked by the ILT (G.O.5).

The number of legal persons with compliance liabilities is considered high for the product groups with EPR, except for packaging (G.O.5). The link between performance of an individual producer and the entire waste management system is harder to establish than between a collective and that system (G.O.5). From an enforcement perspective it is easier if a collective can be hold responsible by law (G.O.5). Additionally, for products where a larger part of the production chain needs to be monitored, monitoring is difficult (G.O.5).

Though it is recognized that producer (organizations) depend on municipalities, producers are still held accountable by the inspection (G.O.5). Generally, after a warning, the ILT does enforcement by means of a *last onder dwangsom* (G.O.5). Enforcement activities can effectively lead to more collection points (G.O.3; G.O.6), but also to higher consumer engagement efforts (G.O.3). Normally, the ILT does not prescribe methods how to achieve targets, however, following a decision of the *Raad van State* (an advisory body and highest general administrative court) the ILT prescribed a PRO to place extra containers to improve the collection rate (G.O.5). Furthermore, self-reported figures by producers are improving in quality due to enforcement efforts in the initial phases of the EPR system, though significant differences still occur between different waste streams (G.O.5). The inspection reports are publicly available, thereby making the sectors subject to political scrutiny, which has caused performance improvements (G.O.5).

Interviewee's opinions differ on the matter of transferring enforcement capabilities to private parties such as PROs. For example, PROs depend on municipalities for collection, but they cannot prescribe actions to municipalities (P.O.2). On the other hand, PROs with an AVV can go directly to court but often connect with the national agencies first to increase pressure on the non-compliant party to comply, which helps them to limit free-riding by individual producers (P.O.1; G.O.1; G.O.5). Another interviewee also states that by means of an AVV free-riders can be caught in the system (G.O.6). However, online sales whereby a foreign party directly targets the consumer without an EPR-importer is expected to be an important issue for the coming years (G.O.1; G.O.5; G.O.6).

Regarding treatment and recycling, enforcement occurs on illegal waste streams to abroad, as well as inspection of scrap companies to make sure they do not scrap products without certification for this (G.O.6). Non-compliance with processing high-value materials is considered problematic (P.O.2). The degree of compliance for processing waste some systems (such as waste of electric and electronic appliances), has to increase (G.O.5). Enforcement is having positive effects on compliance there now according to an interviewee (G.O.5), though another interviewee finds that the enforcement agency barely audits scrap companies (P.O.2). Furthermore, foreign waste processors are also audited by the ILT, and though the ILT depends on other parties for carrying out inspection work in other countries this has rarely been a problem (G.O.5).

Instruments such as certification of waste processors can be adopted by PROs to guide money flows towards the parties, thereby weeding out undesired practices in waste management (G.O.5). In absence of certification and to act legally “appropriate” one interviewee states that producers started a certification system themselves, which is used until the formal quality control system is finished (P.O.2).

The point of measurement can have an effect on recycling performance. By changing the location of measurement for recyclates from a percentage offered on the market to a percentage incorporated in new products the EPR recycling performances can drop significantly (G.O.3).

Municipalities can sanction inhabitants when they do not dispose of waste properly (P.O.2). Some municipalities check the garbage bags of their inhabitants and sanction inhabitants who do not sort well, but this results in angry inhabitants, though sorting is quite well in these municipalities (P.O.2). With regards to incorrect disposal through littering, 10% of the people keep littering according to an interviewee (G.O.3). The amount of littering has barely decreased or remained constant for the recent years (G.O.3). Littering is a leak that has been difficult to close for a long time, despite campaigning efforts by the relevant PROs (G.O.3).

Regarding compliance with product(ion) standards a few issues can be considered. Firstly, producers need to comply with circular-unrelated standards, such as safety standards for food, which can hinder secondary use of materials. Secondly, firms are sensitive to bad public news and harm to their reputation, and therefore comply with product standards (P.O.2). Thirdly, for complex products, the number of components can be over a thousand (P.O.2). This can cause problems when these all have to be checked for substance concentration (P.O.2). However, according to an interviewee, when a material is banned, then the material disappears from the entire value chain, for example, PVC in packaging (G.O.3).

Circular practice beyond waste management

Some materials are prohibited from general use in products, though significant exemptions can exist (G.O.5). Most of relevant legislation focuses on the end-of-life phase of products (G.O.5; G.O.6). Additionally, via the Ecodesign Directive additional complementary product design standards can be implemented, such as recyclability, availability of spare-parts, reparation services, producent contents, as long as it feasible in practice and it can be monitored (G.O.5; G.O.6). However, similar legislation for circular design – in addition to design for minimal energy use – barely exists at the front of the chain and requirements for new appliances are limited (G.O.5).

Few consumer goods are created in the Netherlands and products that are ordered abroad are less influenced by Dutch parties (P.O.2). Manufacturers are more incentivized to adopt changes in product design to lower their costs, when a larger fraction of their market share is located in the Netherlands or Europe (P.O.2). This is enabled by implementing EPR at the EU-level (G.O.6). Research into the potential of tariff differentiation based on environmental consideration to influence on product design is being researched, though an interviewee expects that it is hard to influence product design with current fee modulation (G.O.6). Furthermore, it is not automatically the case that the front of the value chain experiences a problem by increasing, for example, waste tax rates (G.O.6). Over the years, material efficiency has increased, but product quality is expected to be a greater driver than environmental considerations, because without product quality things become unpopular (P.O.2).

Recycled content targets are expected to be a good way to give momentum to the secondary material market, and the EU Commission is checking this (G.O.6). However, it is hard to check whether a product contains recycled material and where material comes from (G.O.6). Before this can be implemented a technical guideline for how to do this, should be existing (G.O.6).

One interviewee was critical about the prospect of new, circular business cases, such as leasing, because: 1) the product is not different from the one that used to be put on the market, 2) the leased product is not property of the user, thereby reducing the incentive to deal with it properly, 3) access to the product becomes cheaper because investment barriers are removed (P.O.2). Furthermore, strategies like pay per use, pay per view or take-back after an amount of years have significant drawbacks, especially when product innovation is high (P.O.2). Relatively few business strategies based on leasing are viable according to this interviewee (P.O.2). Some individual producers that have take-back systems do this more on a business to business level (P.O.2). This way they keep track about where their products are (P.O.2).

According to two interviewees, EPR has seemingly limited effect on product design, due to which one could wonder to have more direct regulation in the spirit of the Ecodesign Directive (G.O.5; G.O.6).

4.6.3 Market failure evaluation

Scale advantages: performance

Here, broader trends in waste are presented in order to put the results EPR can have in a broader context. In figure 23, the total waste of households is presented, made up of three different fractions: separately collected, fine mixed waste and bulky mixed waste. The data is from *Compendium voor de Leefomgeving* (CLO, 2020). The latter got a separate registration in 1991, before which it was part of the fine mixed waste fraction (CLO, 2020). The mixed, bulky waste also includes construction material waste from households (CLO, 2020). The data covers waste that is collected or commissioned by municipalities, including EPR waste streams. Furthermore, separate collection of OPC and electr(on)ic waste by third-parties is included (CLO, 2020).

It can be observed that the total amount of separately collected waste increases sharply from 1990 until 1997. Hereafter, the absolute amount in separately collected waste from households is more stable and increases only slightly. The increase in separate collection coincides with the introduction of EPR in 1990 in waste management policy, and the first EPR-systems in the Netherlands.

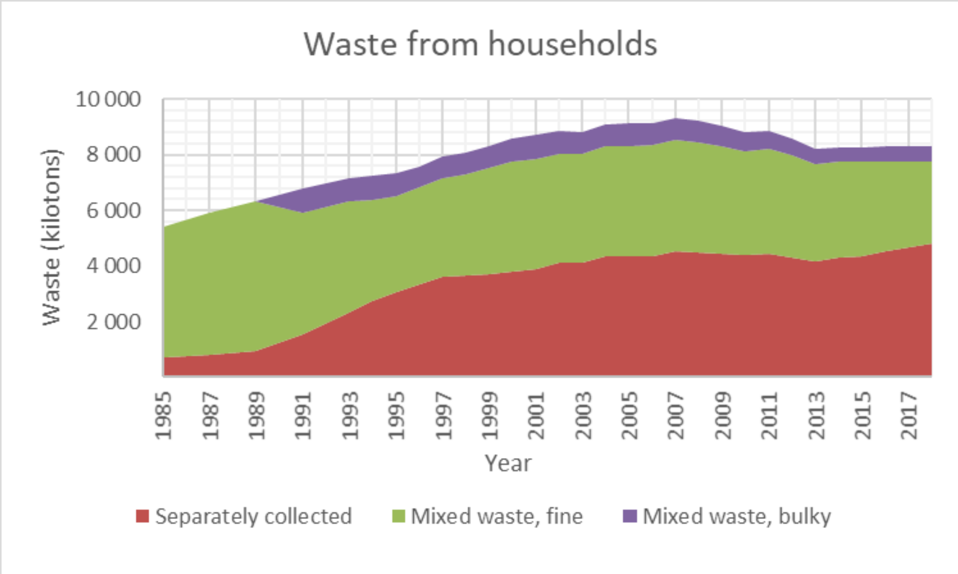

Figure 23: *Total amount of waste from households (author's own, data from CLO, 2020)*

EPR implementation or changes in existing EPR-systems do not seem to coincide with increased separate collection of household waste streams. It should be noted that also other waste policies were implemented in 1990s, including landfilling bans and taxes on waste, such as a tax on landfilling. Furthermore, from 1990 onwards the amount of household waste that serves some kind of useful application - including material recovery and energy recovery - increases (see figure 24). In 2009, the energy efficiency of incineration plants was considered so high that the waste is registered as usefully applied. Most waste is usefully applied now.

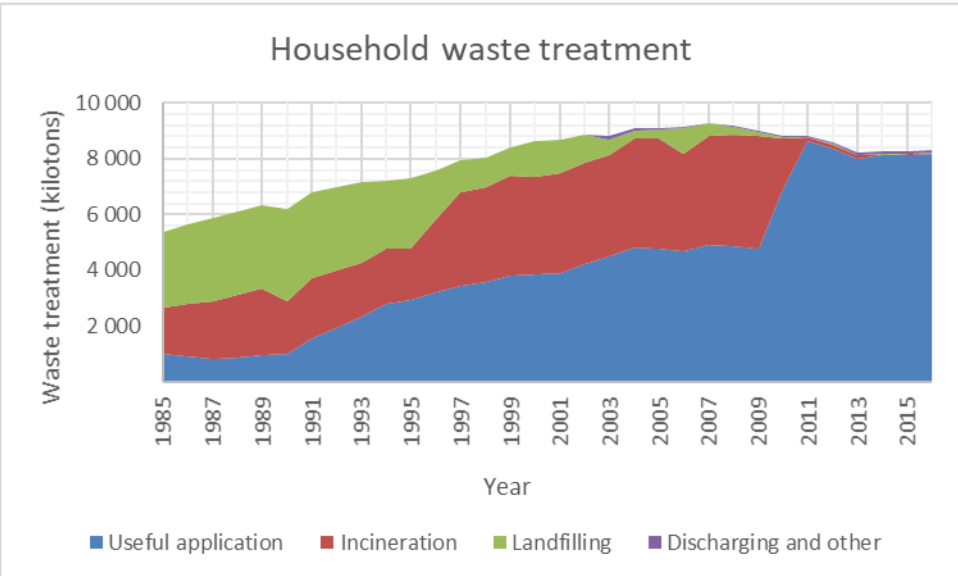

Figure 24: *Application of household waste (author's own, data from CLO, 2020).*

Scale advantages: aggregate costs

In figure 25, the total national municipal waste management costs are presented as incurred by municipalities. These are the costs of the activities that are paid with the *Afvalstoffenheffing* plus other non-EPR-related income sources (Rijkswaterstaat, 2019c). Data from two different sources is used, but show similar trends: between 1988 and 2012 the costs that municipalities have for all household waste (including waste streams that fall under EPR) have increased (Rijkswaterstaat, 2020b; CLO, 2014). This applies to the total costs (figure 25) and costs per ton (figure 26). According to an interviewee, the PROs in the Netherlands spend about 500 million Euros on waste management (P.O.2). This is about 22% of total waste management costs (PROs plus municipalities). No public figures are available for the total spending by producers on fulfilling their EPR responsibilities.

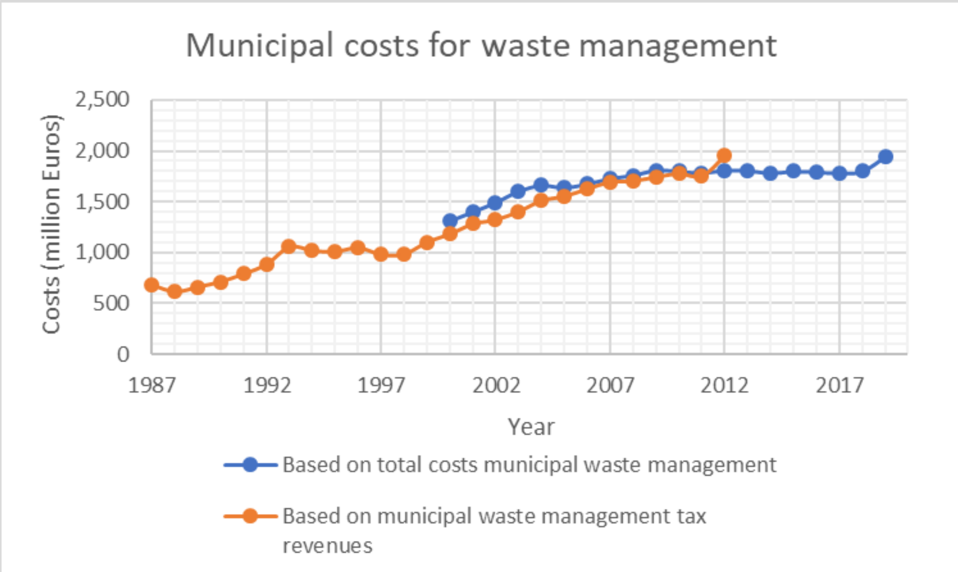

Figure 25: *Municipal costs for waste management (author's own, data from Rijkswaterstaat, 2020b; CLO, 2014).*

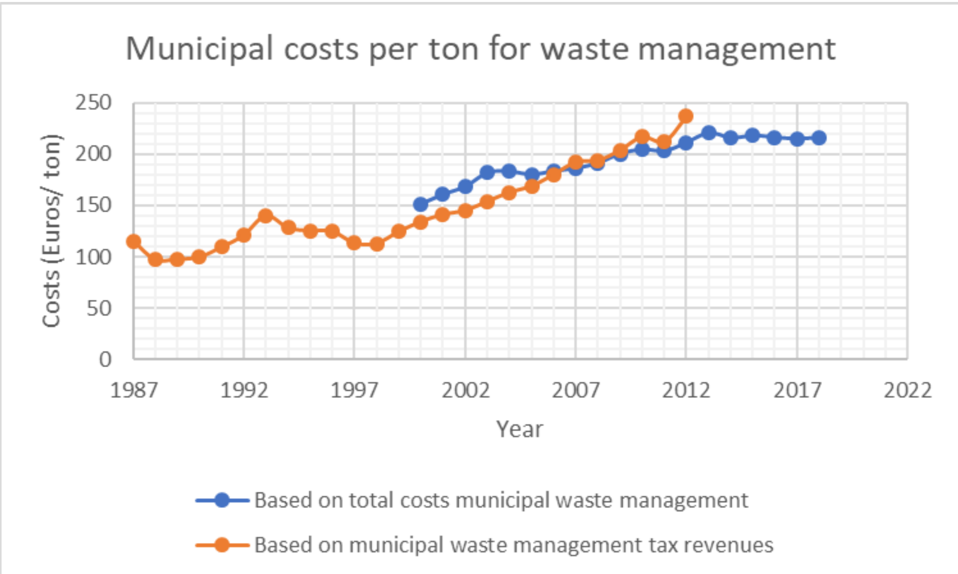

Figure 26: *Municipal costs for waste management (author's own, data from Rijkswaterstaat, 2020b; CLO, 2014; CLO, 2020).*

As mentioned before, since 1990 a range of waste management policies has been enacted. The effects EPR can have are to distill from these policies, but it can be concluded that the cost-shifting that occurs due to EPR does not weigh up to the additional costs municipalities have had. In the subsequent paragraphs, some evaluations on overall costs by interviewees are presented.

Some interviewees do not know whether waste management operational costs have actually gone down for the products subject to EPR in general (G.O.3; G.O.6). One interviewee is more critical and states the costs have only increased per ton of waste collected (P.O.2). Furthermore, the refinement of collection and recycling systems increases the costs per ton due to the additional measures and activities that have to be considered (P.O.2). Another interviewee states that a significant amount of money can be required to comply with legal standards and divert a waste flow away from incineration (G.O.3). For the material streams that do not have EPR and are expensive to recycle, municipalities generally opt for a low-value use such as incineration to keep costs to their inhabitants lows (G.O.3). Municipalities always keep a triangle in mind: costs of management, services to inhabitants and the environment (G.O.3). This applies to EPR and non-EPR streams (G.O.3). Due to EPR, more recycling takes place, also when higher costs have to be made (G.O.3). Another interviewee also states that "substantially better waste management results have been observed for waste streams with EPR than without EPR", because recycling activities often cost net money (G.O.5). Two other interviewees also mention that treatment away from landfilling and incineration has occurred (P.O.2; G.O.6).

According to an interviewee, it is hard to set up a system for creating secondary material streams, which start small and require multiple scale jumps before it gets mainstream and more producers can apply the secondary material (G.O.6). For mono-streams, this is easier (G.O.6). A mix has less appliances, and generally has a negative value (G.O.3). Another interviewee calls it an illusion that waste streams become profitable (P.O.2). This interviewee expects that with lowering metal prices over the years, the net costs of waste processing will only increase (P.O.2). Umicore – a recycling plant in Belgium – is technically able to recycle 20 types of metal, but only do 7, because the other 13 cannot compete with the virgin material (P.O.2). Furthermore, market characteristics are important, such as CO_2 prices, which can increase the incentive for recycling (G.O.6).

Regarding the link between costs and consumers, when a consumer does his best to separately collect the costs to the municipality and producers also drop (G.O.3). Deposit-schemes incentivize consumers to dispose of waste properly, but are expensive to organize due to financial flows and return-flows (G.O.3). A deposit scheme, however, works only for a limited number of flows (G.O.3).

An interviewee emphasizes that voluntary EPR action only works when it is profitable (P.O.2). The cooperation within and between parties keeps costs for individual producers relatively low still (P.O.2). Competition in the management of waste streams with negative value can lead to a race to the bottom in terms of collection and recycling, as in Germany according to this interviewee (P.O.2).

Regarding cost-structure, the costs for separate collection and transport are often significant compared to the cost of the recycling process itself (P.O.2). Though recycling could be profitable, this does not imply that the entire waste management is profitable (P.O.2). Another comment was made regarding product innovation and cost structure. According to an interviewee, innovation implies that new products have to be purchased and old ones do not function fully anymore (P.O.2). However, a separate collection and recycling line for an own product is expensive (P.O.2).

Overall, several interviewees were explicit about the merits of EPR linking costs and performance in general:

1. Establishment of properly working collection structures (G.O.3; G.O.5; G.O.6).
2. Without a legal framework and with negative net prices a recycling system would probable not exist for these cases (G.O.6).
3. More recycling, in line or better than stipulated in EU policies (G.O.3; G.O.5; G.O.6).
4. Robust organization for waste of products with EPR (G.O.3; G.O.5; G.O.6).
5. Cooperation by companies where they should but otherwise would not cooperate (P.O.2).
6. Reduction of waste for some streams (G.O.3).
7. Overall it is considered a strong and important instrument for accomplishing the circular economy (G.O.6). EPR can be a good tool to keep critical materials in the economy (such as rare earth metals), by making collection, recycling and reapplication in the own system mandatory (G.O.6.).

Environmental externalities

No broader quantitative analysis was performed, so in this section, only evaluations of the interviewees are presented.

According to several interviewees, a lifecycle approach can be helpful for determining environmental waterbed effects in the production, use and post-use phase (P.O.2; G.O.2; G.O.3; G.O.6). For example, high material and energy use in the production phase could be more than offset by less environmental pressure in the use phase (G.O.3).

Often, the environmental pressure of a product lies in production of virgin materials (P.O.2). The recycling process often requires less energy than the production of primary resources (G.O.5; G.O.6). Virgin material is often cheaper than secondary material (P.O.2). Environmental toxicity and circularity can also be a tension field: a toxic material can feature good circularity (P.O.2). Furthermore, substances that might be highly toxic and can complicate the recycling process might make a product more durable and make it longer available for reuse (G.O.2). The application of secondary material can also have environmental impacts (G.O.2. Littering is considered to still have a significant environmental impact in the Netherlands (G.O.3). One interviewee states that environmental risks are related to risk perceptions, and what is acceptable for a society (G.O.2).

A critique or points of improvement of interviewee is that collection and recycling targets are not enough, but that environmental criteria (e.g. eco-modulation) should be considered as well (G.O.6). Additional aspects such as standards have to be implemented to be able to execute and monitor environmental requirements (G.O.6). One interviewee expects that more environmental gains can be expected with better product design than continuing the recycling process of the same, complex products (G.O.2).

Information issues

Two kinds of information issues are considered here: product characteristics and product disposal information.

Several comments were made on product characteristics by interviewees. Information flow through the value chain is still very limited, but increasingly, environmental information is disclosed to producers downstream in the value chain (G.O.2). In the recycling phase it takes a lot of effort to determine how safe it is to process a material in a certain way (G.O.2). Another interviewee states that different materials can be present in one component, but that it can be virtually impossible to recover the different materials (P.O.2). According to this interviewee, ideally, in product design should be considered: 1) what material is best to go after or 2) to apply the materials as separate components which should then be communicated through the value chain to inform recyclers about (P.O.2). Disclosing this information is hard (P.O.2). According to one interviewee reporting on waste streams can provide information to competitors on production processes (G.O.2). Some companies therefore take their own waste back (G.O.2).

The visibility of the disposal fee in product prices differs over the five product groups. For cars, the waste removal fee is still visible on the receipt; this is not the case for the other four (anymore) due to political decisions (G.O.6). The interviewee is not familiar with studies discussing the effectiveness of showing the waste management costs of a product upon purchase by the consumer G.O.6).

5. Discussion

5.1 Chapter introduction

In this chapter the followings sections are presented respectively. First, a systematic comparison of the findings per case study and broader experience is presented. Second, the limitations of this study are discussed. Third, the academic relevance is reflected upon. Last, some policy implications are discussed.

5.2 Comparison of results

5.2.1 Section introduction

In this section the case-study findings and broader experiences that were presented in the results chapter are systematically compared per indicator. The distinction between practice and evaluation used in the results chapter is not explicitly used in this chapter. The formal institutional setting indicators and sub-indicators are presented firstly, followed by the incentives and change in practice (sub)-indicators, after which the market failure evaluations are compared. For each sub-indicator, the implication that follows from the comparison is presented.

5.2.2 Formal institutional setting

Formal responsibilities

Legal basis

The legal basis for responsibilities regarding the post-use phase of products is relatively extensive for batteries, with an AVV for a subcategory of the targeted products, EU product legislation, Dutch Product legislation and additional technical guidelines. Non-packaging paper responsibilities are stipulated in only two pieces: an AVV and a covenant. Separate collection of pharmaceutical waste has only recently been put in a national executive policy document.

Overall, it seems that for imposed-EPR, more formal policies are required to keep the systems functioning with regards to self-imposed or absent EPR.

Type of responsibility

The formal waste management responsibilities that are stipulated for batteries and non-packaging OPC are similar in most regards, though allocation of responsibilities is slightly different. In both product categories a collective has financial, organizational and informative responsibilities. In the PRN system a difference is made between producers and “first receivers”, which can be either importers or producers, where producers also have to take back non-packaging OPC and recycle it themselves, whereas first receivers only contribute financially. In the battery system, producers and importers have the same organizational, financial and informative responsibilities, which are different per battery type. Furthermore, in the PRN-system municipalities are still responsible for separate collection of OPC household waste, while in the battery EPR municipalities are not.

For pharmaceuticals, responsibilities are coined in terms of efforts. No financial or organizational responsibilities are outlined for pharmaceutical producers, just efforts disclosing information on environmental effects of their products. Municipalities are legally responsible for collection of pharmaceutical household waste, but pharmacists also put effort in separate collection. Furthermore, waterboards commit to improving knowledge about treatment of waste water.

Overall, imposed and self-imposed EPR systems have similar responsibilities, though in the self-imposed EPR producers seem to be more engaged in the physical organization of the waste management system. When an imposed or self-imposed system by producers is missing, responsibilities still predominantly lie at municipalities, and the role of producers is limited to providing information.

Targeted and exempted products

The battery EPR targets almost all batteries that are put on the Dutch market; the same applies to the PRN system regarding paper and cardboard (products) and the *Ketenaanpak.* In the Battery product Directive, batteries are sub-categorized based on chemistry and application mode. Paper and cardboard products on the other hand do not have legal subcategories. For medicines, all human purposes fall within the *Ketenaanpak*, and four medicine types are explicitly targeted.

Overall, the battery EPR and *Ketenaanpak* both have a more product-type focus, while the PRN system has more of a focus on material management. The Battery EPR and *Ketenaanpak* seem to be more focused on managing waste of products, rather than producing secondary material, but all are comprehensive in their effort. In the *Ketenaanpak* furthermore, a prioritization of products that ought to be management is more present than in the other two, possibly related to starting phase of this system compared to the more advanced battery and OPC cases.

System coverage & regulatory detail

Type of instruments

The policy instruments laid down in negotiated agreement ERP (non-packaging OPC) or imposed (batteries) are similar at the basis: regulatory or mutually agreed requirements and targets plus some rules on financing. For batteries, requirements and/ or targets are imposed regarding material contents, manufacturing, labelling, collection, processing, recycling and reporting hereof. Requirements differ per battery type in terms of chemistry and application mode and are stipulated for multiple commercial actors. For non-packaging OPC, finance rules, collection and recycling targets are also laid down. Overall, the EPR systems allocate responsibility potentially including targets, and the systems create a regulatory framework, that leaves room for employing all kinds of financial instruments. For medicine, the same applies, though the responsibility allocation is not accompanied with a regulatory framework, due to which parties cannot be legally hold responsible for not fulfilling their responsibilities.

Battery product legislation includes all the instruments that can be employed as presented in section 4.1; the non-packaging OPC agreements cover a smaller portion due to its sole focus on waste management and not broader product characteristics. The *Ketenaanpak* does not outline formal policy instruments, but the commitments target the entire product lifecycle and as such is in line with the product lifecycle approach that EPR is.

Overall, the more specific on particular waste streams and the more regulatory in nature (i.e. batteries), more policy instruments are used. Self-imposed systems or absent systems have a less diverse policy instrumentation.

Scope of the system

The three waste management systems – though the *Ketenaanpak* is not really a system, but more a cooperative effort – have a national coverage, which is more implicit in the *Ketenaanpak* and explicit for non-packaging OPC and batteries. This suggests that national harmonization is important in waste management policies, which is more established by imposed and self-imposed EPR than for non-EPR.

5.2.3 Incentives and change in practice

Waste management organization

Waste management structure coordinators

Here, the main coordinators in the waste management systems are discussed: those that hire parties or bring parties together for fulfilling the responsibilities.

In the waste management of batteries, collectives play an important role: Stibat for portable and industrial (electric bike) batteries and ARN for SLI and traction batteries. Furthermore, for car batteries – SLI and traction – producers also fulfill their responsibility individually. PROs are mentioned to be reliable and cost-effective options for producers to fulfill their responsibilities. Stibat and ARN are the most important coordinators. For non-packaging OPC, the PRN is the main coordinator on the national level, together with municipalities at the local level. In the PRN system coordination is also required with *Afvalfonds Verpakkingen*, the PRO for packaging OPC, because the packaging OPC and non-packaging OPC are mixed. The PRN system is mentioned to have increased the cooperation of municipalities for collection.

For pharmaceutical waste management, municipalities are the most important coordinators for collection and treatment of unused medicines on the local level. However, the waterboards' and pharmacists' organizations seem to be most active on the national level for inducing changes in the waste management structure, e.g. by means of the *Ketenaanpak*. More agreements and cooperation on the local level between pharmacists and municipalities have occurred. Pharmaceutical producers are mentioned to be involved in *Ketenaanpak* due to reputation sensitivity but do not coordinate the waste management system in any way.

More general evaluation of EPR finds that EPR has resulted in a robust organization for managing waste of products and cooperation where producers otherwise would not. Furthermore, the coordination between different waste systems is considered to be important due to the mixing of waste streams for which separate responsibilities exist. Also, producers in the different EPR systems were mentioned to face similar challenges, thereby inducing cooperation. Nationally, PROs are considered the most important coordinators, while on the local level municipalities are also still highly involved in the management of EPR waste streams.

Overall, for EPR systems with waste streams with a more negative value, PROs are more involved in coordinating the waste management system. The presence of multiple responsibility delineations (multiple PROs, municipality) for similar waste streams is associated with higher coordination efforts. Imposed and self-imposed EPR systems have both resulted in more coordination in waste management, with respect where EPR is absent.

Waste management structure

Regarding battery waste, Stibat coordinates, but has limited physical presence in the waste management structure: it coordinates mostly by means of agreements and service contracts, not physical market presence. For portable batteries, 25,000 collection points with national coverage have been established by Stibat, including municipalities, school and retail. Furthermore, Stibat commissions parties to transport and sort battery waste. Recycling of battery waste occurs in neighbouring countries, because no battery recyclers are present in the Netherlands. ARN has more physical presence, because it operates a waste processing facility for car waste. Challenges to the waste management system include: 1) increased safety related risks due to ignition of damaged lithium-ion batteries, 2) increased non-removability of batteries in appliances, 3) export leaks of batteries in appliances and vehicles.

The PRN organization has less market presence than ARN and Stibat: it coordinates, but does not hire parties for physical activities. Municipalities operate a system for separate collection, while OPC-companies act as an intermediary between paper producers and municipalities. Paper producers recycle the OPC so that it is used again. Municipalities have invested in the separate collection system, and 93% of the municipalities are a PRN member now. Furthermore, the system has a focus on OPC quality, because OPC quality is important for producers to be able to recycle it and apply it in products they make.

The waste management structure for pharmaceutical is somewhat different from non-packaging OPC and batteries. Pharmacists and municipalities both separately collect unused pharmaceuticals, and both hire parties for subsequent waste management ending with incineration (though as mentioned earlier, coordination on the local and national level is increasing). Pharmacists are mentioned to be important collectors as the bulk of the separately collected pharmaceutical waste is collected by pharmacists. No tangible change in the collection structure per se is observed due to the *Ketenaanpak*. Besides municipalities, waterboards as a public body have physical presence in the operation of the waste management system by operating systems to remove and excreted and flushed pharmaceuticals from waste water.

Generally reflecting on EPR, EPR has led to collection and recycling structures that would otherwise not exist. It is often collectively organized by producers. Municipalities are mentioned to keep an important role in operation. Often frictions occur due to interdependence of parties.

Overall, for EPR waste streams with more positive value, less PROs are less involved in the physical organization of the waste management system and more room is given to individual waste management operators (municipalities or companies). Both establish robust collection and recycling/ reuse systems, especially when compared to where such a system is absent. It should be noted that only unused medicine are potentially available for “reuse” after becoming waste, recycling is not an option.

Number of different products and waste streams

The amount of different batteries put on the market, nor the diversity in waste streams arising from battery products is unknown. However, considering the diversity in size, chemistry, application and increased use of batteries the number can be expected to be high. The delineation between portable, automotive (SLI) and industrial batteries is becoming increasingly blurred, which is a barrier to waste management. For OPC waste, 63 different types are distinguished legally (though not in a productive Directive with EPR), with over 200 different types distinguished in practice. Regarding pharmaceuticals, over 2000 different active ingredients are used in the Netherlands.

The number of different products for EPR in a broader sense is beyond the scope of this study.

Overall, it seems that large numbers of different products are present. Legal delineation efforts for each product or group of products seem to be hard and can potentially lead to a barrier in waste management due to unclarity about which legal regime a product belongs to, if not chosen carefully.

Waste management financing

Rules and agreements on finance

In the battery and non-packaging OPC waste systems, operational costs of the waste management system are covered by producers and first receivers. For pharmaceuticals, municipalities cover most of the costs, while pharmacists also cover a portion. Medicine producers do not face costs for pharmaceutical waste arising from households. Nationally, all activities in the three cases have market prices, but three exceptions exist. The contributions that portable batteries producers and non-packaging paper and cardboards first receivers pay is determined Stibat and PRN, respectively by means of a formal agreement on the waste management fee. Thirdly, a price guarantee is given to municipalities for separately collected non-packaging OPC. For pharmaceutical waste management, local agreements between municipalities and pharmacies exist about who pays what.

Generally reflecting on EPR, collectives are financed by producers and PRO hires parties or brings parties together in waste management. Municipal services are often used, for contract prices.

Overall, EPR/ AVV create clear rules for who pays what, and an EPR-like system could provide more clarity about who pays what for pharmaceutical waste nationally, which is now more fragmented on the municipal level.

Financial instruments

For batteries and non-packaging OPC, producers and first receivers pay a price per unit put on the market. For batteries, a unit is an individual battery, while for paper and cardboard products are paid form in terms of weight PoM. No financial instruments such as deposit-schemes are employed to improve separate disposal by consumers for both categories. Producers include all waste management costs in product prices for both categories; no pay-as-you collect systems have been found for end-users. For both, the costs are considered a fraction of the product price. No financial instruments are employed specifically in the *Ketenaanpak*, though public financial stimuli have been used, such as a subsidy for improving waste water management practices.

Generally reflecting on EPR, non-EPR household waste streams do not have waste management cost incorporation in product prices and are collectively paid for by taxes per household. According to most interviewees, EPR results in a fairer allocation of costs.

Overall, the financial instruments employed in imposed EPR and self-imposed systems seem to be mostly limited to a producer fee, incorporated in the product price, which is then used by PROs to bring together (PRN) or hire (battery EPR) other professionals.

Fee differentiation

Both EPR systems have a chain-deficit funding system where the gap between potential revenues and costs in waste management is filled by contributions of those that put products on the market. However, most battery types consistently have a chain-deficit, while non-packaging OPC seldomly has a chain deficit due to its competitiveness with primary material. Battery waste management fees are differentiated based on chemistry and size, which are formally differentiated in the AVV for portable batteries. In terms of volume, a large fraction of the batteries have positive value: lead-acid batteries. For non-packaging OPC, fee differentiation per unit put on market is absent. For pharmaceuticals no waste management fee is paid by producers to differentiate, but, if producers were to contribute financially a product-specific differentiation is deemed undesirable.

Generally reflecting, the fee differentiation is in line with the broader practices for EPR, where a PRO calculates to the total costs for waste management and allocates these costs to producers in accordance to their volume.

Overall, fee differentiation based on net operational costs is dominant in EPR. This applies to waste streams for which also an AVV has been given, and also to non-AVV waste streams. For pharmaceuticals – like for OPC – product specific differentiation is not preferred, possibly because both are more homogenous than batteries: OPC in terms of material and treatment (recycling), and pharmaceuticals in terms of treatment (burning).

Reporting, compliance & enforcement

Inspection & enforcement

Regarding inspection and enforcement, two separate sections should be considered: 1) inspection on waste management fee dues and put-on-market numbers, and 2) handling of waste material. Regarding the former, good cooperation seems to exist between PROs and the national government, where the AVV is generally considered a helpful tool to catch producers into the system which are actively identified. This applies to non-packaging OPC and batteries. For both streams, PROs also have implemented systems to check the figures reported to them by producer. The PROs can also audit producers and require accountancy statements. Regarding the handling of battery waste material at scrap companies, inspection by public inspection agencies is considered to be insufficient. Transferring additional power, however, to the PRO is not considered favorable. This leaves an important role for inspection to public inspection agencies for battery waste. The inspection and enforcement of duties for management of pharmaceuticals in their post-use phase were not explored.

Besides the case study specific findings, the high number of individually liable producers for the performance of an EPR waste management system is considered to be problematic for effective enforcement on the performance of such a system. One interviewee, when commenting on the broader functioning EPR, states that PRO should receive more power to prescribe and enforce measures, contrasting with the battery-specific finding. Other interviewees oppose or are more hesitant about this.

Overall, producers and PROs have the proper tools to monitor and enforce upstream activities (PoM and financial contribution inspection), but less so downstream (waste processing). The former is characterized by good cooperation with public authorities and AVV is a general strength, cooperation in the latter seems to be more lacking. Overall, public authorities remain to have an important role in enforcement in EPR.

Reporting & compliance

PROs for non-packaging OPC and batteries report annually to the government. Individual parties report to their collectives. For batteries the frequency has not been found. In the PRN-system, producers report quarterly, OPC-companies and municipalities monthly. For pharmaceuticals, the best available data about waste management is found in EURAL data, which appears to be of low quality.

Free-riding on the waste management fee is mentioned to be an issue for battery and non-packaging OPC. There, free-riding occurs mainly, because (new) small producers do not know they have responsibility. Internet sales to end-users directly – circumventing the fee – are mentioned to be an issue for both waste streams, and from PRN numbers, it seems that about 2% of the total non-packaging paper and cardboard is put on the Dutch market without paying the fee. Battery producers are generally compliant (also due to the AVV).

For batteries specific, illegal practices regarding collection and processing are mentioned to be a problem for waste streams with positive value. Also export in appliances and vehicles is considered a problem. This is not explicitly mentioned to be an issue for non-packaging OPC. Furthermore, consumer behavior is considered a problem for both waste streams, with 15% of batteries ending up in residual household waste and an increasing contamination rate of non-packaging OPC. Separate collection rates for pharmaceuticals are not available, but pharmacists are expected to be generally compliant with waste management rules. For waste water, 5% of the pharmaceuticals found in waste water is due to direct flushing of medicine waste.

These case-specific findings are in line with broader EPR evaluations: 1) AVV is a good tool to limit financial free-riding by producers, 2) ensuring proper waste disposal by consumers remains a challenge (littering and unseparated disposal). On the other hand, consumer incentivizing instruments are only employed to a limited extent, though opinions differ about the desirability of these systems due to the high operational costs.

Overall, the level of free-riding on the financial contribution is limited, though small party non-compliance and internet sales are a concern. Significant problems exist for imposed EPR waste streams with positive value, where materials get out of sight in waste management. Also the leaking of materials through product exports, application in other products and residual household waste are problems there. These seem less problematic for self-imposed EPR, which has a more voluntary character: waste collectors that do no want to be a PRN member can choose to not be one. When EPR is absent, reporting on waste streams seems to be of low quality, thus EPR increases reporting quality.

Quality control & certification efforts

In the case of batteries and non-packaging OPC, certification efforts and/ or methodologies have been developed as means of quality control. For batteries, the testing method is used to determine how environmentally friendly the parties involved in waste management operate, with a more ambitious testing than the legal requirements stipulate, thereby being able to evaluate whether legal EPR responsibilities for EPR are fulfilled. Also deconstruction guidelines are developed for cars, relevant for automotive batteries. In the PRN network, a certification method is adopted for OPC companies to ensure administrative and operational quality. Furthermore, minimum quality standards are clearly formulated for non-packaging OPC to ensure proper separate collection by municipalities. Waste management certification efforts are absent for pharmacists, but certification is expected to be of limited value.

The case study findings are in line with the broader finding that often, certification and testing methods are developed by PROs to assess the performance of parties and secure waste handling practices.

Overall, imposed and self-imposed EPR increase quality control efforts for the waste management phase. In absence of EPR, these efforts are less salient, though for pharmaceuticals additional quality control efforts in the form of certification is deemed unnecessary.

Circular practice beyond waste management

Designing and business innovation efforts

First, it should be noted that the effect of EPR on new business cases and product innovation is harder to establish, because many more incentives are present there besides post-use considerations.

Regarding batteries, it was found in the literature that producers and recyclers cooperate only to a limited extent. Furthermore, an interview finding was that EPR has a limited effect on battery design. Some new business models where batteries are reuses as stationary energy storage have occurred, but the relation to EPR is unclear. Transferability of producer responsibility to a new producer is considered a strength here, which is still an issue on the EU-level. Much of current innovation seems to focus on better battery performance, not recyclability. In the PRN-system, no explicit cooperation towards innovative products or business models was found. It was mentioned that the PRN-system cannot have effects here and switching from material input in production is hard due to specific requirements.

Whereas these efforts where not found for batteries or non-packaging OPC, the *Ketenaanpak* also steers towards prevention of pharmaceutical use. Also, inter-pharmacist cooperation on stocks was mentioned to reduce waste. Furthermore, the branch organizations for innovative medicine and KNMP work together on sustainability efforts. Regarding product design, no incentives appear to exist for ecodesign now. In general, active ingredients lose functionality, when they are more environmentally friendly, but innovation is occurring for more efficient application and storage of medicine. Foreign production limits the amount of influence on production.

The broader experience is that EPR in its current design has no to a limited effect on more circular design. The physical distance as well as within a value chain between producer and waste manager is considered to be a barrier, because the signal EPR might send gets mixed with more important incentives to producers. Product innovation has a focus on functionality, not circular characteristics. The expectation is that more direct regulation for circular design is more effective and experiments with a waste management fee differentation based on circularity criteria are conducted now. These findings are in line with the case findings.

Overall, the effects of EPR on circular practice beyond waste management is limited. Other types of policies are considered better steering mechanisms for achieving more circular design.

5.2.4 Market failure evaluation

Scale advantages

Performance

The collection and recycling performance of the three waste management systems differ. Portable batteries have a stable collection rate around 45-50% of PoM, while all batteries together have a more fluctuating collection around 35% of PoM. Recycling efficiency of the collected batteries, however, is double: above 70%. EPR is mentioned for having a positive effect on collection and recycling of battery waste. For the pool of batteries available for collection, the collection rates are mentioned to be high. For paper, recycling more or less equals recycling, resulting in 70-80% recycling with regards to PoM. The PRN system is mentioned for having a positive effect on the stability of separate collection. For pharmaceutical waste, only EURAL data was found, from which good collection numbers could not be obtained. Estimations suggest that 66 ton is available for separate collection. All pharmaceutical waste ending up in residual household waste or in separately collected waste stream is incinerated. WWTPs remove 50-80% of the pharmaceuticals.

When a broader perspective is taken, EPR waste streams outperform non-EPR waste streams in terms of separate collection and recycling. EPR is considered a good and important tool for keeping materials in economy.

Overall, EPR systems enable higher collection and recycling rates, compared to the pre-EPR situation. This applies to imposed and self-imposed systems. The performance comparison with separate collection of pharmaceuticals cannot be made, due to lacking numbers. Of the treated waste, a potentially high portion of waste enters the environment in the Netherlands compared to waste streams batteries and OPC, due to 50-20% discharge of pharmaceutical waste in waster water on surface water.

Aggregate costs

For batteries, the PROs are mentioned to bring down the costs of waste management to individual producers. Higher amounts of batteries collected and processed bring down the costs per ton collected. Between 2011 and 2016 the costs dropped from 1595 Euro/ ton to 1368 Euro/ ton for portable batteries. Combining different battery waste streams is mentioned as an opportunity for benefitting from economies of scale. For batteries, a significant portion of the costs are associated with the collection and transport of battery waste. Also, the revenues that can be obtained from selling of secondary material are important for the overall costs of waste management.

For paper, the costs are low compared to that of batteries: even when a chain deficit occurred, the costs were less than 1 Euro per ton waste or PoM. Higher collection rates are accompanied with lower costs per ton collected. The focus on paper quality in the system, as well as generally more expensive primary paper material are mentioned to be important for the low costs. Also, the collection structure has become more efficient due to cooperation of municipalities and investments in the collection infrastructure.

Rough estimations were made for the management of pharmaceutical waste. Current separate collection and additional waste water treatment have both been estimated to have operational costs in the order of magnitude of a hundred thousand Euros per ton waste. Per ton pharmaceuticals used, additional waste water treatment appears to be more costly than separate collection now: 1,000-2,000 and 39,000-54,000 Euro/ ton used respectively. The total costs amount to 0.11% and 3.1% of total spending on pharmaceuticals in the Netherlands respectively.

Taking a broader perspective, material prices are mentioned to be important for the overall costs of waste management. The further refinement of waste management systems targeting smaller groups of products for separate collection and subsequent recycling is expected to be relatively costly due to loss of scale advantages. Despite EPR, the net costs for municipalities for the management of household waste (including streams that have EPR) has increased since 1990. The effects of EPR on the total cost are unclear. When the net costs of PROs and municipalities are lumped together, than PROs carry about 22% of the total costs, suggesting a significant cost-burden allocation, even if municipalities could operate – which is unclear – those EPR waste systems more efficiently. On the link between recycling and waste management costs, the EPR systems have probably increased recycling, because municipalities would have likely opted for the less costly option: incineration.

Overall, the costs per ton waste greatly differ for the three waste streams. Imposed EPR (e.g. batteries) – though profiting from scale advantages through collective organization of producers – have relatively high costs, due to high costs for collection & recycling. Self-imposed EPR have low costs due to the relative high price of primary material and operational efficiency gains. Non-EPR, in terms of volume a minor stream (pharmaceuticals) have high costs, probably due to the diffuse contamination in waste water, the relatively high number of collection points with respect to the waste volume of separately collected material, and absence of secondary material revenues, including savings by redispensing returned, unused medicines. Despite capitalizing on scale advantage potential and effectively shifting the cost-burden away from municipalities, the effects of EPR on overall costs for waste management are unclear.

Environmental externalities

Environmental damage in value chain

For batteries and non-packaging OPC value chains, the environmental damage that occurs predominantly lies in the virgin material production phase. Recycling of OPC and batteries is better for the environment compared to virgin material production, but can also be energy intensive (paper and batteries) or chemical intensive (batteries). Battery EPR seems to have had a positive effect on the environment, though it is mentioned that requirements should be linked more to the environment. With the high focus on recycling, also the non-packaging EPR also has resulted in environmental gains.

For pharmaceuticals, most environmental damage occurs due to improper waste management during production, outside the Netherlands. In the Netherlands, most environmental effects are associated with waste management: leakage and human exposure during separate collection or residual household waste collection, as well as discharging on surface water of treated waste water effluent. Environmental estimations about current damage and environmental benefits of additional waste water treatment are highly unclear. Considering the high energy and material demand for additional treatment, significant environmental benefits seem to be absent.

From a broader EPR perspective, the lifecycle approach is deemed important by all interviewees for assessing the environmental effects. In line with the case findings, most environmental damage occurs in the virgin material production, but several interviewees also point to the tension point of product ecotoxicity and circularity. With no leakage, materials with high ecotoxicity could be preferred from a circular point of view. Interviewees expert more environmental benefits from better design than from improved waste management process. Most importantly, a majority of interviewees think that EPR should be more closely linked to environmental considerations.

Overall, EPR systems result in a net loss of environmental damage through the replacement of harmful virgin material, though the environmental performance of EPR is insufficiently benchmarked. It is far from clear what the environmental benefits would be for EPR for medicine in the form of additional waste water treatment paid for by producers, or increased separate collection.

Costs and pricing of environmental damage

Considering that materials and components of a product are created all over the world and thus are subject to a wide variety of legal regimes it is impossible to comment on this specifically. However, as stated, virgin material production for batteries – especially in developing countries – is associated with low regulatory pressure. For non-packaging, though pricing efforts in primary production countries have not been evaluated, market prices already favor recycling over virgin material, thereby resulting in the production of more environmentally friendly material. For pharmaceuticals entering the Dutch environment, the environmental effects are largely unclear, let alone the pecuniary costs and required pricing effort. No pricing effort exist for incorporating environmental damage in product prices here.

From a broader perspective, taxes were mentioned as potentially having an effect, such as a carbon tax and taxes on waste. The extent to which these affect waste management costs was beyond the scope of analysis.

Overall, the costs to the environment are insufficiently priced in products, but when lower operational costs are associated with low environmental costs, the preferred option (for waste management) for the environment aligns with the waste management activity.

Information issues

Info on separate collection

For batteries, the communication efforts by means of campaigns and public education are considered strengths. However, information on the product itself about disposal is considered a barrier to proper disposal. For non-packaging OPC, strengths or weaknesses for improving separate collection were not explicitly mentioned. The stability of separate collection was mentioned to be beneficial to the investment environment. Regarding medicines, the *Ketenaanpak* has resulted in better separate collection due to campaigning efforts and public education. More awareness of environmental effects of pharmaceutical throughout the value chain has occurred.

In a broader context, consumer engagement is considered vital to a good functioning of EPR, requiring continual attention. PROs are mentioned that they should better cooperate in this.

Overall, EPR has a positive effect on the information available for enhancing separate collection efforts. However, also non-EPR approaches can result in this, as illustrated by the medicine case.

Product characteristics

For batteries, several informational issues exist. The waste management process is hindered by poor chemistry labelling on batteries, while also cross-border information issue exist such as differences in waste treatment (e.g. recycling or incineration) between different countries. For non-packaging OPC, no informational issues or particular benefits were found. Regarding pharmaceutical waste, the low reporting on environmental characteristics of pharmaceuticals and their waste is considered a barrier for waste water management. Furthermore, uncertainty surrounding storage conditions and the quality of unused, medicine hinders the re-dispense of medicine.

Evaluating EPR more generally, product information that is beneficial to waste management is still only disclosed to a limited extent. This is in line with the case study findings.

Overall, information disclosure throughout value chains is still limited, though EPR does have a minor effect here.

5.3 Limitations

5.3.1 Reflection on methodology

This study has covered significant ground. Some sections have been assessed in great detail, while others have been to a lesser extent. This was required to come to a comprehensive understanding of and find answers to all research questions. Some estimations were presented in this paper, for example, the costs for medicine waste. These are all rough and should be considered a first attempt at exploring costs and benefits, for example, neglecting co-benefits arising from combinations with treatment for other waste streams. The lack of clear data on financial flows, product characteristics, waste characteristics and environmental impacts hindered a thorough quantitative analysis. Due to this, insights from the interviewees and the rough quantitative assessment got a more prominent in this study than originally planned.

5.3.2 Reliability

Reliability is high when the results are consistent internally (i.e. consistent findings from the same data source) and externally (i.e. consistent findings upon replication of the study). Internal reliability was assured by having control questions in the interviews as well as by asking follow-up questions when interviewees seemed to contradict themselves. In all cases, except once, the apparent contradiction unraveled into a consistent story. External reliability has not been checked, as this is not a follow-up study nor has this study been replicated.

5.3.3 Validity

Validity is high when the observed effect variables are solely affected by the independent variables (internal validity) and the relation can be generalized to other settings (external validity). Ensuring validity for this study was an immense task, because EPR is an approach rather than a specific policy instrument. To identify potential cause-effect relations, a broad scope on the institutional and market was taken. To ensure validity, triangulation was used. Results were obtained from academic literature, policy & legal documents, databases, grey literature, self-reporting by organizations and interviewees. This assured internal validity for the case studies. External validity was strived for by comparing the different case studies, as well as aligning it with broader findings that were not specific to the case studies. Additionally, by interviewing a large range of different expert actors external and internal validity was improved. Considering that these systems are so complex and intricate that relatively few people in the Netherlands know the functioning hereof, these proved to be a valuable source of information.

Some limitations exist regarding validity. First, the empiric economic academic literature of EPR is not well-developed globally. The studies that exist are either simple theoretical models or technology focused business evaluations. Hereby, the external validity could not be evaluated with regards to the academic literature nor could the methodology be benchmarked, requiring a completely new approach that was synthesized from different disciplines analyzed with an institutional welfare economics lens. Second, considering the institutional complexity surrounding and diversity of product characteristics makes generalizing findings difficult. Context seems to be important to the functioning of an EPR system.

Third, a counterfactual is lacking. Ideally, one would want to create a counterfactual. However, the Dutch EPR systems and economy have several unique characteristics that disable the use of another country or set of countries to act as counterfactual (e.g. the ability to apply for an AVV). It was attempted to derive a counterfactual by comparing specific household waste flows with the respective company waste flows by means of the EURAL code data. However, this data turned out to have low quality (e.g. spikes in data, legally impossible activities such as medicine recycling). The self-reported data by producers are of high quality, but have such a limited and specific scope that they are not comparable to other waste streams. Overall, the findings of this report should be considered an exploratory overview of important characteristics for the functioning of EPR systems that derives it validity from the extensive combinations of different data sources, though each data source by itself does probably not provide the highest quality findings.

5.4 Academic relevance

5.4.1 Academic implications

The added value of this study is an empirical understanding regarding the governance and economics of EPR. Institutional and market conditions determine the degree of collective action and free-riding. Many of the forms of free-riding and collective action that one would expect are actually observed. For example, 1) when no benefits are expected, collection and recycling barely exceed the legal requirements, or 2) when benefits are expected non-compliance occurs when bureaucracy is costly and enforcement is low. Furthermore, this study presents a detailed description of the governance mechanism that could be used as benchmark for how EPR systems look in practice. The importance of market imperatives is also discussed. Non-surprisingly, the price balance between secondary and primary material is an important determinant for how valuable it is to recycle. At the same time recyclate quality is important to be competitive with primary resources. Data on material quality and the connection with pricing has not been found, though high quality appears to be an important reason for the success of the PRN system and low quality is associated with downgrading and incineration.

On the other hand, this study shows that allocating incentives to producers to internalize waste management externalities in product design are outweighed by other considerations, most notably functionality for the primary user. Allocating circular incentives at the margin, does not necessarily lead to improving circularity or social welfare. The potential for circular design by EPR is thus overestimated in the simple economic models that compute efficiency by evaluating marginal costs and benefits.

5.4.2 Future research

Many different directions for future research exist. First, the governance mechanisms as described in high detail for the systems in the Netherlands could also be explored for other countries to see how EPR systems are different from each other. Second, it would be interesting to see how EPR scores on achieving policy goals or broader impact categories with respect to other policies that could potentially achieve the same results such as additional pricing efforts on the primary material market. Third, from a normative perspective it would be interesting to evaluate whether EPR systems lead to normative change regarding circularity or the environment. Most interviewees stated that EPR sends a signal that uncontrolled production has environmental consequences. Green norms survey data could be used to see how EPR system implementation changed those norms.

The lack of empiric literature found by means of the literature review could be explained by the lack of proper amounts of quantitative data of sufficiently high quality. In this study, it was tried to great lengths to find numbers and figures - e.g. regarding finance or (pecuniary) costs and benefits of impacts on the environment - but these were simply unavailable for the most part. When these numbers become more readily available in the future, due to more transparent financial flows and better reporting on environmental effects, a similar analysis can be performed as presented in this study. With new updates of the EPR regulatory frameworks, EPR systems remain an important topic of analysis for studying circular economy.

5.5 Policy implications

EPR regulation has been designed to stimulate more environmentally friendly products, and to increase the collection and recycling of those products. The overall aim is to reduce environmental stress and shifting the cost-burden away from municipalities. Given the results, some policy implications and recommendations can be made.

First, EPR effectively creates structures for separate collection and recycling, but positive environmental impacts – though occurring – and operational efficiency – occurrence unclear – are not sufficiently benchmarked. Higher collection and recycling rates do not necessarily correspond with more environmental benefits or higher operational efficiency. Therefore, given the importance of competitiveness (price) of secondary materials with primary materials for the cost-effectiveness of recycling, Pigouvian pricing efforts, based on emissions, can be considering, targeting both the emissions in primary and waste management. The production of secondary materials would be promoted relatively, compared to virgin material, because virgin material is associated with higher environmental impact. Ideally, the pricing efforts such as environmental taxes are harmonized or implemented on the EU-level with corrective pricing effort for imports at the EU border, because the EU has an internal market in which products can freely go from one country to another. For material imports at the EU-border, a reporting scheme on associated emissions could be established by the EU institutions. Though beyond further analysis in this study, the ideas of the European Commission on establishing a carbon border adjustment mechanisms are in line with this (European Commission, 2020).

Given the diversity in products, from an administrative point of view, Pigouvian pricing of emissions seems a more attractive option than tariff differentiation based on circular characteristics of a product, because the same materials and associated emissions can be recombined in a multitude of different products. Furthermore, if a product causes issues in the recycling phase, the operational cost for that group of products can be expected to be higher – especially if emissions are priced: incineration generally being more expensive than recycling – thereby resulting in higher costs for that product group in another way. This does not take away the risk that within a product group a producer might free-ride on the innovation efforts by others in that product group that seek to reduce the costs. Therefore, a second policy recommendation is given.

Second, the incentive that EPR puts on producers for designing more circular products – for example through the waste management fee – is relatively weak compared to other incentives. Direct circular design regulation is expected to be more effective. Therefore, on the EU-level, the Ecodesign Directive could be complimented with circular design requirements such as repairability, durability and modularity, besides the energy efficiency stipulations that it has now. This addresses the 'design-externality' that current EPR seems unable to affect: the negative effects a product's design or harmful substances can have downstream in the value chain to consumers and waste managers.

Third, waste management systems, including EPR systems, are legally and operationally intertwined. The complexity and required amount of coordination as well as other transaction costs can be expected to increase when more EPR systems are implemented and more responsible parties are created, or existing systems are further refined. To evaluate the environmental benefits with regards to potential additional costs, and considering the lack of data on cost-benefit creation and allocation, an assessment method could be created in line with a reporting method – based on existing and data, for example on emissions during waste management – to evaluate the merits of EPR systems on the national level by Rijkswaterstaat or I&W. This could help in consistently comparing EPR systems, and waste streams under review for EPR.

Fourth, the distance in the value chain between producers and recyclers is large in general. Systems where recyclers and producers are the same party more recycling is occurring (e.g. OPC) or expected to be occurring (e.g. batteries, due to the EU-efforts to create giga-battery factories that also make use of battery waste). Potentially, individual producers and recyclers can be brought together by requiring recyclate material contents, or through joint innovation efforts for recycling aimed at increasing the suitability of recylate for the production of products that producers put on the market. Pilots can be done here, initiated by PROs, Rijkswaterstaat or the Ministry.

Fifth, specifically regarding pharmaceuticals, the environmental impact of a medicine after it has been used can become a criterion for market access of the medicine on the European level. The overall weight that this criterion should have is beyond this study, but considerations could for example include: the presence of an environmentally more friendly alternative or the product's ecotoxicity.

Regarding the waste management of medicine, it is relatively unclear what benefits EPR would have other then cost-shifting – if that is the goal – because the situation as it is now is not well monitored or documented. An assessment can be made regarding the amount of material that is available for separate collection. Furthermore, a clearer picture of the overall expenses that are occurring for the waste management of pharmaceuticals can be co-created and co-monitored by the associations of municipalities, pharmacists and waterboards. First, a decision should be made regarding to what extent separate collection and/ or additional waste water treatment have broader benefits to society, because the costs per ton waste seem high now. Then, a more elaborate decision on financial, organizational and informational responsibility allocation amongst actors, be it EPR or another form of waste management. The implementation of EPR is not recommended at this stage.

A final recommendation concerns the fate of separately collected, unused medicine. Now, these are disposed of out of precaution, though they might be suitable for reuse. It is recommended to the Ministry of Health, Welfare and Sport that clear criteria are developed for when a returned, unused medicine can be redispensed. This can potentially steer the innovation in technologies monitoring storage conditions of medicine and reduce the amount of medicine that is wasted.

6. Conclusion

This study presents an empirical contribution to an understanding of the functioning of EPR systems in a comprehensive, societal context by evaluating - through case study analysis - how effectively EPR can incentivize circular, social welfare-increasing practice. Five themes were central to this study, together enabling a conclusion on the contribution of EPR to circularity and social welfare. The five themes can be categorized as: 1) key effect variables (i.e. market failures) and, 2) explanatory indicators, consisting of: i) formal institutional setting, ii) restructuring of incentives and organization, iii) circular practices and iv) cost-benefit outcomes.

First, regarding the market failures that are present in value chain leading to excessive waste and low circularity, three have been explored explicitly and exist: informational issues, environmental damage and neglected scale advantages in waste management.

Second, a range of instruments is employed in formal EPR policy documents that – amongst others – have a link to those market failures. The instruments are delegatory and regulatory in nature, including material bans, collection and recycling requirements (often accompanied with targets), as well as information requirements for disclosing information about product-specificities and management and disposal of post-use products. The central instrument to all EPR: shifting the cost burden of waste management to producers by reallocating financial responsibility. The legal requirements can differ significantly between EPR-systems, but also differ significantly within an imposed EPR, illustrated by the different legal regimes for different types of batteries with the Battery Directive.

Third, in practice producers fulfill their waste management practices predominantly through collectives (PROs), that coordinate a waste management network. This keeps costs to individual producers low. Often, municipalities are still heavily involved in separate collection and are compensated for these efforts by the collective. Furthermore, EPR legislation in the Netherlands enables sectors to create their own waste management system targeting household waste, as illustrated by the PRN-system. PROs differ in terms of market presence: PRN mostly brings together parties to come to mutually benefitting agreements and monitors performance hereof, Stibat also operates a structure and hires parties to do this, while the ARN also has a factory that helps the recycling process. For pharmaceuticals no EPR exists and the waste management system is more fragmented.

Producer responsibility organizations and individual producers make use of different tools that to different extents incentivize other parties, such as consumers, municipalities and waste processors. Parties that put a product on the market generally incorporate an advance disposal fee in the product price, from which the PRO or individual producer activities are paid. Consumer-rewarding systems for separate collection are largely absent. In EPR systems, extensive quality control methods are developed, including testing, auditing and certification efforts. Quality control incentivizes and benchmarks: 1) better separate collection (e.g. municipalities' compensation for collected OPC is tied to contamination of it), 2) better handling of waste, 3) monitoring of financial, product and waste flows. AVVs are considered a particular strength for limiting financial free-riding producers.

Challenges exist in the form of: financial free-riding through internet sales to end-users, second-hand exports reducing the pool for collection and inter-dependence of and frictions between parties regarding collection and quality of separately collected material. For pharmaceutical waste, discussion still exists for who should pay in the first place, next to the height of contributions. In EPR systems, furthermore, non-compliance issues exist for waste with net positive values. PROs and public organizations experience friction here, due to a by some parties perceived lack of monitoring and enforcement on these sites. Overall, EPR is associated with robust organization of the waste management systems by producers, but governmental organizations still have an important role in collection and enforcement.

Fourth, increased circular practice beyond waste management seems limited: circular design and circular business models do not seem to result from EPR, though EPR could have an effect at the margin. For batteries, even a reduced removability of batteries from appliances has been observed. Direct regulation on circular design is expected to be more effective. Product innovation is largely driven by functionality to primary users. The effects of EPR policies are concentrated in waste management, where significantly more separate collection and recycling occurs due to EPR.

Fifth, costs and benefits – also tied to the market failures – are created and (re)allocated by the way the systems operate in practice. EPR has effectively moved operational costs for waste management away from municipalities: waste costs, previously constituting a production externality, have been transformed in producer costs. Producer costs for post-use management of management seem to be about 22% of the total costs that municipalities and PROs have. However, the total nor the municipal costs for waste management have decreased. It should be noted that a counterfactual for this finding is absent. Higher costs are probably due to the further refinement of collection systems as well as additional policies, such as minimum waste recycling treatment requirements and taxes on waste. Recyclates can often not compete with virgin material, but when it can, the costs for operating the system are low (e.g. lead-acid batteries, OPC). Overall, it is unclear whether EPR has resulted in operational efficiency gains, but in practice producers benefit from economies of scale by means of collective organization.

Regarding environmental costs and benefits, as well as environmental externalities (unpriced costs and benefits), it seems that EPR has as positive effect. However, EPR steers on activity – collection and recycling – not on impact. Overall, the environmental impact from the supply chain is likely to have been reduced so far, due to increased recycling and collection: unpriced, environmental damage arising from material production in the front of the chain is reduced. It is widely acknowledged that environmental consideration should be incorporated more in EPR.

Regarding costs and benefits, tied to information market failures, EPR seems to have had a positive effect on consumer engagement in separate collection due to campaigning. Product labelling is still considered an issue, due to a lack of knowledge by the consumer and waste managers on material contents, recyclability and potential (eco)toxicity. Strategic considerations – for example, to not potentially inform competitors about important product(ion) characteristics – seem to be at the basis.

Overall, it can be concluded that EPR – so far – has resulted in higher social welfare and circularity gains, but the circularity gains are mostly associated with material waste management, not due to improved circular design or new business models.

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Acknowledgements

This thesis project draws from the insights, feedback and guidance from a lot of people. First, I want to thank my Utrecht University supervisor, Walter Vermeulen, a real academic expert in the field of circular economy and waste management. Second, I want to thank my CPB academic supervisor, Sander Hoogendoorn, and the person with whom I have closely worked together during my time at the CPB, Joep Tijm. I felt a real part of the project team and could approach you with whatever problem I had, thank you. Lastly, I would like to show gratitude to all the experts in the field who generously made time and shared their professional experiences with me, in alphabetical order:

- André Habets
- Arie de Jong
- Arjen Brouwer
- Dirk Stobbe
- Hans Spiegeler
- Hielke van den Brink
- Janet Kes
- Joris Quick
- Mark Overman
- Mark van Waas
- Marcel Verweij
- Michaël Bentvelsen

Togethers, all the mentioned persons have enabled me to write this thesis. Thank you.

Appendix 1: Preliminary assessment criteria

Indicator	Qualitative sub-indicators	Quantitative sub-indicator
1. Waste management operation	Type and extent of collection, treatment & disposal by producers & municipalities	Rates, cost-structure for operation
2. Environmental externalities	Greenhouse gases; soil, air & water pollution in production & waste management	Emission rates, energy use, mitigation costs
3. Secondary-primary material markets	Fair innovation environment & competition between and within markets (reflected by material prices)	Taxes & subsidies for producers
4. Responsibility	Type and extent of responsibility: physical, financial, informative & collective or individual	Expenditure by producers & municipalities
5. System coverage	Targeted & exempted products	Number of different products, product/ waste volumes
6. Legal regulation	Level of detail for EPR system operation, type of instruments	Xxx
7. System financing	Internalization of waste management prices in product, who pays what (i.e. how activities and expenses under indicator 1 are paid for)	Expenditure by municipalities & producers & inclusion in consumer price
8. Targeted choice margin	Affected activity in the value chain: consumption, production, innovation, collection, treatment, disposal	Xxx
9. Compliance	Types of sanctions, presence of free-riders, quality control in scheme	Frequency non-compliance, sanction height, inspection frequency
10. Firm strategies	Changes in design, material/ component use, product mix, take-back logistics, producer-consumer relations, contracts and reasons for these changes (market opportunities and policy imperatives)	Material volumes, R&D expenditure, costs and access to best available technology
11. Solving market failures	Improvements (lower costs to public and/ or producers) in waste management operation, environmental externalities and secondary-primary material market	Reduction in operational costs and (monetized) environmental externalities

Appendix 2: Interview questions

In the table, the questions for the interviews are presented along with themes to be explored in with the question (can be used in follow-up question if the interviewee does not say something about this). Some themes are optional and can be asked depending on time availability, knowledge and position of the interviewee.

Name:

Recording:

Anonymization:

NOTE: these questions are explicitly linked to the assessment criteria in Appendix 1.

Questions	Relates to indicator
1. What is your background?	Control question
2. What organization do you work for?	Control question
3. What is the relation of your organization to circular economy?	Control question
4. Are extended producer responsibility schemes in place in the sector?	Control question
5. How is the product's waste organized? - role of municipalities and producers - Type extent of collection, treatment and disposal. *Optional*: - collection, treatment, disposal rates and costs	1
6. Which emissions to the environment occur in the production and waste management process? - soil, air, water *Optional:* - emission rates, energy use, mitigation costs	2
7. To which extent does a level playing field exists between secondary and primary material markets for your products? - material prices - market power *Optional* - taxes & subsidies	3
8. What kind of responsibility do producers of your product category have? - physical, financial, informative - collective, individual *Optional:* - expenditures by producers and municipalities	4
9. Which brands and products are subject to those responsibilities? *Optional:* - number of different product, product and waste volume	5
10. What level of freedom do producers have regarding giving shape to those responsibilities? How does the government influence this? - role of instruments	6
11. Are waste management costs reflected in prices? Who pays for the waste management?	7

Optional - Expenditure by municipalities and producers	
12. Which choices in the value chain do the policies seek to influence? - consumption, production, innovation, collection, treatment, disposal	8
13. To what extent does free-riding behavior occur regarding waste management (responsibilities)? - Sanctions, compliance *Optional* - Frequency of inspection and non-compliance	9
14. Which changes take place in the way producers do business due to the waste management policies (responsibilities)? - Eco-design, material use, product mixes, take-back logistics, contracts - Role of the market: available techniques *Optional:* - Material volumes - R&D expenditures - Costs of best available technology	10
15. To what extent does allocating responsibility to producers for managing their products in the post-use phase help overcome problems regarding waste management, environmental pollution and secondary material use?	11
16. What do you think are strengths and weaknesses of EPR?	Control question
17. Which other things would you like to say or ask?	Control question

Appendix 3: Overview formal overarching institutional setting

Indicator	Sub-indicators	Results
Formal responsibilities	Legal basis	Overarching *Wet Milieubeheer*, incorporating: Waste Directive (EU), Reach Directive (EU), Product Directives (EU), Regeling AVV (NL) *Future:* UPV Besluit (NL, based on EU) Single Use Plastic Directive (NL, based on EU)
	Type of responsibility	Physical, financial and informational, collective and/ or individual
	Targeted products	Batteries & accumulators (also AVV), car wrecks, car tires (also AVV), packaging (also AVV), electric and electronic appliance (also AVV), non-packaging paper and cardboard (only AVV), Flat glass (only AVV)
System coverage & regulatory detail	Type of instruments	Take-back requirements, collection & recycling targets, minimum requirements for processing waste, restrictions and bans on use of dangerous substances in products, information disclosure requirements. Different per product regime.
	Scope of system	National

Appendix 4: Overview batteries & accumulators

Indicator	Sub-indicators	Results: formal institutional setting
Formal responsibilities	Legal basis	Battery Directive, Besluit beheer batterijen 2008, Regeling beheer batterijen en accu's 2008, AVV for portable batteries.
	Type of responsibility	Informative, organizational, financial. Different for each battery type, but same for all producers within type. Individual responsibilities so far.
	Targeted and exempted products	Industrial, portable, automotive batteries; lead-acid, nickel-cadmium, other chemistries
System coverage & regulatory detail	Type of instruments	Design, manufacturing, collection, processing and recycling requirements. Obligation to accept returned batteries waste by distributors. Collection targets for portable and recycling efficiency targets for chemistry types. Imposed waste management fee portable batteries.
	Scope of system	National

Indicator	Sub-indicators	Results: incentives & change in practice	
		Practice	Evaluation
Waste management organization	Waste management structure	Portable: nationally about 25,000 collection points (municipalities, schools, retail), sorting in NL, treatment outside NL. SLI & traction: ARN system + ARN pre-recycling plant;	Increasing safety related risks; issues with non-removable batteries in appliances; export leaks of batteries; no incentives for collection/ recycling beyond target
	Waste management structure coordinators	Portable & electric bikes (industrial): Stibat SLI & traction: ARN & individual	PROs reliable and cost-effective option for producers
	Number of different products and waste streams	Unknown, but 3 major regimes (i.e. industrial, automotive, portable)	Delineation between portable, automotive, industrial increasingly blurred
Waste management financing	Rules and agreements on finance	Portable: AVV; automotive, industrial: agreed price between parties	No explicit evaluation.
	Financial instrument	ARN & Stibat: pay per battery PoM	Product price reflective for waste management costs (minimal fraction of total product price)
	Fee differentiation	Based on net operational costs collection, recycling (chain deficit). Differs for chemistry and weight of battery.	Relatively high logistic costs. Mostly negative costs, except for lead-acid and potentially for lithium in the future.

Reporting, compliance & enforcement	Inspection & enforcement	No explicitly mentioned practices other as mentioned in section 4.1.	Relatively few ILT activities. Good cooperation Stibat with ILT. Government enforcement remains important, but inspection issues regarding waste processors.
	Reporting & compliance	Stibat: annually to government. Producers: via web-environment, frequency of reporting unknown.	Some free-riding on *Afvalbeheerbijdrage* (e.g. internet sales), but producers generally compliant due to AVV. Illegal practices around waste with positive value. 15% of batteries in residual household waste.
	Quality control & certification efforts	PRO: Ecotest, KZW, audits. No certification schemes.	Ecotest slightly more ambitious than legal requirements
Circular practice beyond waste management	Designing and business innovation efforts	Limited cooperation producers & recycling for innovation	No or limited effect of EPR on battery design. Some new business models with stationary energy storage.

Indicator	**Sub-indicators**	**Results: market failure evaluation**
Scale advantages	Rates of collection & recycling	Portable: stable collection rates between 45-50% of PoM. All batteries: lower collection, fluctuation around 35%. High recycling, above 70% for all batteries.
	Aggregate costs of collection & recycling	Portable batteries: increased cost-effectiveness between 2011 & 2016: 1595 & 1368 Euros per collected ton respectively. Collective: reduces costs to individual producers.
Environmental externalities	Environmental damage in value chain	Most environmental damage in virgin material production. Recycling better, but also chemical/ energy intensive. EPR: positive effect on environment, but environment should be more considered in EPR-design
	Costs and pricing of environmental damage	Virgin material production is associated with bad mining conditions and minimum regulations: limited pricing
Information issues	Info on separate collection	Strength: Stibat communication efforts; weakness: info on product itself
	Product characteristics	Issues in waste management, due to: insufficient chemistry reporting, cross-border information issues

Appendix 5: Overview on-packaging cardboard and paper

Indicator	Sub-indicators	Results: formal institutional setting
Formal responsibilities	Legal basis	AVV for non-packaging OPC, *Papiervezelconvenant*
	Type of responsibility	Self-assumed by negotiated agreement. *Papiervezelconvenant* plus AVV: financial ("first receivers"), organizational (PRN) and informative (PRN).
	Targeted and exempted products	Non-packaging paper and cardboard products, defined as a product with the largest weight fraction being OPC
System coverage & regulatory detail	Type of instruments	Financial instruments, collection & recycling targets
	Scope of system	National

Indicator	Sub-indicators	Results: incentives & change in practice	
		Practice	**Evaluation**
Waste management organization	Waste management structure	Municipalities: separate collection; OPC-companies intermediary between paper producers and municipalities; paper-producers: recycle OPC.	Increased collection due to municipal investments; 93% of municipalities PRN member now; focus on OPC quality, because OPC quality important for producers.
	Waste management structure coordinators	PRN: network coordination of market parties & municipalities Municipalities: coordinate separate collection	Coordination required between *Afvalfonds Verpakkingen*, municipalities & PRN for packaging OPC products; increased cooperation between municipalities
	Number of different products and waste streams	63 legal different types of OPC waste.	Over 200 in practice
Waste management financing	Rules and agreements on finance	AVV waste management fee; 25 cents/ kg guarantee, also when chain-deficit. Rest: contract and market prices.	Non-packaging: 1 chain deficit in 2009. No costs borne by municipalities.
	Financial instrument	Producer pay for weight PoM; municipalities & other receive for amount collected	Secondary material often cheaper than primary material, resulting in good market prices for collected OPC
	Fee differentiation	No fee differentiation between non-packaging products	Sorting non-packaging & packaging OPC: compensation for packaging fraction from *Afvalfonds Verpakkingen*
Reporting, compliance & enforcement	Inspection & enforcement	PRN: checks numbers reported to them; identification efforts non-compliers	No explicit evaluation.

	Reporting & compliance	To PRN: producers (quarterly) OPC companies & municipalities (monthly). PRN to national government: annually.	About 2% non-compliance in terms of weight PoM (including internet sales).
	Quality control & certification efforts	Certification for OPC companies regarding administration/ operation; quality standards for separately collected OPC	Slightly increasing contamination of OPC.
Circular practice beyond waste management	Designing and business innovation efforts	No explicitly mentioned practices.	No effects by PRN system. Switching from paper input hard due to specific recipe requirements

Indicator	Sub-indicators	Results: market failure evaluation
Scale advantages	Rates of collection & recycling	Almost 100% recycling of the collected material, resulting in 70-80% collection & recycling of total PoM
	Aggregate costs of collection & recycling	Slightly increasing costs per ton and lowering total PoM since 2005. In 2009, when chain deficit occurred: less than 1 Euro per ton collected or PoM.
Environmental externalities	Environmental damage in value chain	Recycling better than primary production of paper materials, due to land use impacts. Recycling better than incineration.
	Costs and pricing of environmental damage	Not explicitly evaluated. However, extensive recycling efforts by market parties and environmental benefits of recycling: market and environmental incentives for material production align
Information issues	Info on separate collection	No explicit evaluation. But, separate collection stability provides favorable investment environment.
	Product characteristics	No explicit evaluation.

Appendix 6: Overview medicines

Indicator	Sub-indicators	Results
Formal responsibilities	Legal basis	No AVV or EPR by Product Directive. Chain cooperation & policy: *Ketenaanpak medicijnresten uit water*.
	Type of responsibility	Voluntary efforts outlined for wide range of actors. No financial or organizational responsibilities for pharmaceutical companies, only informative. Distributors (pharmacists) & municipalities most explicit responsibilities for collection & information provision about separate collection. Municipalities have legal obligation to take care of pharmaceutical household waste
	Targeted and exempted products	All medicines used by humans. Explicit about: X-ray contrast liquids, psychiatric medicines, cytostatica, liquid medicines
System coverage & regulatory detail	Type of instruments	No explicit policy instruments mentioned: chain approach stipulates efforts that actors should take.
	Scope of system	National

Indicator	Sub-indicators	Results: incentives & change in practice	
		Practice	Evaluation
Waste management organization	Waste management structure	Pharmacists & municipalities: separate collection & subsequent transport, processing (incineration) of unused medicines. Waterboards: waste water treatment.	More awareness about waste management throughout chain due to information provisioning; pharmacists are important collectors; no tangible change in collection structure
	Waste management structure coordinators	On local level: municipal policies for collection and treatment and potential agreements with pharmacists Nationally: coordination efforts by range of representatives	More agreements and cooperation on local level between pharmacists and municipalities; reputation mentioned as important reason for producers to be engaged in *Ketenaanpak*
	Number of different products and waste streams	More than 2000 different pharmaceutical substances PoM, falling within several different waste categories.	No explicit evaluation.
Waste management financing	Rules and agreements on finance	Potentially, local agreements about compensation for pharmacists by municipalities for separately collected pharmaceutical waste; contract and market prices	Conflict about status pharmaceuticals collected by pharmacists: company or household waste, potentially high costs to pharmacists. High diversity in costs to pharmacists nationally; highly different municipal policies. Now, only 30 municipalities do not

		for collection, transport and processing	compensate for separate collection efforts by pharmacists. Without EPR: conflict about what pays what remains.
	Financial instrument	Municipal and waterboard board taxes levied to pay for household waste management.	Producers ought to be contributing to waste management, e.g. through a fund that waterboards can draw from
	Fee differentiation	No product-based fee or fee differentiation for producers.	Product-specific differentiation deemed undesirable if EPR in a form is implemented.
Reporting, compliance & enforcement	Inspection & enforcement	No legal requirements for producers regarding post-use.	No explicit evaluation.
	Reporting & compliance	Waste management reported through EURAL. No other documentation found.	Non-compliance in waste management expected to be low; EURAL data low quality. Strict regulation large barrier to reuse of returned medicines.
	Quality control & certification efforts	No practices explicitly mentioned.	Certification for pharmacists & general practitioners expected to have no added value
Circular practice beyond waste management	Designing and business innovation efforts	Pharmaceutical use prevention efforts, cooperation between VIG and KNMP on sustainability, pharmacist cooperation on medicine stocks	No incentive for ecodesign now. Environmentally friendly substances less effective in body. Innovation occurs in monitoring of storage conditions & application of medicines. Non-EU production barrier for having more influence on production. Pharmaswap reduces the amount of medicines that expiries.

Indicator	Sub-indicators	Results: market failure evaluation
Scale advantages	Rates of collection & recycling	Estimations suggest that not more than 66 ton pharmaceutical waste is available for separate collection. All pharmaceutical waste is incinerated. Now, 50-80% removal of environmental substances entering the waste water system.
	Aggregate costs of collection & recycling	**Rough estimations.** Separate collection & waste water treatment both in order of magnitude of hundred thousand Euros per ton waste. Per ton used, separate collection: 1000-2000 euro (costs now); waste water treatment: 39,000-54,000 Euros (additional costs). Total waste management costs as percentage of spending on medicine: separate collection (0.11%) now and additional WWTP (3.1%).
Environmental externalities	Environmental damage in value chain	Mostly due to improper waste management during production outside EU. Some effects in aquatic environment in the Netherlands, but limited knowledge.

		Exposure to highly toxic unused medicine in residual household or separately collected waste also considered a risk. Environment benefits of additional treatment not trivial, due to higher energy/ material input for WWTPs.
	Costs and pricing of environmental damage	The pecuniary costs of environmental damage in the NL are not known, nor are the benefits. Environmental damage due to use/ waste not in any form incorporated in the price of medicine. Unlikely that environmental damages during production are priced in due to low regulation abroad.
Information issues	Info on separate collection	Has increased due to campaigning efforts. No explicit finding about info on disposal of products themselves.
	Product characteristics	Reporting on environmental characteristics is low and perceived to be a barrier for waste water management.

Appendix 7: Overview broader experiences

Indicator	Sub-indicators	Results: Incentives & change in practice Evaluation
Waste management organization	Waste management structure	EPR led to: collection & recycling structures that would otherwise not exist. EPR considered to be a good and important tool for keeping materials in economy. Often collectively organized by producers. Municipalities keep important role in operation. Consumer engagement considered vital to good functioning of EPR, requiring continual attention. Often frictions due to interdependence of parties.
	Waste management structure coordinators	EPR led to: robust organization for waste of products and cooperation where producers otherwise would not. Also coordination required between different systems due to mixing of waste streams. Producers of different EPR systems face similar challenges. PROs most important national coordinators; on local level, municipalities still highly involved.
	Number of different products and waste streams	Not explicitly evaluated here.
Waste management financing	Rules and agreements on finance	Collective finance by producers, PRO hire parties or brings parties together in waste management. Municipal services often used, for contract prices.
	Financial instrument	Funding non-EPR waste streams: municipal taxes (*Afvalstoffenheffing)* and waste water taxes. EPR: Waste management fee. EPR seen as fair, due to operational cost internalization in product price.
	Fee differentiation	Collectively: PRO calculates the total costs, then translates this into volume and allocates costs to the producers in accordance to their volume.
Reporting, compliance & enforcement	Inspection & enforcement	Inspection by municipalities at scrap companies considered low. High number of individually liable producers deemed a problem for enforcement efforts by ILT on performance of waste management system. Different opinions of interviews whether PROs should get more means to prescribe and enforce measures. PROs have and use means to review and audit different parties.
	Reporting & compliance	AVV limits financial free-riding by producers. Consumer behavior remains a challenge, e.g. persistent littering behavior and materials in residual household waste. Consumer incentivizing instrument employed to limited extent.
	Quality control & certification efforts	Often, certification and testing methods are developed by PROs to assess and secure waste handler practices.
Circular practice	Designing and business	EPR has no to limited effect. Value chain and geographical distance between production/ waste management

beyond waste management	innovation efforts	problematic. Direct regulation such as material bans and additional ecodesign regulation expected to be more effective. Innovation focuses on functionality, not on circular aspects.

Indicator	**Sub-indicators**	**Results: market failure evaluation**
Scale advantages	Rates of collection & recycling	Evaluated for all household waste. EPR waste streams outperform non-EPR waste streams. Producer contribution enables higher recycling rates: recycling costs too high for municipalities.
	Aggregate costs of collection & recycling	Important for overall costs of waste management: material prices on markets. Costs for all household waste to municipalities have increased since 1990 (now about 200 Euro/ ton), but not clear what effects of EPR are. Significant cost-shifting (22%) away from municipalities. Scale advantages due to cooperation in EPR system, but refinement of separate collection or expanding to new products could be costly due to high collection costs. Overall, EPR effect on overall costs of all household waste management unclear
Environmental externalities	Environmental damage in value chain	Lifecycle assessments considered to be important. Virgin material production generally worse for environment than recycling. Tension between (eco)toxicity and circularity of a substance. Risks and risk perception considered to be important to waste management. More environmental benefits expected for better ecodesign than improvements in waste management process itself. EPR targets should be more reflective of environmental consideration.
	Costs and pricing of environmental damage	Not explicitly evaluated here. But, virgin material production with relatively low amount of regulation. Probably high externalities in virgin material production.
Information issues	Info on separate collection	Not explicitly evaluated here.
	Product characteristics	Product information beneficial to waste management only disclosed to a limited extent. This is considered a barrier for recycling.

Appendix 8: AVV application requirements

Source: VROM (2000).

1) Present name, address and registration number of the chamber of commerce of those party to the agreement.
2) Clearly describe the object subject to the waste management fee and this object must be put on the market by those party to the agreement
3) Show the height of the fee as well as the cost structure on which the fee is based. The fee can be either fixed or be the result of a formula, which should be present in the agreement. In the consultation version of the updated regulatory basis for an AVV, are mentioned to include, if relevant, fee differentiation based on: 1) sustainability criteria, 2) intended form of useful application and 3) presence of harmful substances (personal communication, Spiegeler)
4) Describe when and how the waste management fee should be paid
5) Describe who is the subject responsible for paying the fee (e.g. importers).
6) Describe who is the receiver of the fee
7) Ensure that confidential information is treated properly by the organization managing the fund that is filled with the fees.
8) Describe compliance-ensuring efforts, including: a third-party tasked with auditing, auditing frequency and auditing methods.
9) Ensure that products of all parties that pay the fee can enter the waste management structure, including the products of those that are not member to the agreement that is filed for becoming generally binding
10) Describe the period for which he intends to have the AVV (maximum of 5 years)

Furthermore, information should be provided on the:

11) to be achieved environmental goals (i.e. how the waste is processed, e.g. used as fuel) and feasibility hereof
12) the organizational aspects of the waste management system, including amongst others: waste and financial flows and which parties participate in the structure and their respective responsibilities.
13) the technical aspects, including: quality requirements for to be collected products, point at which waste is handed over to another party (such as municipalities or other companies) as well as the agreements that have been made, sorting activities, transport of to be collected products, frequency of collection and processing technologies.
14) the financial-economic structure for the waste management system, including:
    a. budgetary information that shows the occurrence of deficits that hinder an environmentally sound waste management system and which the revenues from AVV fees should compensate
    b. a more detailed description of how, why, when the fee should be collected as well as the activities that are funded with the fee revenues.
    c. How the fund that the fee revenues flow to is managed, as well as what happens upon termination of the waste management fee obligations.
15) The relation of the waste removal structure with respect to surrounding and other relevant countries

16) General market characteristics as well as the potential effects of the fee on the market.
17) How those that are liable to the fee were involved in filing the AVV.
18) How consumers and company do not pay a waste management fee twice for the same product
19) How the consumer or company that will pay a removal fee will be informed about the waste management system.
20) How will be reported, including amongst others: products put on market, products collected, performance on environmental goals (e.g. recycling and landfilling), incoming and outgoing cash flows and quality of the reported figures.