COLLECTORS

Work package 3
Quantification of costs and benefits

ASSESSMENT OF SOCIO ECONOMIC AND FINANCIAL PERFORMANCE
OF 12 SELECTED CASE STUDIES

T. VAN LEEUWEN

Disclaimer

The sole responsibility of this publication lies with the authors. The European Union is not responsible for any use that may be made of the information contained therein.

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 776745.

TECHNICAL REFERENCES

Grant Agreement N°	776745	**Acronym**	COLLECTORS
Full Title	Waste collection systems assessed and good practices identified		
Work Package (WP)	3		
Authors	T. van Leeuwen (PNO Consultants) M. Siebenlist (PNO Consultants) S. Alnajar (PNO Consultants) J. Hardjopawiro (PNO Consultants)		
Document Type	Deliverable		
Document Title	Deliverable 3.2: Assessment of socio economic and financial performance of 12 selected case studies		
Dissemination Level	Public		

DOCUMENT HISTORY

Version	Date	Partner	Author
v1	10-04-2019	PNO	T. van Leeuwen
v2	24-07-2019	ACR	-
v3	08-10-2019	WF, ACR, VTT	-
v4	04-12-2019	ACR, VTT, LDE	-
v5	29-01-2020	PNO	T. van Leeuwen
v6 (final)	13-03-2020	PNO	T. van Leeuwen

SUMMARY

This deliverable is part of the European Horizon 2020 project COLLECTORS and provides the financial assessments of 12 COLLECTORS case studies; focusing on 5 paper and packaging waste (PPW) cases, 5 waste electrical and electronic equipment (WEEE) cases and 2 construction and demolition waste (CDW) cases. The report is part of Task 3.2 and will highlight the financial flows for the assessed waste collection practices.

The financial and economic assessment is carried out by means of a Cost-Benefit Analysis (CBA). CBA strives to estimate positive and negative effects of a project or policy on the welfare of the region or country in which it is located and thereby provides insight into the financial performance of the waste collection systems. The assessment is initially performed from the perspective of the municipality, but ultimately broadened in order to include relevant costs and benefits further up the waste value chain. The CBAs for the COLLECTORS project have been conducted in accordance with the EC CBA guidelines (Guide to Cost-Benefit Analysis of Investment Projects, European Commission, December 2014).

It is possible and quite common to also include environmental aspects in a CBA. However, the COLLECTORS project has a dedicated deliverable on the environmental performance of the cases – the Life Cycle Assessment (LCA) performed in Task 3.1. To prevent double-counting of environmental performance, it is decided to restrict the CBAs to the financial assessments of the CBA.

The CBA approach and waste stream scope varies per waste stream and is explained in the sections below. For each waste stream different case studies are selected based on their geography, waste production, tourism, GDP and population density. For this reason, the cases are not directly comparable, as they serve as a good practice in their specific context.

Data were provided by stakeholders (interviews or questionnaires) and published data (i.e. in, regional, national or European reports). However, it is important to mention that financial information on the waste collection systems often covers (price-)sensitive information, which is not publicly available or, in some cases not even documented. This means that certain parts of the assessments were made under data uncertainty, especially with regards to financial information. The results and evaluation of the assessment should therefore be understood as preliminary insights into the economic performance of these waste collection systems.

In the PPW assessment it was found that it is possible to achieve high performing separate waste collection while maintaining acceptable fees for citizens. However, local authorities are largely dependent on national incentives such as financial contributions from EPR schemes, revenues from sold materials and tax savings or incentives.

In the WEEE assessment it was found that PRO's face many financial challenges; the EEE get smaller and more complex while less valuable materials are used resulting in an less material recovery potential; and competition grows between PRO's resulting in reducing fees. Despite these challenges all studied cases managed to increase their WEEE collection, however not all were found to have a positive FNPV.

The CDW assessment concludes that while separate collection systems can be introduced relatively easily and without large investments, they are largely dependent on the local recycling value chain and gate fees. From the municipal point of view, transport costs and gate fees are the two crucial parameters; meaning that lower gate fees in combination with a nearby demand for recycling will result in the favourable financial option. As CDW consist of many different sub-waste streams, it was found that the options and outcome varies per waste stream.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

B/C ratio	Benefit Cost ratio
CAS	Civic Amenity Site
CBA	Cost Benefit Analysis
CAPEX	Capital Expenditures
CDW	Construction and Demolition Waste
DTD	Door to Door collection
FNPV	Financial Net Present Value
Hh	Household
LCA	Life Cycle Assessment
MRF	Material Recovery Facility
OPEX	Operational Expenditures
PAYT	Pay As You Throw
PMD	Plastics, Metals and Drinking Cartons
PPW	Paper and Packaging Waste
WCS	Waste Collection System
WEEE	Waste Electrical and Electronic Equipment
WP2	Work Package 2
WP3	Work Package 3

1. INTRODUCTION

This report provides the financial assessments of 12 selected waste collection systems; 5 Paper and Packaging Waste (PPW) cases, 5 Waste Electrical and Electronic Equipment (WEEE) cases, and 2 Construction and Demolition (CDW) cases. The financial and economic assessment of these 12 selected waste collection systems is carried out by means of a Cost-Benefit Analysis (CBA).

1.1. PROJECT BACKGROUND

The EU's vision of sustainable economic growth and global competitiveness will be facilitated by the transition towards a circular economy, with its aim of extending the useful lifetime of materials by promoting recycling, whilst lowering resource use and environmental impacts. About 500 kg of municipal waste per capita are generated every year in the EU. These wastes contain large volumes of valuable materials for Europe's industrial base. Proper collection of waste is a pre-condition for their optimal recovery.

Improving the collection performance of waste collection systems (WCS), thus diverting more recyclable material towards the appropriate material sorting facility and treatment processes, and away from sending it for disposal, is the obvious first step towards achieving the ambitious recycling targets proposed by the EU. For instance, common EU targets of recycling 75% of paper, 50% of plastic packaging, 50% aluminium, 70% ferrous metal and 70% glass by 2025 (increasing to 85%, 55%, 60%, 80% and 75% respectively by 2030) have been put in place. Under the EU WEEE directive vendors have an obligation to recover end-of-life devices. A target of 85% (based on the average of electrical and electronic equipment put on the market in the last 3 years) or 65% of WEEE produced that year needs to be collected by 2025.

1.2. THE COLLECTORS PROJECT

Good regional practices have the potential to serve as good examples for other regions and go some way to achieving these targets. So far, however, results of existing studies of high performing waste collection systems have not been effective enough in supporting the implementation of better-performing systems elsewhere. The main objective of the COLLECTORS project is to overcome this situation and to support decision makers in shifting to better-performing collection system.

The **objectives** of the COLLECTORS project are to:

1. Increase awareness of the collection potential by compiling, harmonising and presenting information on systems for PPW, WEEE and CDW via an online information platform.
2. Improve decision-making on waste collection by the assessment of twelve good practices on their performance on:
   (1) quality of collected waste;
   (2) economics;
   (3) environment;
   (4) societal acceptance.
3. Stimulate successful implementation by capacity-building and policy support methods that will increase the technical and operational expertise of decision-makers on waste collection.
4. Engage citizens, decision-makers and other stakeholders throughout the project for validation of project results and to ensure the usability of COLLECTORS-output.

Thereby, the COLLECTORS project is specifically focussing on the following waste streams:

1. Paper and Packaging waste (PPW) from households:
    - Paper & cardboard (both packaging and non-packaging);
    - Plastic packaging;
    - Glass packaging.
    - Metal packaging;
    - Packaging made from composite material.

These materials represent all the paper and packaging materials targeted by different municipalities in accordance with the packaging and packaging waste directive.

2. Waste Electrical and Electronic Equipment (WEEE) from private households:
    - Small household appliances;
    - Information technology (IT) equipment;
    - Light bulbs.

This is only a few categories of WEEE. These were considered due to the high quantities of these materials that are still being thrown in residual waste.

3. Construction and demolition waste (CDW) with a focus on wastes that are managed by public authorities:
    - Bricks;
    - Sanitary;
    - Insulation material;
    - Gypsum.

1.3. AIM OF THIS REPORT

The objective of the work in Work package 3 (WP3, Quantification of costs and benefits) of the COLLECTORS project is to evaluate the environmental and economic performance of 12 case studies selected as good examples of WCS in Europe. Hence, WP3 will evaluate the potential environmental impacts and economic viability of the collection methods employed by the municipalities of the selected case studies. To assess the economic viability of the WCS of the selected case studies, a Cost-Benefit Analysis is applied. The costs and benefits for a defined scope will be identified, aiming to gain insight in the overall performance of different waste collection systems but also to understand the options and incentives of different stakeholders to invest in a better-performing system. It is important to note that the rationale of this report is not to find a perfect viable business case for waste collection, but rather to see if and how high recycling performances can be achieved by maintaining acceptable fees for citizens.

1.4. COST BENEFIT ANALYSIS

A cost-benefit analysis (CBA) strives to estimate all costs and benefits of a project or policy. A (financial) CBA is an assessment performed from the perspective of the project owner, where only the direct cost and benefits of this project owner are included. A more comprehensive (economic) CBA is done from the perspective of society as a whole, including direct and indirect costs and benefits for all stakeholders, not only the project owner. In the latter case, the CBA often includes elements on the environmental and socio-economic level. For the Collectors project, a detailed analysis of the environmental impact is performed in Task 3.1 and Task 3.3, which is why the CBA scope in the Collectors project is generally chosen from the perspective of the project owner. The scope varies for the PPW, WEEE and CDW analysis, which is discussed in further detail below. The CBAs for the Collectors project have been conducted in accordance with the EC CBA guidelines (Guide to Cost-Benefit Analysis of Investment Projects, European Commission, December 2014).

1.5. CASE STUDY SELECTION

Data collection took the form of consultation with stakeholders and an extensive literature review of national reports and isolated case studies. The characteristics of the municipalities included in this study varied in terms of area size, population density, level of tourism, GDP and total waste generated. Data were collected on each of these characteristics, as well as on the performance of the WCS employed by each municipality with regards to each of the waste streams included within the scope of the study.

For PPW, data were compiled on the waste collection systems of 135 municipalities from 24 EU member states. For WEEE, 73 municipalities from 18 member states were considered. For CDW, 34 municipalities from 17 member states were considered. In total, 5 PPW, 5 WEEE and 2 CDW cases were selected from the Collectors database. The selection of these 12 case studies was based on in-depth analyses in Work Package 2 and dialogue with involved stakeholders as part of Work Package 3. To do this, comparisons were made between the collection systems and with national statistics. The well-performing systems were then analysed in a participatory approach with local and regional authorities with the objective of building the methodology for a multiple-criteria decision making (MCDM) approach from which the case studies could be ranked.

For PPW, the capture rates of each waste stream were weighted in relation to importance as concluded by the focus groups; all capture rates received similar weightings, with plastic being regarded as slightly more important than the others. For WEEE, the criteria deemed most important was the total WEEE collected per inhabitant and the share of WEEE in mixed residual waste. For CDW, the number of inhabitants per civic amenity site (CAS) was the most important factor. Case studies were than selected based on their high ranking and characteristics, and lastly on availability of data.

Figure 1 - The PPW caste studies: Parma (IT), Tubbergen (NL), Gent (BE), Berlin (DE) and Rennes (FR)

Figure 2 - The WEEE case studies: Pembrokeshire (UK), Genova (Italy), Cyclad (France), Vienna (Austria) and Helsinki (Finland).

Figure 3 - The CDW case studies: Odense (DK) and Reimerswaal (NL)

2. BACKGROUND OF THE CASE STUDIES

2.1. BACKGROUND OF THE PPW STUDY

In this paragraph, the five case studies for the PPW analysis are further explained.

1. Parma, Italy
2. Ghent, Belgium
3. Berlin, Germany
4. Tubbergen, The Netherlands
5. Rennes, France

For all cases a certain reference period is defined, which aims to highlight the good practice. In the case of Parma, Tubbergen, Berlin, and Rennes a recent shift in the waste collection system has been made, e.g. from comingled collection to a separate Pay-As-You-Throw (PAYT) system. For the case of Ghent, a PAYT waste collection system already has been introduced in 1998. The CBA will aim to investigate the required investment costs for the system change, the shift in operational costs, collected quantities and lastly the shift in benefits.

2.1.1. PARMA, ITALY.

Parma is a city located in Northern Italy at the foot of the Apennines with ca. 194,000 inhabitants. Well known for their food and quality of life, the region produced significant amounts of waste, 636 kg of waste per capita in 2014. This is roughly 150 kg above the Italian average, and 160 kg above the EU average. By that time, the region recycled 58.2% of the municipal waste, meaning that significant quantities are still sent to disposal, to be landfilled or incinerated. Fortunately, the situation is changing and Parma is leading the transition towards Zero Waste in the region[1].

Parma started its zero-waste strategy by improving the separate collection of waste through door-to-door collection, introducing eco-stations and eco-wagons. Currently, the PPW collection in Parma can be described as PMD commingling method, meaning plastic, metal and composite material (“drinks cartons”) are collected together. Paper and glass are separated separately. The residual waste, paper, and PMD are collected at the kerb, using home containers and bags. Also, several bring points (glass) and eight eco-stations (automated CAS where citizens can bring all waste except residual) are available. By providing citizens ample and easy opportunities to separately discard their waste, Parma performance rates have increased significantly (see Figure 4 below).

[1] Zero Waste Europe, Casestudy ‘The story of Parma’, 2018.

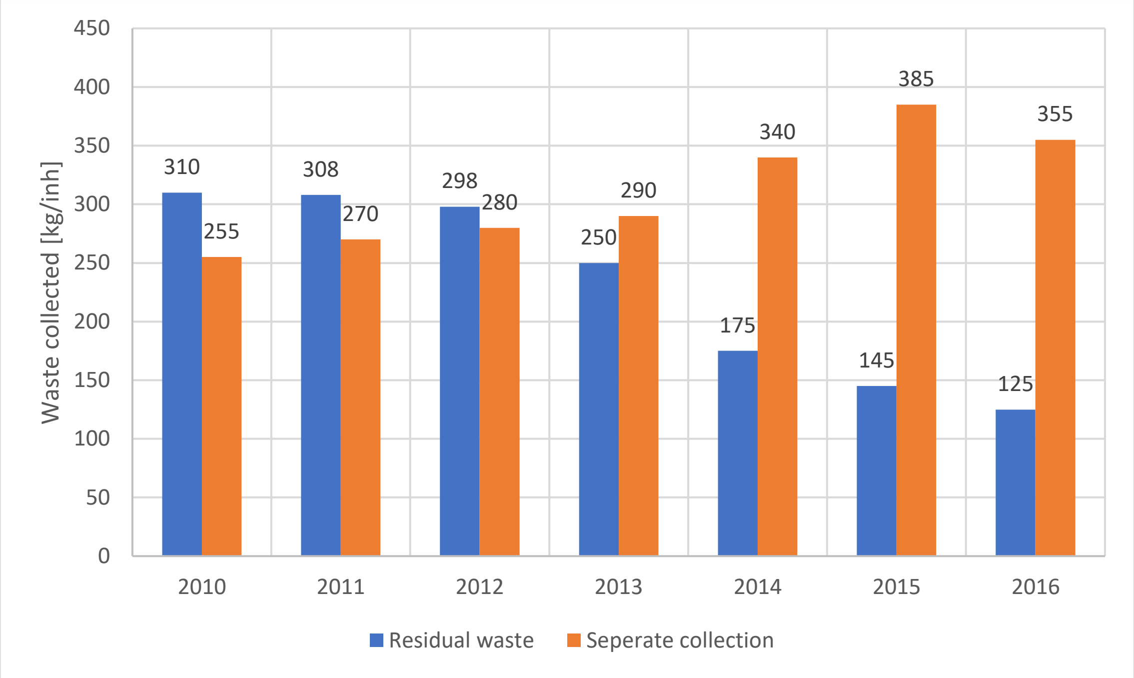


Figure 4 - Performance of PPW collection in Parma 2010 - 2016[1]

Parma's historical centre, food-scene and mountainous suburbs all pose various challenges regarding to the waste collection. In order to collect the waste as good and efficient as possible, Parma uses different collection zones, with different collection frequencies and pickup times. The map below shows the Parma region, with four different zones. E.g. to avoid blockage and nuisance, the waste collection in the historical centre happens mainly in the evening.

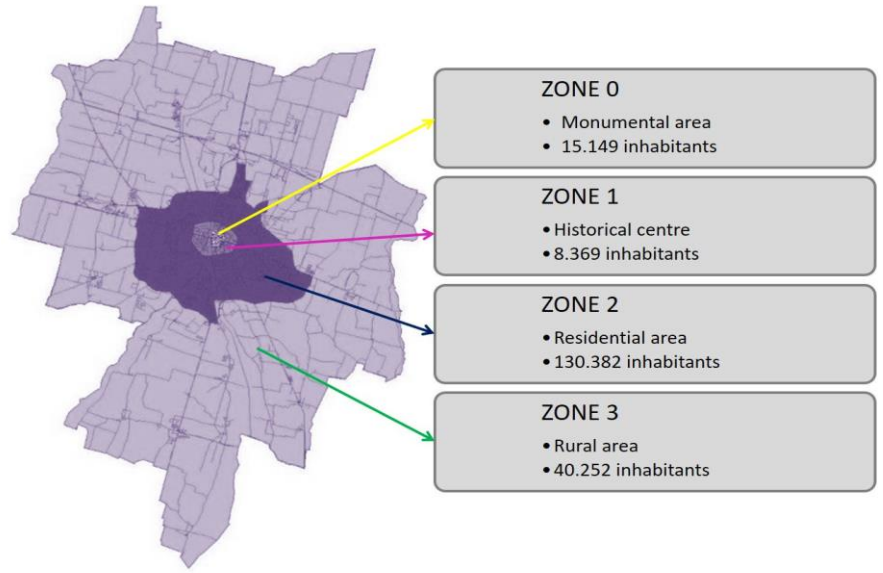


Figure 5 - Various zones in Parma[51]

For the waste collection, treatment and disposal, Parma works together with Iren Ambiente[2]. Iren Ambiente performs collection services for more than 2.3 million residents, amongst others in the provinces of Parma,

[2] Iren Ambiente, 2019 https://www.gruppoiren.it/en/ambiente

Piacenza and Reggio Emilia. Iren Ambiente manages waste from collection to treatment, disposal and recovery and has 30 treatment plants that yearly process over 2 million tonnes of waste.

Fee system: Parma implemented a PAYT system with a variable fee. Citizens pay the fixed fee (€ 244 for 3person and 100m2 household in 2017) and can collect eco-points; a discount on their waste bill for the following year. Eco-points are collected for brining e.g. electronic waste, hazardous waste and medical waste and depend on the quantity and sort waste. Disposing packaging waste is for free, but yields no eco-points. Each eco-point is worth a discount of € 0.15, and citizens can receive a maximum discount of € 20.

Regional characteristics: Parma is an inland city with 194,000 inhabitants, close to the Apennines. On average, Parma has 660,000 tourist overnight stays per year.

2.1.2. GHENT, BELGIUM

Ghent is a port city in northwest Belgium with almost 250,000 inhabitants. The intermunicipality of IVAGO serves both the city of Ghent and the neighbouring municipality of Destelbergen. IVAGO has its own collection equipment but works together with private company SUEZ to complement the collection services. Since the introduction of the PAYT principle in 1998, the collection system for household waste in Ghent has remained practically unchanged[3]. However, continuous improvements have been implemented over the years, which result in the continuous downward trend of collected residual waste and illegal dumping (see Figure 6), while PMD, glass and paper collection rates stay fairly constant, decreasing even a little bit.

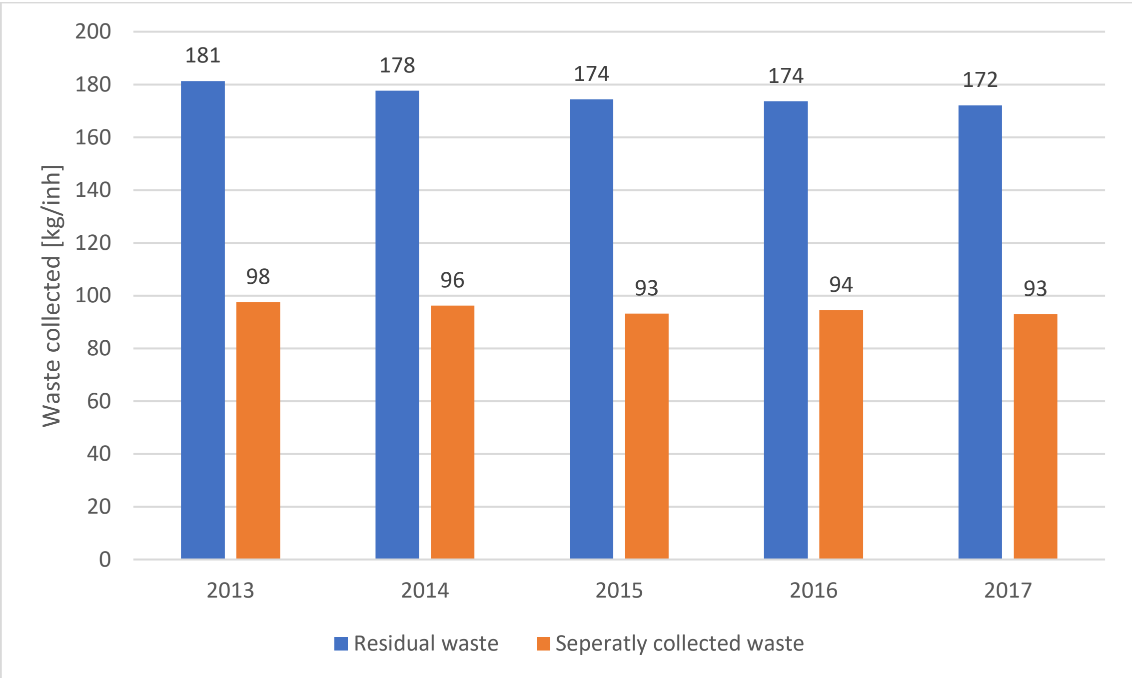


Figure 6 - Performance of residual waste collection Ghent[3]

IVAGO collects residual waste, PMD, glass and paper and cardboard separately throughout the city and has defined zones with each their own collection approach. Depending on your address or type of building, the waste is collected in one of the following fashions:

- In the so-called C-zone (Container zone) waste is collected using containers. The containers are equipped with electronic chips, that register every time the container is emptied. Citizens pay in advance for the waste collection.

[3] Activiteitenverslag IVAGO, 2017

- In the Z-zone ('Zakken' or bag zone) waste is collected using bags. IVAGO uses different colour bags per waste streams; yellow bags for residual waste, blue bags for PMD, and glass and paper and cardboard in a box.
- High-rise buildings have their own waste containers, for residual, PMD, glass and paper and cardboard waste. Again, citizens pay for their residual and PMD waste. The arrangement for payments is made at building level.
- Throughout the city waste can be brought to underground waste containers, called 'sorteerpunten'. Citizens need their IVAGO card to open the container, and pay for residual, PMD and organic waste. Bringing glass and paper and cardboard waste is free.

Fee system: Ghent has a PAYT system with a fixed fee. Citizens pay a fixed 'deposit' fee depending on their housing situation and container size[4]; e.g. in 2018 households that use a >120L container pay € 50 and get five free uses, and households that use a bring bank pay a fixed fee of € 25 and get five free uses as well. Households that make use of the door to door residual waste collection pay € 17.50 for 10 60L/15kg yellow waste bags, or a subsequent € 3.5 for a 120L container (after first five uses). Collection of paper and cardboard and glass is for free. 20 blue 75L bags for PMD collection cost € 6.

Regional characteristics: Ghent is an inland city with 250,000 inhabitants, and receives almost 1 million tourist overnight stays per year.

1.1.2. BERLIN, GERMANY.

Berlin is a large capital city with over 3.5 million inhabitants. Based on the 'Kreislaufwirtschafts- und Abfallgesetz Berlin', it is the public authority's responsibility to collect waste from households and other sources. The waste collection is organised and carried out by the Berliner Stadtreinigungsbetrieben (BSR), the service company of the state of Berlin owned by the state of Berlin. BSR is responsible for waste collection, street cleaning and waste treatment. This includes the waste fractions considered for the so-called Dual Systems (German producer responsibility scheme for the packaging waste), which are recyclables such as paper, cartons, glass and light packaging. Residual waste is collected using grey household waste bins ('Hausmülltonne'). There are five different sizes available, which can be ordered depending on the amount of household waste arising in a specific household (varying from 60 – 1,100 litres)[5]. Citizens pay a waste fee based for collection of residual waste depending on their bin size for the door-to-door collection and quantities delivered to the civic amenity sites. Glass, paper and cardboard and lightweight packaging material is collected separately. Paper and cardboard is collected separately using door-to-door collection via blue wheelie bins, occasionally "bundled" collections by various organisations; and bring systems such as the BSR civic amenity sites which are located throughout the city. Since 2013 PMD, or light weight packaging (plastic, metal, or composite materials) is collected in 190,000 yellow and orange bins throughout the city. Glass is collected separately throughout the city via door-to-door collection, green and brown wheeled containers for apartment buildings (90,000) and ca. 6,000 bottle bank containers (bring systems)[6].

Figure 7 below shows the decrease in waste quantities from households (including all waste streams) in the period 2009 – 2015.

---

[4] https://stad.gent/system/files/regulations/2018_RE_IVAGO_huisvuil.pdf
[5] Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, Abfalbilanz des Landes Berlin 2015
[6] Municipal waste management in Berlin | Titel der Broschüre | Berlin's municipal waste, 2013, www.berlin.de/senuvk/umwelt/abfallwirtschaft/downloads/siedlungsabfall/Abfall_Broschuere_engl.pdf

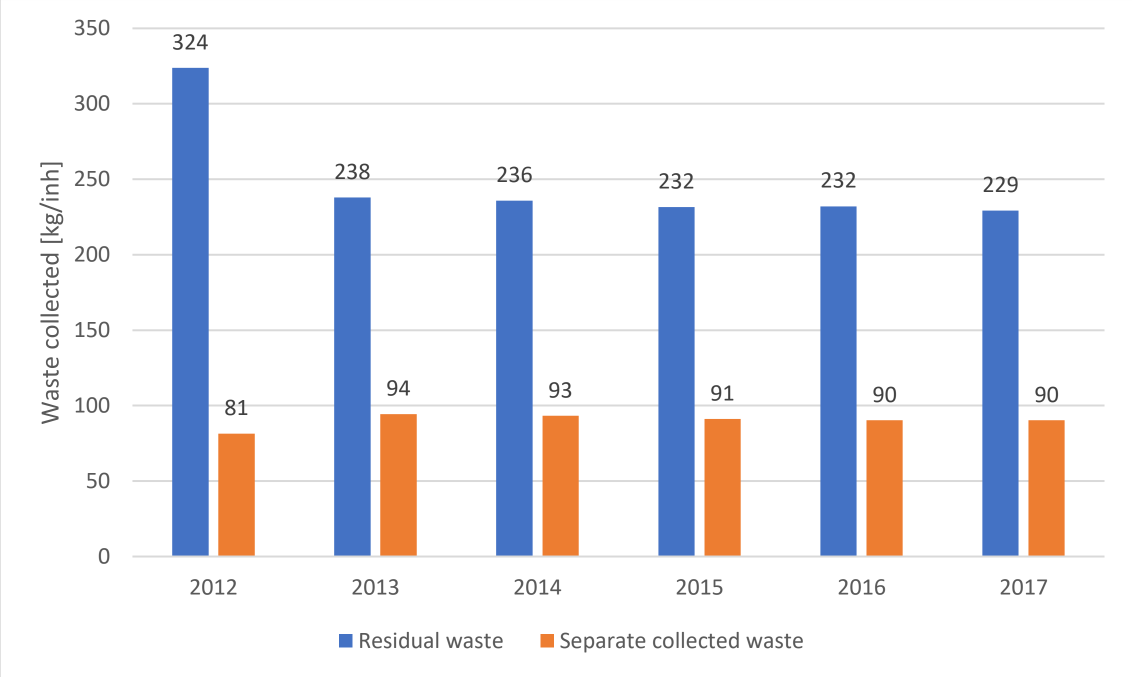


Figure 7 - Evolution of the volume of household waste 2009 - 2015 in Berlin[5]

Fee system: Berlin has a PAYT system with a fixed fee. Every quarter, each unit that is part of the general collection scheme, pays a mandatory base fee ('Ökotarif') of € 6.39 (2018). Citizens pay a fixed quarterly fee for residual waste depending on the container fee: e.g. 60L - €55.38; 240L - € 82.30. In addition, there is a cost structure in place that considers the distance and steps a waste collection worker has to take to get to the waste bin. For example, for a distance of 50 - 100m or 16 - 20 steps, an additional fee of € 33.80 per quarter can be charged. Collection of recyclables (plastic, metal and drank cartons packaging) is collected free of charge. Collection of glass is free as well. Collection of paper and cardboard is € 2.38 per emptying of a 120L container.

Regional characteristics: Berlin is a large capital city with more than 3.5 million inhabitants, receiving almost 33 million tourist overnight stays per year.

1.1.3. TUBBERGEN, THE NETHERLANDS.

The municipality of Tubbergen is a small municipality (21,142 inhabitants) in the rural east side of the Netherlands, close to the border of Germany. The municipality works together with the regional waste management company NV ROVA for the execution waste management. ROVA collects municipal waste for 23 municipalities in a working area of ca. 850,000 inhabitants. ROVA is responsible for the collection, treatment and processing of household waste, as well as the operation of bring banks and Civic Amenity Sites.

Following the ambition "Afvalloos Twente" (: waste-less Twente), Tubbergen has opted the ambition in their waste policy plan “Van Afval naar Grondstof, Van Idee naar Aanpak, Van Betalen naar Belonen” to achieve a residual waste amount of only 50 kg per inhabitant per year in 2030. To achieve this, various measures were implemented in 2015 as Tubbergen introduced the current PAYT system, which has resulted in a sharp decline in residual waste and significant increase in separately collected waste (see Figure 8 below). As shown in the graph a decrease in residual waste from 200+ kg per inhabitant per year in 2015 to 63 kg in 2017 was realised. In addition, the achieved separation percentage in 2017 is at 81%, already above the national standard of 75% for 2020[7].

[7] Grondstoffen Monitor Tubbergen, 2017, Gemeente Tubbergen & ROVA

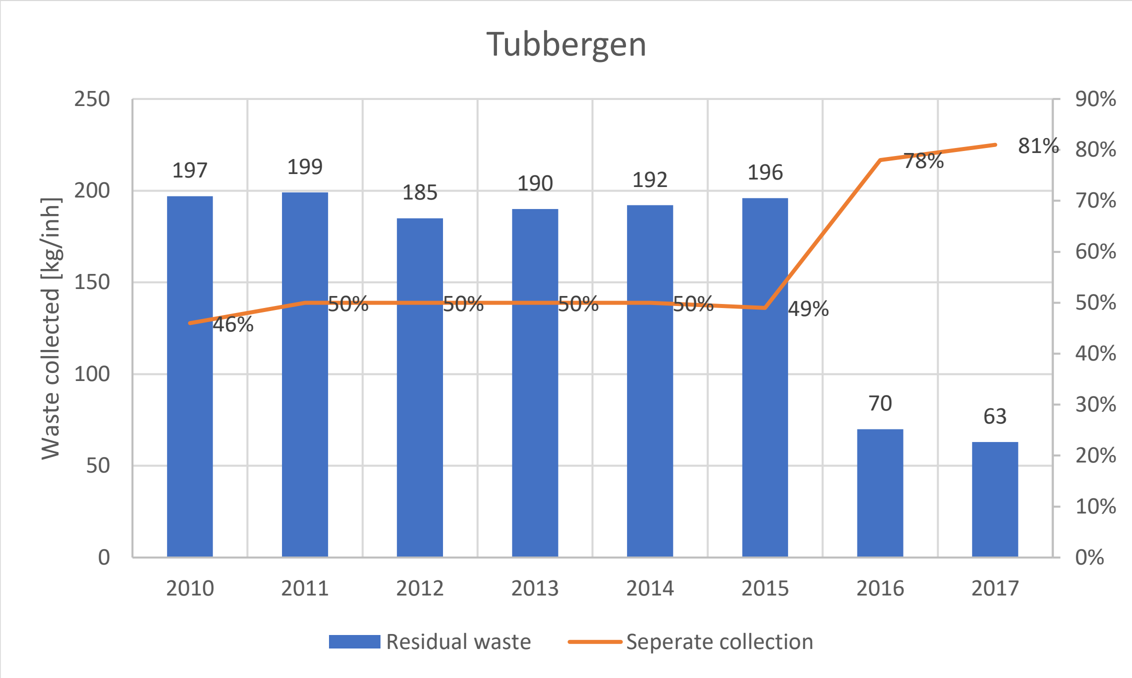


Figure 8 - Performance of PPW collection Tubbergen[7]

Fee system: Tubbergen charges her citizens with a basic tariff of € 80 per year per household[8]. Emptying a 140L residual waste container costs € 5.60, and € 9.20 for a 240L container. The door to door collection of PMD is organised every four weeks , and can be used free of charge. Paper and cardboard and glass is free of charge as well.

Regional characteristics: Tubbergen is a small rural inland city with 21,000 inhabitants, and receives almost 185,000 tourist overnight stays per year.

1.1.4. RENNES, FRANCE.

Rennes Métropole is a city located in Brittany (France), gathering 43 municipalities taking a census of 438,865 inhabitants in 2017. Those inhabitants are living on a territory of 654 km² (617 inhabitants per km²) counting 36% of detached and semi-detached houses and subsequently 64% multi-family houses (terraced houses, apartment buildings, housing blocks). Being the economic capital of this region of France, the GDP per inhabitant was about € 30,770 in 2012. Brittany also known for being a touristic destination in France, Rennes Métropole indicated a total number of 1,613,810 tourist overnight stays in 2016.

With regards to waste management, Rennes Métropole together with Brest Métropole were selected by the French ministry ("ministère de l'Ecologie, du Développement Durable et de l'Energie) as pilot areas of the national programme on zero waste ("Zéro déchets, zéro gaspillage"). In Rennes, waste collection is managed by Rennes Métropole ("Direction des déchets et des réseaux d'énergie") and operated in collaboration with various subcontractors such as Sita Ouest for household and recyclable waste, Tribord for door-to-door vegetable and bulky waste and La Feuille d'erable for paper and cardboard from professionals. The Métrople operates 18 civic amenity sites (24.381 inhabitants per CAS). Concerning recyclable waste, glass is collected separately at bring points. Paper, newspapers and magazines from households are collected co-mingled with plastic, metal and composite packaging. Yellow bins collected door to door or bring points have been implemented for collecting those recyclables ("Multi-matériaux"). In July 2017, the list of recyclables to be included in those yellow bins or bring points was extended to all plastic packaging and small aluminium. Important communication campaigns

[8] https://www.tubbergen.nl/afvalstoffenheffing

followed this scope extension. As shown in the graph, 466 kg of waste per capita were collected in 2017, with 93 tonnes collected separately.

The national waste programme set a 10% reduction of waste generated per inhabitants from 2010 to 2020. The objective of Rennes Métropole is thus to reduce the waste generated per capita to 437 kg by 2020. Also reflected in the graph, in 2014 inhabitants from Rennes Métropole were already generating 70 kg of waste per year less than average national inhabitants (460 kg/capita compared to 560 kg/capita in average in France).

The figure below shows the downwards trend in total waste, both in total, residual and recyclable waste.

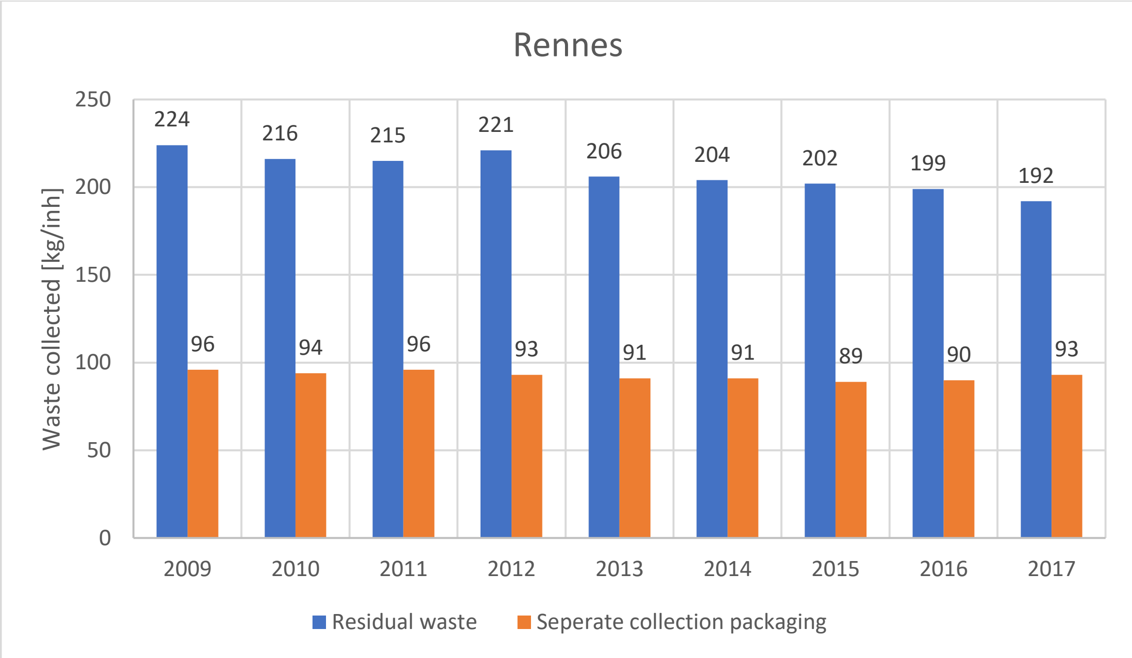


Figure 9 – Downwards trend in residual waste in Rennes

Fee system: The citizen waste tax in Rennes is based on the property value. The legal responsibility for the provision of the waste service resides with the local municipality, although domestic services are generally run on an inter-communal basis. Most municipalities charge for the service through a tax, called the Taxe d'Enlèvement des Ordures Ménagères (TEOM), which is collected with the annual property rates bill, the taxe Foncière[9]. However, the TEOM is a discretionary tax, and some councils simply decide to fund the service through the general budget. In 2017, the Rennes metropole collected a total TEOM of € 64.50 per inhabitant.

Regional characteristics: Rennes is an inland city with almost 450,000 inhabitants and receives almost 1.6 million tourist overnight stays per year.

[9] www.french-property.com/guides/france/finance-taxation/taxation/local-property-taxes/waste-rubbish-collection

1.1.5. OVERVIEW OF PPW CASES

In the table below, all cases are summarised presenting the collection modes and fee systems.

	Parma (IT)	Ghent (BE)	Berlin (DE)	Tubbergen (NL)	Rennes (FR)
Glass (G)	Separated (G, PC, PMD)	Separated (G, PC, PMD)	Separated (G, PC, PMD)	Separated (G, PC, PMD)	Separated (G, PMD+P)
	Road containers CAS	Dtd (monthly) Bring-points (monthly) CAS	Dtd (2-weekly) Bring-points CAS	Bring-points	Dtd (weekly-monthly) Bring-points
	Free	Free	Free	Free	Free
Paper and cardboard (PC)	Seperate	Seperate	Seperate	Seperate	Comingled (P,M,D,PC)
	Dtd (weekly) Ecostations CAS	Dtd (monthly) Bring-points (monthly) CAS	Dtd (4-8 weekly) CAS	Dtd (monthly) Bring-points (monthly) CAS	Dtd (1-2weekly) Bring-points CAS
	Free	Free	PAYT: € 2.38 per emptying of 120L	Free	Free
Plastic (P), Metal (M) & Drinking (D) composite packaging	Comingled (P,M,D)	Comingled (P,M,D)	Comingled (P,M,D)	Comingled (P,M,D)	
	Dtd (weekly) Ecostations	Dtd (biweekly) Bring-points (biweekly) CAS	Dtd (weekly-biweekly)	Dtd (monthly) Bring-points (monthly) CAS	
	Free	PAYT: € 6 for 20 blue bags	Free	Free	
Residual waste	Dtd (weekly)	Dtd (1-2weekly)	Dtd (biweekly)	Dtd (monthly)	Dtd (1-2weekly)
	FIXED € 249/y (3p - 100m²)	FIXED € 25 /y bringbank (5 uses) € 100/y container (5 uses)	FIXED € 6.39 /quarter	FIXED € 80 /y	Waste tax based on the property value
	PAYT: First 960L free, then € 1.40 emptying Discount system for disposed recyclables[10].	PAYT: € 17.50 for 10 60L/15kg yellow bags € 3.50 for 120L container	PAYT: € 55.38 / quarter for 60L container	PAYT: € 0.24/kg at CAS € 5.60 for 140L container	

Table 1 - Overview of the collection modes and waste fees

2.2. BACKGROUND OF THE WEEE STUDY

In this paragraph, the five case studies for the WEEE study are further explained.

1. Pembrokeshire, United Kingdom
2. Vienna, Austria
3. Cyclad, France
4. Genoa, Italy
5. Helsinki, Finland

In all cases a certain action or investment to tackle the local collection challenge is at the centre of the assessment. The assessment focuses on the investments done by the PRO, municipality or collection entity in

[10] http://servizi.irenambiente.it/index.php/centri-di-raccolta/

order to improve the amounts of officially registered WEEE in the local collection sites. Within this period the investment costs, operational costs for collection, processing and recycling as well as the benefits of the system are identified and graphed. The operational costs and the revenues from the PRO are mapped. All these financial flows are processed in a Cost Benefit Analysis, which ultimately aims to highlight the cost effectiveness of increasing the WEEE collection, the options of different stakeholders to invest in a better-performing collection system and the financial flows of the WEEE collection system.

The WEEE assessment focusses on the following streams: Lamps, Small equipment and Small IT and telecommunications equipment (henceforth: small IT). These streams were chosen due to their similar characteristics and challenges at collection level[11]. The three categories can be characterized by their small size, which makes it easy to dispose e.g. a lamp, cable, or an old mobile phone in the residual waste. In addition, it is known that many IT appliances within these categories are kept at home or exit countries via illegal export routes and are not being reported to the official registers.

2.2.1. PEMBROKESHIRE, UNITED KINGDOM

Pembrokeshire is a coastal county in the south-west of Wales and therefore part of the UK, with around 125,000 citizens living on 1,590 km^2, i.e. 79 inhabitants / km^2. In Wales the GDP per capita amounted to £ 19,002 (2015)[12].

The industry is focused on agriculture, oil and gas, and tourism. Many of Pembrokeshire's beaches have won awards. In 2015 4.3 million tourists visited the county, staying for an average of 5.24 days.

Wales, situated in the South-West of the UK, is a nation of the UK Member State. With respect to WEEE, the WEEE Directive applies to the whole of the UK and there are UK wide Regulations[13] which implement the updated European WEEE directive 2012/19/EU of 2012 on WEEE collection. Wales has devolved powers with respect to municipal waste management and has its own waste management plan as described under the Waste Framework Directive[14]. Wales has taken an extra step and obligated themselves to even higher recycling rates for their general waste. In May 2009, the Welsh government introduced the “One Wales: One Planet” initiative. It is a sustainable development scheme laying out the basic principles to becoming a country without producing waste by 2050 (0% of waste is landfilled). Due to the subsequent improvements to the collection system, Wales is now one of the world’s top-performers in recycling, third only to Germany and Singapore[15].

The amount of waste put on landfill has decreased from 640,000 to 170,500 tons since 2012 and general waste recycling rate has risen to 60.2% in 2016[16,17].

Due to the successes, the government brought out the “Municipal Sector Plan – Collections Blueprint”, a comprehensive guidance paper outlining the contributing factors of the welsh waste collection system. It is designed to deliver high-quality recyclate and increase collection rate while becoming more economically efficient.

[11] At treatment level, small (IT) household appliances and lamps are very different. The lamp stream is a quite homogenous stream; while small equipment and small IT stream are streams composed by a large variety of different products.

[12] https://www.pembrokeshire.gov.uk/performance-and-statistics/data-and-statistics

[13] https://www.gov.uk/guidance/regulations-waste-electrical-and-electronic-equipment

[14] https://gov.wales/sites/default/files/publications/2019-05/towards-zero-waste-our-waste-strategy.pdf

[15] https://www.leaderlive.co.uk/news/17509742.global-recycling-day-survey-reveals-wales-is-third-best-in-the-world-for-recycling/

[16] Percentage of Waste Reused/Recycled/Composted (Statutory Target) in 2017-2018 as defined by Statutory Local Authority Recovery Target LART, as percentage of total municipal waste collected/generated

[17] https://www.bbc.com/news/uk-wales-37787961

From the municipal collection points, retailers and local collection facilities, the WEEE is processed mainly in Wales and England[18]. A state-of-the-art recycling facility was opened in 2009 for 12 million pounds in Newport, Gwent. It has the capacity to recycle 100,000 t of appliances a year and is home of the biggest refrigerator recycling plant in the world[19].

Due to the national efforts the collection rate of Small WEEE/IT electronics and lighting has increased in the last couple of years by more than 30%. The WEEE is in most cases considered as waste and treated accordingly, however, when possible, the SHA and lighting are refurbished and reused. In the figure below, the increase in collection numbers is presented[20].

Figure 10 - WEEE collection data Pembrokeshire

2.2.2. VIENNA, AUSTRIA

Austria capital lies in the west of the country, covers 414.87 km^2 and has 1.87 million inhabitants (2017) with an average population density of 4,502 inhabitants/km^2. The GDP in 2017 amounted to €47,700 EUR /cap.

Household waste disposal is organized by the municipality via the MA-48. They are responsible for various parts of the collection. Street cleaning cars, waste recycling centers (Mistplaetze), public toilets and large bulky waste, among others. The portion of WEEE in residual household waste has kept quite stable around 0.8 – 1.1% in the last 10 years.

Austria has celebrated great successes in recent years in improving their collection rates of electronic waste. In 2016, the 45% collection rate target was successfully reached thanks to an average of 9.51 kg per inhabitant officially recovered. In Austria, around 80,000 tonnes of WEEE are collected every year; the ARA service group (specifically, the ERA compliance service) accounts for 40 % of this amount. This collection rate is mainly due to the high collection point density. There are over 2,100 collection points spread out over the country where it

[18] https://myrecyclingwales.org.uk/destinations
[19] https://www.edie.net/news/5/12m-advanced-WEEE-recycling-plant-opens-for-business/15976/
[20] National statistics Wales on waste collection, 2018, https://statswales.gov.wales/Catalogue/Environment-and-Countryside/Waste-Management/Local-Authority-Municipal-Waste/annualwastereusedrecycledcomposted-by-material-source-year

can be deposited free of charge. Vienna alone has 16 recycling-centers or Mistplaetze[21], 93 mobile collection points and 4 stationary collection points on markets, plus the retail collection points[22]. Separate WEEE collection is divided among 4 PROs (extended producer responsibility organisations set by producers) operating in the entire country (ERA, UFH, ERP and ISA).

In Vienna, specific attention is given to reuse of EEE, before it becomes WEEE. In recent years there has been a significant increase in the reuse and recycling of electrical and electronic appliances in particular. Based on the Directive on waste electrical and electronic equipment (WEEE) 2012/19/EU, the reuse of WEEE is a high priority in legal terms.

To facilitate the reuse practice, Austria has a dedicated reuse network, RepaNet. Together with the City of Vienna (MA48) and the ReparaturNetzwerk Wien, RepaNet works on the establishment of a reliable Vienna wide network, in which reusable devices will be categorized separately, tested and get repaired in order to be sold as high quality secondhand products. The DRZ (Dismatling and Recycling Center) is one of Vienna's biggest reuse centers. Annually, the DRZ processes 1,500 tons of electrical equipment (mainly large, small and IT appliances), of which they manage to reuse and sell 150 tons[23]. As can be seen in the figure below, the collection rate of Small WEEE/IT electronics and lighting has been increasing significantly in the last couple of years[24].

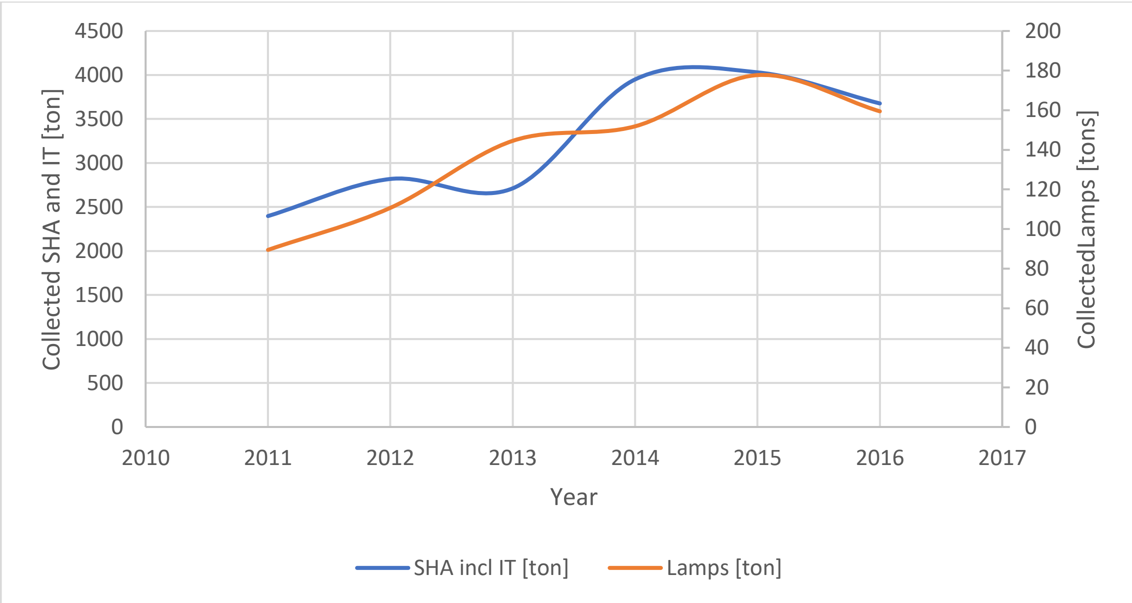


Figure 11 – WEEE collection data Vienna

2.2.3. CYCLAD, FRANCE

Cyclad is the collective waste collection organisation of a large part of the Charente-Maritime area in the rural mid-west of France. Cyclad is responsible for the collection, treatment and final disposal of the waste of six community of communes (Aunis Atlantique, Aunis Sud, Vals de Saintonge, Coeur de Saintonge, Gémozac and Saintonge Viticole)[25], comprising of 188 communes with 148,659 habitants and covering an area of 2,704 km^2,

[21] https://www.wien.gv.at/umwelt/ma48/entsorgung/mistplatz/adressen.html
[22] Strategische Umweltprüfung zum Wiener Abfallwirtschaftsplan (Wr. AWP) 2019-2024 und zum Wiener Abfallvermeidungsprogramm (Wr. AVP) 2019-2024
[23] Interview with DRZ, July 2019
[24] Taetigkeitsbericht EAK 2017, EAK, Coordinating entity of WEEE in Austria, https://www.eak-austria.at/presse/TB/Taetigkeitsbericht_2017.pdf
[25] Cyclad territories, 2019, http://www.cyclad.org/page.php?P=80

resulting in a population density of 55 inhabitants/km^2. The average GDP in Charente-Maritime was ca € 28,140 per cap in 2015, being below the national average of € 27,811 per cap.

In addition to the waste collection and processing, Cyclad also organizes awareness campaigns for sorting and reducing waste. The syndicate's formation shows the political will of a rural area to make use of synergies for an efficient waste management in a sparsely populated area.

The recycling of WEEE is financed by the Eco-participation fee paid with each purchase of new equipment. Under the EU WEEE directive vendors have an obligation to recover end-of-life devices. More and more communities are offering this line to their waste treatment centers to facilitate sorting and promote recycling. This is the case for Cyclad, offering the collection in partnership with the PRO Eco-systèmes. Together they collect about 90% of the local WEEE. Lamps and batteries are collected separately by CorePile and Récylum.

The biggest problem related to WEEE collection Cyclad has been facing was theft of valuable WEEE components. In order to protect metals, WEEE and batteries Cyclad bought containers (20ft) with special locks. In addition, Cyclad invested in video surveillance at all sites. Marking appliances with bright orange paint to make collected WEE easier to recognize has been another effective measure. Furthermore they have a special contract with the police, who regularly checks the collection sites. The national ban in 2011 on cash transaction for metals, to avoid WEEE leakage at borders and to include scrap dealers in the system and avoid WEEE non-compliant treatment.

Figure 12 – Marking the WEEE (L) and storage containers against theft (R)

Additional measures include awareness raising campaigns to mobilize small WEEE that people keep at home in their drawers. For a long time, there was a hoax in France that all collected WEEE was going straight to India, which discouraged people to bring their WEEE to the correct collection points. Several campaigns have been launched to inform the general public on the correct WEEE treatment routes in France. All the measures together have resulted in a constant increase of collected small WEEE quantities as shown in the figure below.

Thanks to these measures the stealing decreased significantly and the WEEE flow is better under control. In 2017, Eco-systèmes collected 533,640 t of WEEE amounting to 50 % of the global amount, i.e. 10.2 kg/capita. Out of this number 6.6 kg (65 %) are collected at CAS, 1.7 kg (17 %) at supermarkets and retail stores and 0.3 kg (3%) at social reuse centers, and 1.5 kg (15 %) via others channels. In the Cyclad region, a total of 1,568 t of WEEE has been collected in 2017 (equivalent to 260,104 domestic appliances) in 5 categories, small WEEE & IT (546.8 t), screens (218.4 t), cooling devices (258.3 t) large WEEE (544.9 t)[26] and lamps (3.0t).

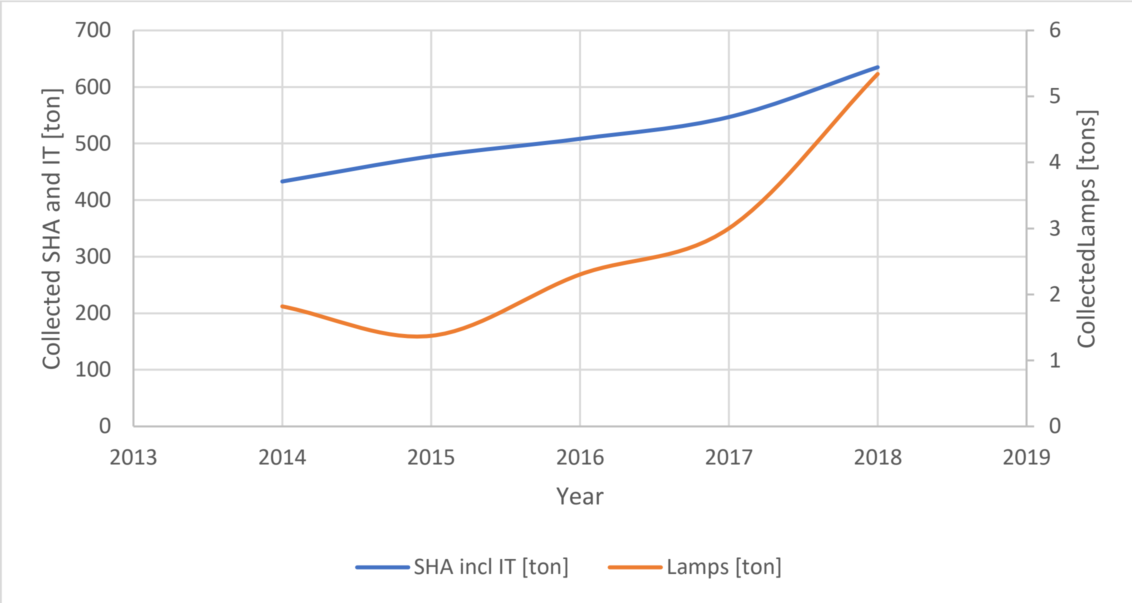


Figure 13 – WEEE collection data Cyclad

2.2.4. GENOA, ITALY.

Genova is the capital of the Italian region Liguria and the sixth-largest city in Italy. It is located in Northern Italy on the Gulf of Genoa in the Ligurian Sea, covers 240 km^2 and has 580,097 inhabitants (2017) with an average population density of 2417 inhabitants /km^2. The GDP in 2012 amounted to € 20,529 EUR per capita.

Azienda Multiservizi e d'Igiene Urbana (AMIU) organises the WEEE collection for the city of Genova and is totally owned by Genova Municipality. AMIU is financed by the City of Genova through the citizen waste tax as well as the Italian PRO's. As an intermediar AMIU receives efficiency prices from the PROs for good collection (113 €/ton). The scope of the CBA however, is from the PRO's perspective. AMIU, as a vital part of the Genova WEEE collection network, is included in the CBA and their operational costs are assumed to be covered by the PRO.

AMIU collected a total of 3,533 ton WEEE in 2017, i.e. 6.1 kg per cap. The non-retail bring-points receive 706 t of WEEE (1.2 kg/cap), while the civic amenity sites (CAS) received 2,825 t (4.9 kg/cap).

With the launch of the WEEENMODELS project, the WEEEE collection system in Genoa has been completely revised. AMIU created 47 new mobile collection points for small WEEE and 4 ecological islands, i.e. collection and recycling areas, distributed all over the territory, where citizens can bring their WEEE. The mobile collection system operates daily in different parts of the city. In practice the mobile collection system operates through a system of two equipped vans (ECOVAN +, and ECOCAR) which stop at different stations at scheduled times and locations and where citizens can confer their small WEEE, including lamps. Small household equipment can be brought to the ecological islands and to the ECOVAN +. IT equipment can be brought to the ecological islands or to the ECOVAN+.

The WEEENMODELS project involved the testing of a mobile collection system of WEEE in 6 locations (all located to the western side of Genoa) for 5 months (September 2015 - February 2016) in order to understand if citizens would appreciate such collection system. Of the 6 collection stations, 2 have received very positive results, 2

[26] Annual report DEEE Cyclad 2017, ESR http://www.cyclad.org/UserFiles/medias/doc/2017%20-%20Rapport%20DEEE.pdf

were moderately used by citizens, and other 2 were almost not used. In total 1,172 kg of small WEEE were collected, out of which 377 kg could be re-used.

The retailers who joined the WEEENMODELS project have a free platform, a container for collecting small WEEE, which is provided by AMIU, a low-cost collection service and the possibility to take WEEE to the AMIU Collection Centre, renovated for that purpose.

The communication campaign, carried out by AMIU, has increased awareness about the separate collection of WEEE. Workshops and laboratories were organized for young participants to increase their knowledge on the concept of circular economy.

The measures taken within the WEEENMODELS had a positive impact also in the following years[27], as shown in the figure below.

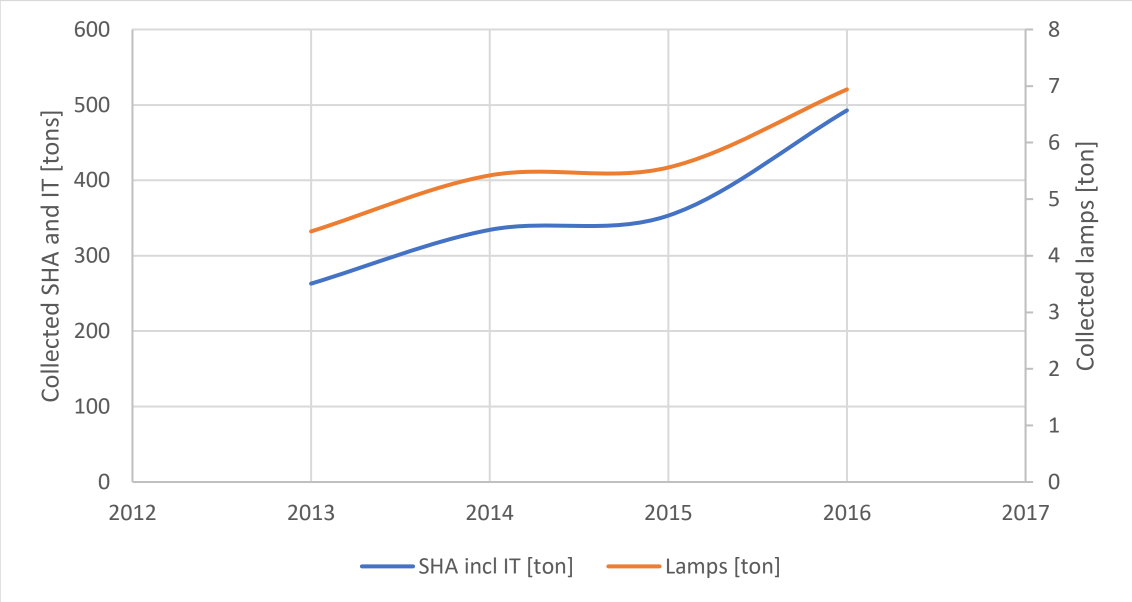


Figure 14 – WEEE collection data Genova

2.2.5. HELSINKI, FINLAND

Finland has 5.43 million inhabitants with an average population density of less than 18 inhabitants /km^2. The distance between the southernmost to the northernmost points of Finland is almost 1.200 km. The majority of Finns live in the southern and western parts of the country. The most populous area is the Helsinki Capital Region including the cities of Helsinki, Espoo, Vantaa and Kauniainen and Kirkkonummi in the southern coast, with about 1.2 million inhabitants in total covering 1,157 km2, i.e. 1,037 inhabitants/km^2. The GDP amounts to € 50,741 per capita[28]. The study focuses on the Helsinki capital region.

At the moment, there are five producers associations (FLIP ry, ICT-tuottajaosuuskunta, SELT ry, SERTY ry, and ERP Finland ry) providing centralized services to manage practical affairs related to the obligations set out in the WEEE Directive and to fulfil the corresponding obligations of Finnish legislation. The total WEEE collecting in

[27] WEEENModels collection data 2013-2016,
http://www.weeenmodels.eu/allegati/C1%20WEEE%20Data%20Overview%202013-2016%20.pdf
[28] HSY Jätehuollon vuositilasto 2017;
www.hsy.fi/sites/Esitteet/EsitteetKatalogi/Jatehuollon_vuositilasto_2017.pdf
HSY(2017) Vuosikertomus 2016;
HSY (2016) Pääkaupunkiseudun seka- ja biojätteen koostumus

2018 was 13.250 tons, or 11.2 kg/cap, with a collection rate of 52%. Since 2007, the overall WEEE collection rate in Finland has exceeded 9 kg/inhab/year, ranking third best in the European Union.

In 2011, approximately 450 collection points existed around the country. Permanent collection points are, in most cases collectively financed by the producer associations, provided by the municipality and, in some cases, by private companies or social enterprises. Private users and households can bring their end-of-life products to the collection points free of charge. However, permanent collection systems are not always efficient, due to e.g. long distances and low quantities of returned devices. Therefore since 2013, WEEE collection in Finland is also organized as a mobile collection in the 50 smallest or least populous municipalities. In Helsinki region, mobile collection of small WEEE is organized twice a year, in addition to the permanent bring points and civic amenity site (CAS). While one round is organized by the regional waste management company HSY, the other one is organized by the regional recycling center (Kierrätyskeskus). The recycling center collects only functional devices (169 tons/year)[29].

In addition, the amounts of WEEE received in retail stores have also increased. End of life EEE devices can also be returned to the retailers in association with buying a new, corresponding device, to the store the new device is bought at. Additionally, fluorescent lamps and LEDs as well as portable batteries and accumulators can also be returned to the retail shops with no purchasing obligations. The transportation of WEEE from reception points and registered stores to the regional treatment plants is managed by the producer associations. The logistics services are typically sourced from private regional operators. At the collection points, the WEEE is divided into four different fractions with lamps and batteries being collected separately: Cooling appliances, large domestic appliances, small domestic appliances and IT appliances (incl. screens). All kinds of lamps are collected separately of other SDA by FLIP Association, a producer organization responsible for the producer responsibility of lamps falling within the scope of the WEEE directive.

At the regional sorting plants, WEEE is separated based on brands, not on product categories or source, for different product cooperatives, weighed, and sorted into reusable and not reusable fractions. Functional devices are manually separated and directed for preparation for re-use. The rest of the WEEE is sorted out according to WEEE categories and is pre-treated before sending to the various treatment plants for final treatment. The companies offering sorting and dismantling services to producers associations are typically social economy enterprises but a few private companies also exist in the field. Some of the dismantling and pre-treatment plants provide also final treatment services for particular WEEE fractions; however, most of the sorted and pre-treated WEEE is forwarded to detached recovery and/or final treatment plants located mainly in Finland. While all WEEE of a certain producer is treated at the same pre-treatment stations, they are all sent to the same final recycling plants. Another reason for the increased collection quantities is the improved reporting and reporting accuracy thanks to new treatment operators.

In the Helsinki urban area where HSY operates, the collection of SHA, IT and lamps has been steadily increasing, as can be seen in the figure below.

[29] Ylä-Mella, J., Poikela, K., Lehtinen, U., Tanskanen, P., Román, E., Keiski, R.L., Pongrácz, E., 2014. Overview of the WEEE Directive and its implementation in the Nordic countries: national realisations and best practices. Journal of Waste Management 2014

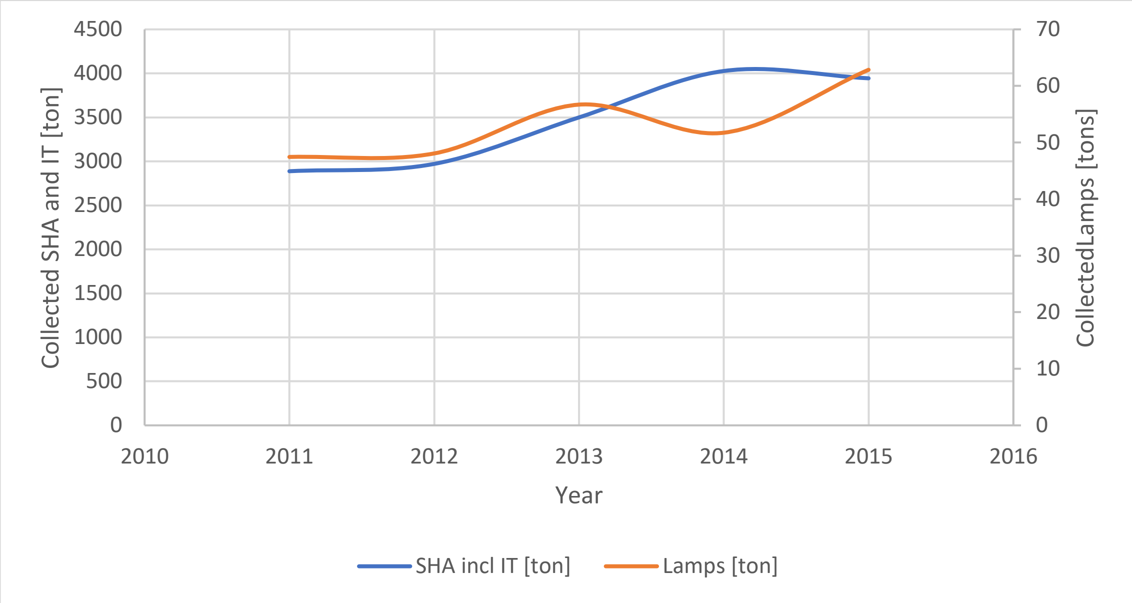


Figure 15 – WEEE collection data Helsinki

2.3. BACKGROUND OF THE CDW STUDY

In this paragraph, the two construction and demolition waste case studies are further explained.

1. Odense, Denmark
2. Reimerswaal, the Netherlands

In contrast to PPW and WEEE, the collection of CDW is mainly in hands of private companies, being construction companies and contractors. The relevance of publicly organised waste collection systems is very different for CDW compared to PPW and WEEE, and mostly limited to providing a service to citizens for the collection of specific fractions of CDW that citizens want to get rid of. Both cases successfully implemented a separate collection approach for construction and demolition waste streams that have recycling potential.

For the Odense case, the study will focus on brick, insulation and sanitary waste. The Reimerswaal case studies the separate collection and disposing of gypsum waste.

2.3.1. ODENSE, DENMARK

Odense is the 3rd largest city in Denmark with a population of 204,200[30]. Odense is the commercial hub of Funen, and has a notable shopping district with a diversity of stores. Several major industries are located in the city including the Albani Brewery and GASA, Denmark's major dealer in vegetables, fruits and flowers. Odense has 8 recycling stations (CAS), with over 40 containers for collecting different waste materials. The vast majority of containers will be found at all the recycling stations in Odense. However, the smallest recycling stations do not have space for all 40 containers. Five of the eight stations facilitate the separate collection of all these categories.

Odense is a good example of a municipality involved in innovative CDW management schemes, leading the way in the reuse of old bricks which are being refurbished in Odense Renovation A/S's recycling centres. Previously, when bricks were delivered to Odense Renovation A/S, they were crushed and reused in construction projects, just like concrete and slate, but discarded bricks now have their own dedicated containers at the recycling centres[31]. When a container is full, it is driven to the Gamle Mursten factory in Svendborg on Funen, where they

[30] Statbank Denmark, 2019. Statistics Denmark, https://www.statbank.dk/BY1
[31] Gamble Mursten, 2019. Old bricks with character and history, http://gamlemursten.dk/

are cleaned and sorted before being stacked on pallets ready for reuse in new constructions. Odense also collects both waste mineral wool insulation and waste ceramic sanitary ware separately in order to repurpose this material. In 2016 Odense started working with Noreco and KI Hansen for the recycling of both these materials streams. The figure below shows the collected quantities in Odense.

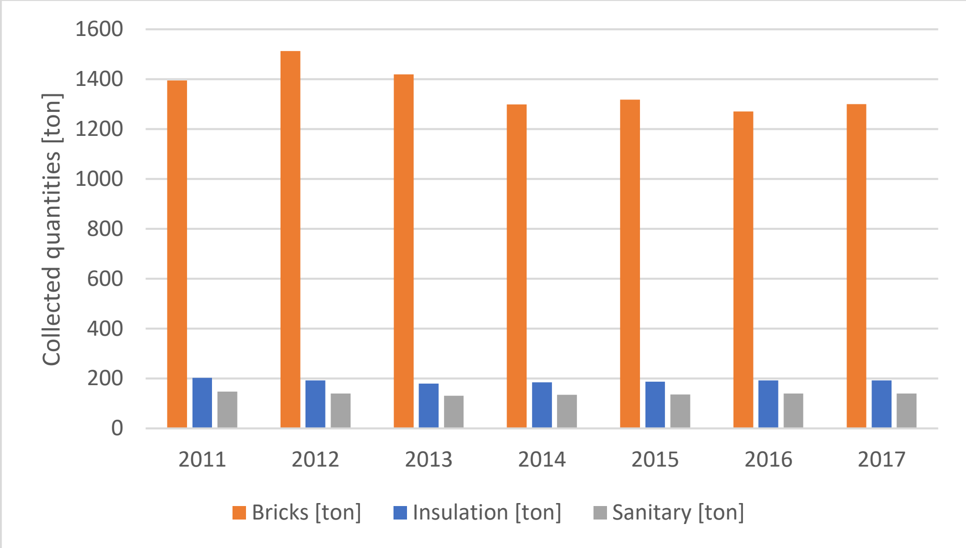


Figure 16 – Brick, insulation and sanitary waste collection in Odense 2011 – 2017[32]

2.3.2. REIMERSWAAL, THE NETHERLANDS

Reimerswaal is a municipality in the province of Zeeland in the south-western Netherlands on Zuid-Beveland. The municipality had a population of 22,432 in 2017, and has a surface area of 242 km^2 of which 140 km^2 is water. The municipality of Reimerswaal was established in 1970, from the aggregation of the municipalities Krabbendijke, Kruiningen, Rilland-Bath, Waarde, and Yerseke.

The municipality is responsible for the collection and management of household waste and has this outsourced to private scheme The Zeeuwse Reinigingsdienst (ZRD). ZRD does the collection of all household waste (residual, organic, plastics and beverage cartons) as well as the management of all the CAS in Zeeland, where 25 different CDW categories are collected. ZRD focusses on collecting clean gypsum, providing high quality input flows for the recycling process, and instructs citizens to dispose their gypsum free of contamination such as tiles and wood. In 2011 and 2012, the ZRD received the gold certificate for the large amount of clean quality gypsum waste collected, of which the quantities have been increasing over the years.

[32] Odense collected CDW quantities, Affald private husstande 2011 - 2016

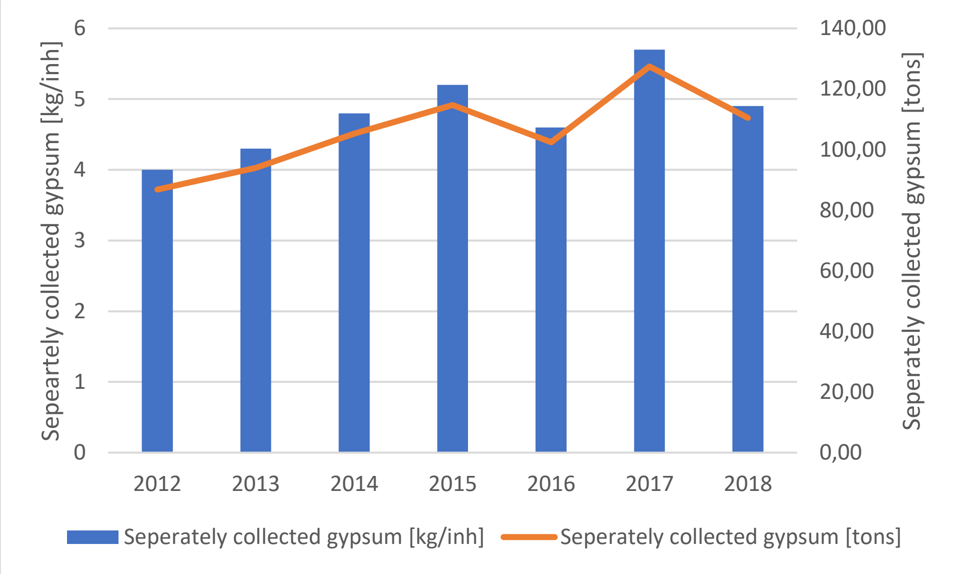


Figure 17 – Gypsum collection in Reimerswaal 2012 – 2018[33]

ZRD has been working on gypsum recycling for many years. In the past the gypsum waste was recycled through GipsrecyclingNL, who worked together with Danish gypsum recylers Knauf Danogips A / S and Gyproc A / S. Since a few years however, ZRD started working together with the New West Gypsum Recycling facility in Kallo near Antwerp.

3. METHODOLOGY

3.1. COST BENEFIT ANALYSIS

A cost-benefit analysis (CBA) strives to estimate positive and negative effects of a project or policy on the welfare of the region or country in which it is located. It takes the perspective of society as a whole and thus includes costs and benefits for all stakeholders, not only the project owner. The CBAs for the COLLECTORS project have been conducted in accordance with the EC CBA guidelines (Guide to Cost-Benefit Analysis of Investment Projects, European Commission, December 2014).

A CBA generally consists of the following steps:

1. Definition of the project owner, project and the reference case
2. Estimation of costs and benefits
3. Monetization
4. Discounting future effects
5. Sensitivity analysis

Firstly, it is important to define the perspective of the analysis, which can be done by defining the project owner. Depending on the waste stream, the project owner can vary. In all PPW cases, the initial project owner will be the municipality, potentially in combination with the outsourced waste management company. For the WEEE cases, the initial project owner can vary, but will often be either the PRO or the municipality. In the COLLECTORS CBA for WEEE, the PRO is chosen as the main project owner. For the CDW cases, the project owner is the municipality in combination with the local waste management company.

Subsequently the project definition describes what the project entails, what scope is chosen, and which assumptions are made. In a typical CBA the project or investment is compared to a reference case, often a

[33] Afvalmonitor, 2018

situation without implementation of the project. This allows for a clear comparison between the costs and the benefits. In all cases a reference case is defined, however not for all cases the comparison between project case and reference case is made. For the studies performed on the PPW and WEEE systems, the *additional investments* are identified, however the *absolute operational costs and revenues* are mapped, in order to discuss the practical financial viability of the collection system. In addition, data availability and complexity of the assessment made it impossible to perform a full incremental assessment. For the CDW systems, the project case is compared to the reference case on all cost and benefit items, resulting in a full assessment of the incremental costs and benefits.

The main costs that need to be taken into account for the COLLECTORS project are investment costs (including e.g. machinery, trucks, containers, and land) and operational expenses (collection and processing costs and taxes). The benefits include direct revenues (e.g. revenues from recovered materials, EPR fees from the packaging industry and citizen waste taxes, PRO fees from the EEE producers and government subsidies). Indirect benefits may also occur (e.g. effects on other markets such as the labour market and utilization of valuable secondary materials), however these are left out of the Collectors scope. Potential externalities, or unintended impacts of the project on third parties such as GHG emissions, air, water or noise pollution are a part of the environmental analysis and therefore excluded from the CBA in order to avoid double counting. These results are further analysed in the COLLECTORS Life Cycle Assessment (LCA) – see Deliverable 3.1.

To make current and future costs and benefits comparable, future effects are discounted to obtain their present value (PV). The present value is generally lower than the future value because the money has interest earning potential, often referred to as the time value of money. For this CBA, a discount rate of 4% and a time horizon of 10 years are used, as suggested by the EC CBA guidelines. In case of data unavailability however, some assessments cover a shorter time horizon. The following equation is used for discounting to obtain present values of costs and benefits:

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} \qquad PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

The net result of the CBA is the Net Present Value (NPV), computed by the following equation:

$$NPV = PV(B) - PV(C)$$

In this equation, n indicates the project lifetime in years, B the benefits in year t, C the costs in year t and s indicates the discount rate. The NPV therefore presents the difference between the present value of cash inflows and the present value of cash outflows over a period of time; indicating whether the waste collecting is costing money, breaking even, or generating revenues. Obviously, the goal of a waste collection system is not to generate profit, but first of all to provide a public service and keeping the city clean. However, it is interesting to assess the net present value, as this will reflect on the financial viability of a waste collection system, and therefore the practical feasibility for an actor to implement such a system.

Including the environmental costs and benefits as well as other externalities within the project scope, would results in the Economic Net Present Value. In this report solely the Financial Net Present Value is used, as the Collectors Deliverable 3.3 already reflects on the environmental aspect.

3.2. DATA SOURCES AND OVERALL ASSUMPTIONS

A standardized approach was established for data collection, overall assumptions and evaluations. In this way, results of the CBAs are to a large extent comparable. It should be noted, however, that because of the specific characteristics of the waste collection systems (e.g. different context and locations, different interpretations and measuring methods of data, as well as data uncertainty) it is important to be prudent with drawing conclusions on comparisons between these CBA-results.

DATA COLLECTION

The data for the CBAs is collected using public data sources (local, national and EU databases), annual reports and/or interviews. As the CBA results are highly sensitive to the underlying assumptions and data, the analysis is approached and the data is collected using the following systematic prioritised approach.

(1) Data from local databases or reports;
(2) Data from interviews with local stakeholders;
(3) Data from national databases or averaged national benchmark reports;
(4) Data from European databases or averaged European benchmark reports (e.g. Eurostat);
(5) Data from peer-reviewed article or institutional reports/databases;
(6) Data from market prices – based on at least 3 quotations;

In all cases, the relevant municipalities and/or their waste management companies and waste experts are consulted to validate (and adjust) the selected data and assumptions.

DATA UNCERTAINTIES AND BIASES

As the outcomes of the Collectors case studies rely largely on data collected outside of the project, by local, regional, national or European governments or organisations, Collectors cannot guarantee the comparability of the data. In data collection often many assumptions have to be made, and these are not always stated and transparent. The potential inconsistencies that have been identified focus mainly on the quantification of the actual costs of waste collection. In many cases, it is unclear how operational costs are allocated to the different budget items by the local authority; e.g. how do you split the costs for collection of co-mingled materials to single fractions; how do you divide costs when separate waste streams are collected in the same pickup route; and how are staff costs allocated to various waste streams? For the WEEE collection, there is the issue of competition and therefore data confidentiality. In addition, discrepancies for staff costs, VAT and depreciation can make comparison difficult. Where possible, it is aimed to work around data inconsistencies and make data comparable. All assumptions and data sources are stated, for PPW see Chapter 4, for WEEE see Chapter 5 and for CDW see Chapter 5.1.

OVERALL ASSUMPTIONS FOR PPW ASSESSMENT

All CBA's are calculated with a 4% financial discount rate. All cases are assessed in a period of 10 years. For future years where relevant the anticipated population growth or decline is accounted for, as the generated waste is strongly dependent on population. Furthermore, it is assumed the waste per inhabitant rate will stay the same as the most recent available value.

It was aimed to identify investment costs, operational costs and revenues from the waste collection system. Below the case overarching elements are discussed per category.

Investment costs: the investments costs in the 'generic' waste collection infrastructure (bins, trucks, etc.) are not included. In all cases, these elements are already present (either in possession by the municipality or through the subcontracting party). What has been included in the investment section are the additional costs required for setting up the new waste collection system. These costs can include e.g. new bring points, chipped bins, awareness and communication campaigns or brochures. In addition, the presence of a well-functioning recycling value chain is a crucial aspect. Without capacity to recycle the waste, the (financial) performance of the collection system can be expected to be poor. Absence of a proper recycling value chain can also incentivise actors to find other ways to dispose the waste (e.g. incineration or export). This report focusses specifically on the collection system, therefore investment costs for such elements are out of the scope of this assessment. The Collectors deliverable 2.4 provides more information on the recycling value chain.

Operational costs: Collection costs are interpreted as the operational costs required for collecting and transporting the waste from the municipality's citizens to the waste management company's storage or sorting facility. The collection costs are defined as all costs that are directly attributable to the collection of the paper and packaging waste. These costs consist of: personnel, transport, means of collection, outsourced services, and other costs such as, for example, PAYT costs. Also costs for cleaning up littered packaging waste is included.

The processing costs are interpreted as all the operational costs required for the reprocessing, post-sorting and potential transport of the waste streams. As all waste streams have a different density and composition, the collection and processing costs often vary significantly.

Also the missed opportunity costs from (plastic, paper and cardboard) waste diverted from incineration is included. Almost all cases realised a significant drop in residual waste numbers, which results in less quantities and less combustible waste for waste to energy plants.

Revenues: The identified revenues or incoming cash flows in the PPW cases are the waste tax paid by citizens, recovered waste materials sold, incineration profits, government incentive funds, and EPR fees from the packaging industry.

The exact structure of the operational costs and revenues varies per case, and is discussed further in detail in Chapter 4.2 - 4.6.

OVERALL ASSUMPTIONS FOR WEEE ASSESSMENT

All CBA's are calculated with a 4% financial discount rate. It is aimed to assess in a period of 10 years, however for the WEEE case studies data was available for only 4 - 6 years. Since the collected quantities and price trends vary considerably, due to large uncertainties no extrapolation for future years has been included.

It was aimed to identify investment costs, operational costs and revenues from the waste collection system. Below the case overarching elements are discussed per category.

Investment costs: the investments costs in the 'standard' waste collection infrastructure (bins, trucks, etc.) are not included. It is assumed these base elements are already present. What has been included as investment costs are the additional costs meant to boost the WEEE collection rates. These costs can include new bring points, campaigns on awareness, communication campaigns, measures for safety and surveillance against theft, etc. In addition, the presence of a well-functioning recycling value chain is a crucial aspect. Without demand and capacity to recycle the WEEE, the (financial) performance of the collection system will be poor and actors will be incentivised to find other ways to dispose of the WEEE. This report focusses specifically on the collection system, and will not reflect on the recycling value chain in detail. The Collectors deliverable 2.4 has more detail on the WEEE recycling value chain.

One important factor that may condition the investment in collection infrastructure is the short duration of the contracts and agreements set between the actors in the value chain. E.g. it occurs that a PRO has a one year permit for collection, meaning that they will not be inclined to set long-term commitments with recyclers or collection facilities, and therefore will not have the stability to invest in better-long term treatment or collection campaigns for improving their services.

Operational costs: The operational costs are interpreted as the operational costs required for collecting and transporting the WEEE from the municipality's citizens to the sorting and/or recycling facility. In general, it was found that since the WEEE collection has become very competition sensitive, little case specific financial data regarding operational costs and benefits has been obtained. Further elaboration on these costs is provided in Chapter 5.1.

Correct and environmentally friendly disposal of WEEE often comes at a high costs, whereas the costs associated with unreported WEEE treatment are lower, generating a situation of unfair competition with the 'legal' sector. This unbalance in the costs is estimated in the report of the WEEE economics of EERA[121].

Revenues: The identified revenues or incoming cash flows are assumed to be the fees paid by producers to the PRO's. The revenues gained from selling recovered waste materials such as metals are assumed to be out of the scope and fully collected by the recyclers further up the value chain. In some cases additional revenues from e.g. government incentives are included.

FNPV: From the investment costs, operational costs and revenues the financial net present value (FNPV) is calculated taking into account the discount rate as mentioned above. The FNPV ideally reflects a period of 10 years, however for some cases only 4-6 years of data were available.

The exact structure of the operational costs and revenues varies per case, and is discussed further in detail in Chapter 5.

OVERALL ASSUMPTIONS FOR CDW ASSESSMENT

All CBA's are calculated with a 4% financial discount rate. All cases are assessed in a period of 10 years. For future years of which no data is available, the anticipated population growth or decline is accounted for, as the generated waste is strongly dependent on population.

In the assessment the investment costs, operational costs and revenues from the waste collection system are identified.

Investment costs: the investments costs in the 'generic' waste collection infrastructure (bins, trucks, etc.) are not included. In both cases, these elements are already present (either in possession by the municipality or through the subcontracting party). What has been included are the additional costs required for setting up the separate waste collection approach. These costs include the investment of new containers in both cases.

Operational costs: Collection costs are interpreted as the additional operational costs required for separate collection approach. These include transport costs and gate fees at the recycling or disposing facility. The collection costs are defined as all costs that are directly attributable to the collection of studied waste streams.

Revenues: The identified additional revenues that spring from the separate collection approach are savings in taxes, gate fees and transport costs.

The exact structure of the operational costs and revenues varies per case, and is discussed further in detail in Chapter 6.2 - 0.

DATA AVAILABILITY

A correct reflection of reality can only be made by including dynamic tariffs, e.g. detailed information per unit of time. Through the years, the operational costs, charged waste fees to citizens, market prices for secondary materials, EPR packaging fees and gate fees can vary. It is aimed to map these trends as detailed as possible, however, not in all cases data was available. The tables below gives an overview of the type of data used and indicates whether;

- Data for multiple years is available (✓);
- Data for only a single year is available (✓);
- No data is available (✗).

	Parma	Ghent	Berlin	Tubbergen	Rennes
Operational costs	✓	✓	✓	✓	✓
Investment costs	✓	✗	✗	✓	✓
Waste fee	✓	✓	✓	✓	✓
Recovered materials	✓	✓	✓	✓	✓
EPR fees	✓	✓	✓	✓	✓
Collection data [years]	7	5	6	8	9

Table 2 - Data availability per PPW case

	Pembrokeshire	Vienna	Cyclad	Genoa	Helsinki
Operational costs	✓	✓	✓	✓	✓
Investment costs	✓	✗	✓	✓	✓
PRO fees	✓	✓	✓	✓	✓
PRO fee[34]	National	Local	National	National	EU
Collection data	✓	✓	✓	✓	✓
Collection data [years]	6	6	5	4	6

Table 3 - Data availability per WEEE case

	Odense	Reimerswaal
Operational costs	✓	✓
Investment costs	✓	✓
Gate fees	✓	✓
Collection data	✓	✓
Collection data [years]	7	8

Table 4 - Data availability per CDW case

3.3. SENSITIVITY ANALSYIS AND EVALUATION

In order to highlight the sensitivity of the CBA results and reflect on potential uncertainties in the data, a sensitivity analysis is performed. The most relevant, uncertain or dynamic parameters are selected for the sensitivity assessment, as these are deemed most likely to influence the results. For PPW, WEEE and CDW different parameters are used in the assessment. The parameters and scenarios are described below. Lastly, the case results will be evaluated by looking how cases performed on specific aspects.

PPW

SENSITIVITY

The sensitivity analysis for PPW is performed on the following parameters; i) the total operational costs; ii) the material prices; iii) the EPR fees; and iv) the capture rate. From all parameters, these are deemed the most likely to fluctuate over the years and the most likely to have significant effect on the total financial viability.

Operational costs: The scenario assessed in the sensitivity analysis is a decrease of 10% in the total operational costs (including the cost of collection, processing, transport, communication and prevention) for all future operational years.

[34] This row indicates whether local, national or EU average data was available and used.

Material prices: The scenario assessed in the sensitivity analysis is an increase of 10% in the all material prices for all future years. Better waste collection practices are expected to increase the quality and therefore price of the collected materials. Also an increasing scarcity of primary materials could drive up future material prices. It is expected the material prices could influence the end results significantly.

Producer fees: The Extended Producer Responsibility schemes present a crucial financial lever for high quality separate waste collection. Further stimulation of high quality waste collection could be incentivized with higher EPR fees. The effect of this parameter is assessed with an increase of 10% for all future years.

Capture rate: The following hypothetical scenario is assessed; What would the costs and benefits look like for a 100% capture rate at the end of the project period. To analyse this, the most recent residual waste composition is taken as a starting point, and a gradual increase in capture rate is assumed up to 100% in the final project year. For instance; case A has a 75% capture rate for waste stream X in year 1; gradually increasing to a 100% capture rate for waste stream X in year 10. It is expected such a development would result in more expensive pickup routes and other shifts in operational costs. Information on this is not available and this effect is therefore not included. It is assumed the operational costs in Euro per ton stay equal to the cost of the most recent year.

The sensitivity assessment is done only for future years, as for these years the data is uncertain. E.g. for Parma data is available up until 2017, meaning that the in the sensitivity assessment parameters have been changed starting in 2018.

For all scenario's the effect on the financial net present value and the benefit/cost ratio will be calculated. This will indicate how sensitive the results are to the change in the chosen parameters. For all scenario's the effect on the financial net present value and the benefit/cost ratio will be calculated. This will indicate how sensitive the results are to the change in the chosen parameters. The FNPV is calculated as described in Chapter 3.1. The benefit/cost ratio is calculated by summing all project benefits and dividing this by the sum of all project operational costs. The investment costs are thus not reflected in the benefit/cost ratio, this merely shows to what extent the project operational costs are in line with its revenues.

EVALUATIONS

The final results will be evaluated looking at the waste fee, the total investments, the collected waste quantities and the operational costs. The evaluation of the CBA-results will be performed on indicators shown in Table 5. The numbers presented in this table summarize the operational and financial performance of the waste collection system.

Evaluation	
Waste fee drop	%
Total investment	€
Investment per inhabitant	€ per inhabitant
Drop in residual waste	%
Increase in separate collected recyclable PPW waste	%
Decrease in operational costs for residual waste EUR/inh	€ per inhabitant
Decrease in operational costs for separate PPW EUR/inh	€ per inhabitant

Table 5 - Setup of evaluation parameters

WEEE

SENSITIVITY

A sensitivity analysis has been performed on three parameters; i) the PRO fee; ii) the collection costs and iii) the recycling costs.

The PRO fee: The PRO fee is an aspect that can fluctuate year to year, and PRO to PRO. Due to competition and price sensitivity, exact data is difficult to come by. Hence, in many cases national average PRO fees are used. Further competition could lead to lower PRO fees, whereas environmentally sound recycling could inspire higher PRO fees. Lastly, PRO fees may be affected by the level of market share (the more volumes a PRO treats, the better price they get for recycling) as well as the market prices of won materials (scrap, plastics, etc.). As all these aspects introduce uncertainties in the data, the sensitivity analysis foresees three scenarios;

1. A stable PRO fee;
2. A decreasing PRO fee with 10%;
3. An increasing PRO fee with 10%.

The exact scenarios are further discussed individually for each case in Chapter 5.

Collection costs: The collection costs are largely based on estimated operational costs from previous studies (see Chapter 5.1.1), which might be outdated and have decreased due to efficiency gains. Therefore, a scenario is foreseen where the collection costs decrease by 50%.

Recycling costs: Recycling is officially out of the scope of the assessment. Since recycling makes up for a large part in the EPR cost scheme, marks an important challenge faced in the value chain (due to expensive and complex recycling processes) and plays a crucial role in a well-functioning circular (W)EEE model, this aspect is included. The recycling costs consist are largely based upon previous studies (see Chapter 5), which might be outdated and have decreased due to efficiency gains. The recycling costs consist of the cost for shredding, sorting, dismantling; recycling and recovery. It is quite possible that either one of these processes has become more efficient or cost effective in the last years, which would mean a decrease in cost. Similar to the collection costs, a scenario is foreseen where the recycling costs decrease by 50%.

These scenarios are combined in three potential scenarios, displayed in the table below. The first scenario is marked as the standard scenario, as this is based upon the currently available information. The second scenario is marked as the worst-case scenario, where the PRO fee further decreases due to competition between PRO’s. The collection costs and recycling costs stay at the standard values. Lastly, the third scenario is marked as the best-case scenario, since in this scenario the PRO fees increase (more budget for compliance and recycling), and both the collection and recycling costs decrease (less expenditures on collection and recycling).

Scenario	PRO fee	Collection costs	Recycling costs
1 Standard	Stabilized	Std	Std
2 Worst-case	Decreasing	Std	Std
3 Best-case	Increasing	Decreased 50%	Decreased 50%

Table 6 - Scenarios for the sensitivity assessment

EVALUATIONS

The evaluation the final results will be assessed based on the total investments, the extra collected WEEE quantities and the cost effectiveness. This last parameter is calculated by dividing the total investment by the extra WEEE collected, resulting in a price per ton. The numbers presented in Table 7 will shed some light on the operational and financial performance of the waste collection system.

Evaluation	
Total investment	€
Extra WEEE collected	Tons
Cost effectiveness	€ /ton

Table 7 - Setup of Evaluation parameters

CDW

SENSITIVITY

For CDW, a sensitivity analysis will be performed on the following parameters; i) the transport costs in euro per kilometre; ii) the gate fee for recycling; and iii) the gate fee and/or tax for landfilling. From all parameters, these are deemed the most likely to fluctuate over the years and the most likely to have significant effect on the total financial viability.

Transport costs: The scenario assessed in the sensitivity analysis is a decrease of 10% in the overall transport costs per kilometre for all project years.

Gate fee recycling: The scenario assessed in the sensitivity analysis is a decrease of 10% in the gate fee for recycling for all project years. It is likely that new innovations and technologies improve the recycling process and therefore enable recyclers to charge lower gate fees.

Gate fee or tax landfill: The scenario assessed in the sensitivity analysis is an increase of 10% in the gate fee for landfilling for all project years. Stricter national policy on landfilling waste could take form in a higher landfill tax (resulting indirectly in a higher gate fee for disposal services).

For all scenario's the effect on the financial net present value and the benefit/cost ratio will be calculated. This will indicate how sensitive the results are to the change in the chosen parameters. The FNPV is calculated as described in Chapter 3.1. The benefit/cost ratio is calculated by summing all project benefits and dividing this by the sum of all project operational costs. The investment costs are thus not reflected in the benefit/cost ratio, this merely shows to what extent the project operational costs are in line with its revenues.

EVALUATION

The evaluation the final results will be assessed based on the investment, disposal costs for recycling and lastly the disposal costs for landfilling.

Evaluation	
Total investment	€
Investment per inhabitant	€ per inhabitant
Total disposal cost recycling	€ per ton
Total disposal cost landfill	€ per ton

Table 8 - Setup of Evaluation parameters

4. PAPER AND PACKAGING WASTE

4.1. PROJECT AND REFERENCE CASE

4.1.1. PROJECT RATIONALE

In Europe most municipalities are responsible for the collection and processing of the locally generated household waste. In order to provide this waste collection and management service, municipalities either own waste management companies, outsource the required activities to the private sector or use a combination of the two. In this analysis the waste collection system is analysed from the perspective of the entity or entities that are performing waste collection activities.

The waste collection approach for the paper and packaging waste (PPW) streams often varies per country and even per municipality, however, roughly three generic approaches can be distinguished;

i) Source separation into homogeneous fractions;
ii) Source separation into comingled fractions + post separation of comingled fractions;
iii) Post separation of recyclables from comingled residual waste prior to disposal.

As the project focuses on good practices in waste collection, the third approach of post separation – which occurs *after* the collection process – is not taken into consideration.

Scope

A schematic overview of the financial and material flows from the municipal perspective is shown in Figure 18. It shows the municipality collecting the waste and in turn receiving contributions in the form of taxes or fees from her citizens, as well as the waste transferred to a collection and sorting entity who will further process the waste flows, a service which will come with operational costs. This schematic however, shows an incomplete overview, where one could argue that there is solely an incentive to implement the cheapest as possible collection system – as this translates low waste taxes for the inhabitants.

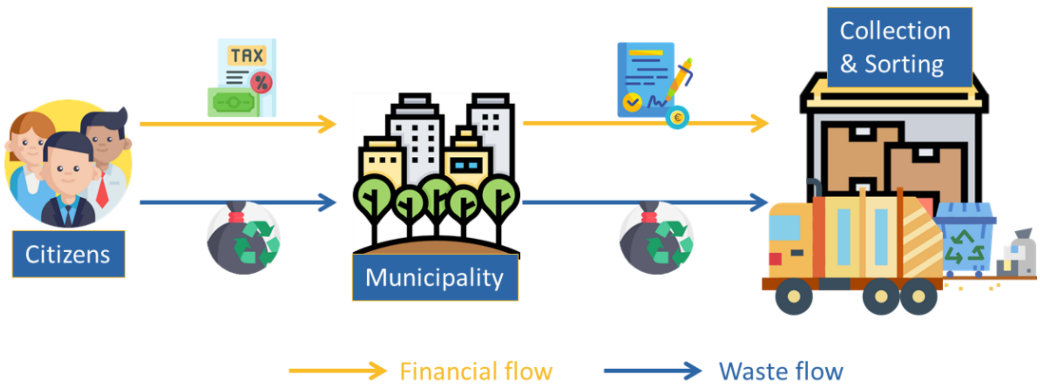


Figure 18 - Financial and material flows from municipality perspective

COLLECTORS defines a good practice in waste collection as a system that uses separate collection, which results in better quality waste and more recycling potential. Intuitively, a separate waste collection is expected to be more expensive, as e.g. more pickup routes, bins and communication campaigns are required. The narrow scope in Figure 18 therefore does not make sense in a financial context, as it does not explain the reasoning and financial mechanisms of the good practices.

In order to gain understanding of the overall economic performance and the financial mechanisms of the good waste collection practices, the scope has been broadened as presented below in Figure 19. Additional actors such as recycling and incineration facilities, authorities and producer responsibility organisations are included, giving a complete view of the relevant material and financial flows. The blue dotted line presents the scope of the financial assessment, making (the combination of) the municipality and the collection and sorting entity the project owner.

Figure 19 - Project scope for the PPW analysis (blue = waste flow; yellow = financial flow, blue dotted = project scope)

Material flows

The blue arrows depict the waste material flows. The following input flows are included; paper and cardboard packaging waste, plastic packaging waste, ferro and non-ferro metal packaging waste, drinking cartons, glass packaging waste and residual packaging waste. These waste streams are collected separately in most cases, sorted if required, and subsequently sold to recycling facilities or send to waste incineration (or landfill). The material output flows leaving the scope are i) the separate waste streams (sold to recyclers) and ii) the residual waste fraction disposed to incineration or landfills (at a gate-fee).

Residual waste is included in the analysis as often a significant amount of packaging waste ends up in the residual waste. Moreover, most cases have shown a significant drop in residual waste collection and at the same time an increase in the separately collected packaging fractions. The change in financial flows driven by decreasing amounts of residual waste treatment and incineration to more recycling is interesting to assess.

It is important to note however that there are differences in the residual waste composition between the cases, as can be seen in Table 9 below. Including the full residual waste stream would therefore skew the calculation and comparability. The table shows the mass percentage of the packaging waste fractions, as well as the organic fraction – which in most cases makes up a significant part of the residual waste stream. The final row in the table presents the percentage of the PPW streams in the residual waste, which varies largely on a case to case basis. In order to exclude non-packaging waste streams, only the packaging waste within the residual waste is included.

	Parma, 2014[35]	**Ghent, 2014**[36]	**Berlin, 2015**[37]	**Tubbergen, 2017**[7]	**Rennes, 2007**[38]
Organic (incl. diapers)	23.0%	33.4%	44.0%	27.0%	30.9%
PMD	36.4%	16.7%	10.0%	5.0%	16.0%
Paper and cardboard	14.4%	17.5%	10.0%	9.0%	16.0%
Glass	0.4%	3.1%	6.0%	3.0%	5.8%
Sum PPW in residual	*51.20%*	*37.30%*	*26.00%*	*17.00%*	*37.80%*

Table 9 - Overview of residual waste composition per case (wt%)

35 http://wasteinprogress.net/Documents/2017/PARMA.pdf
36 https://www.ovam.be/sites/default/files/atoms/files/Sorteeranalyse-onderzoek-huisvuil-2013-2014-def.pdf
37 Abfalbillanz BSR 2015
38 La composition des ordures ménagères et assimilées en France, 2007

Financial flows

The financial flows are depicted by the orange arrows. The included costs are; the operational costs for collection, sorting and processing; street cleaning; and regional or national taxes on incineration/landfilling of residual waste.

The incomes or benefits are; the citizen waste tax, Extended Producer Responsibility (EPR) fees from the packaging industry, financial compensation from the recovered materials (paper and cardboard, various types of plastic polymers, metals and glass); and stimulating incentives for good performance.

Lastly, in order to assess the shift in financial flows (see Chapter 4.1.3), the opportunity costs of incineration is included as a cost (missed revenue) as well as the financial incineration benefits (both not depicted in the figure).

4.1.2. REFERENCE CASE

One of the main objectives of the Collectors project is to gain insight into the overall performance of waste collection systems and to subsequently support decision-makers in shifting to *better-performing* systems. "Better" can of course only be defined when compared to a reference. Within a financial CBA analysis, the effect of the project is generally assessed by comparing it to an alternative situation, for example, a situation without the implementation of the proposed project. Since all cases have a different regional context and starting point, it is not possible to define a single fitting reference case. Therefore another approach has been applied.

Four of the five cases; Parma, Tubbergen, Berlin and Rennes; recently shifted to new and better-performing waste collection system. Better here means significantly less residual waste and more source separation of recyclable waste streams. It therefore has been decided to assess these cases in light of these changes.

The CBAs will not make use of a single defined reference case, but rather assess the cases in a relevant reference period. This reference period will cover a total of 10 years (standard depreciation time of a waste collection system), starting slightly before the new collection system has been implemented. For instance, in 2013 Parma started investing in their new collection system, therefore the analysis on Parma covers the period 2012 – 2021. This approach will allow to gain insight into the changes in the financial and waste landscape.

For the fifth case (Ghent), a good performing separate waste collection system using a PAYT mechanism has already been in place since 1998. It is expected no recent changes in the system nor financial flows will be found. The Ghent case will therefore be used in order to assess the financial and material flows in a longstanding separate waste collection practice using PAYT. Comparing Ghent with the other cases might reveal a difference in waste fee trends, producer contributions and waste quantities compared to the cases that have recently shifted.

4.1.3. SHIFTS IN THE FINANCIAL FLOWS

As mentioned earlier, it is expected that the costs and benefits will change when shifting from a comingled collection system (collecting all or multiple waste streams together) to system using source separation. This paragraph discusses changes in operational costs, citizen waste fees, opportunity costs of incineration vs. recycling, and lastly, the dynamic of the market price for waste materials is discussed.

CHANGES IN THE FINANCIAL LANDSCAPE

Prices for collection of waste are to a large extent a function of the quantities of waste as well as the waste collection system in place. In this paragraph, the changes in the waste collection costs for Parma are assessed.

For the Parma case, the financial shift from comingled collection, incineration and landfilling to more separate collection and recycling between 2013 and 2014 is presented in the table below. These are the technical collection costs directly paid by the Parma municipality. The table shows the complete overview of all operational costs in 2013 and 2014, the period in which Parma shifted to a separate collection system. As seen in Chapter 2.1.1 the residual waste quantities dropped, which resulted in ca. 3.5 million euros less expenditures on residual waste treatment and incineration. The costs for collection, transport and treatment of recyclable materials did increase with a combined 1.8 million euros. In total, Parma saved € 450,000 at the end of the year.

	2013	2014	Delta
Residual waste collection and transport	€ 5,300,099	€ 6,868,191	€ 1,568,092
Residual waste treatment and incineration	€ 9,050,214	€ 5,563,844	**-€ 3,486,370**
Recyclable materials collection	€ 14,063,648	€ 15,049,744	€ 986,096
Recyclable materials treatment and transport	€ 1,957,782	€ 2,752,128	€ 794,346
Incomes from recyclable materials (EPR fees)	-€ 805,295	-€ 1,340,000	**-€ 534,705**
Street cleaning and other services	€ 5,908,646	€ 6,127,451	€ 218,805
Total	€ 35,475,094	€ 35,021,358	**-€ 453,736**

Table 10 - Overview of operational costs for Parma in 2013 - 2014[39]

As the collection quantities changed significantly over these years as a result of the new waste collection system, the numbers are transferred from Euros to Euros/ton to provide insight in the cost effectiveness. For 2013, 2014 and 2016 detailed numbers are available and presented in Table 11.

Operational costs in Euro [€]	**2013**	**2014**	**2016**
Residual waste collection and transport	€ 5,300,099	€ 6,868,191	€ 6,341,332
Residual waste treatment and incineration	€ 9,050,214	€ 5,563,844	€ 3,232,810
Recyclables collection	€ 14,063,648	€ 15,049,744	€ 12,426,828
Recyclables treatment and transport	€ 1,957,782	€ 2,752,128	€ 4,259,854
Incomes from recyclables (EPR fees)	-€ 805,295	-€ 1,340,000	-€ 1,572,999
Operational costs in Euro per ton [€/ton]	**2013**	**2014**	**2016**
Residual waste collection and transport	€ 113.04	€ 207.02	€ 251.08
Residual waste treatment and incineration	€ 193.03	€ 167.71	€ 128.00
Residual waste [ton]	46885	33176	25256
Recyclables collection	€ 546.15	€ 516.20	€ 348.28
Recyclables treatment and transport	€ 76.03	€ 94.40	€ 44.09
Recyclables [ton]	25751	29155	35681

Table 11 - Overview of the total costs and costs per ton for Parma

In the two graphs below these financial results have been depicted in a similar fashion.

[39] Parma towards zero waste, G. Folli, Municipality of Parma, 2015

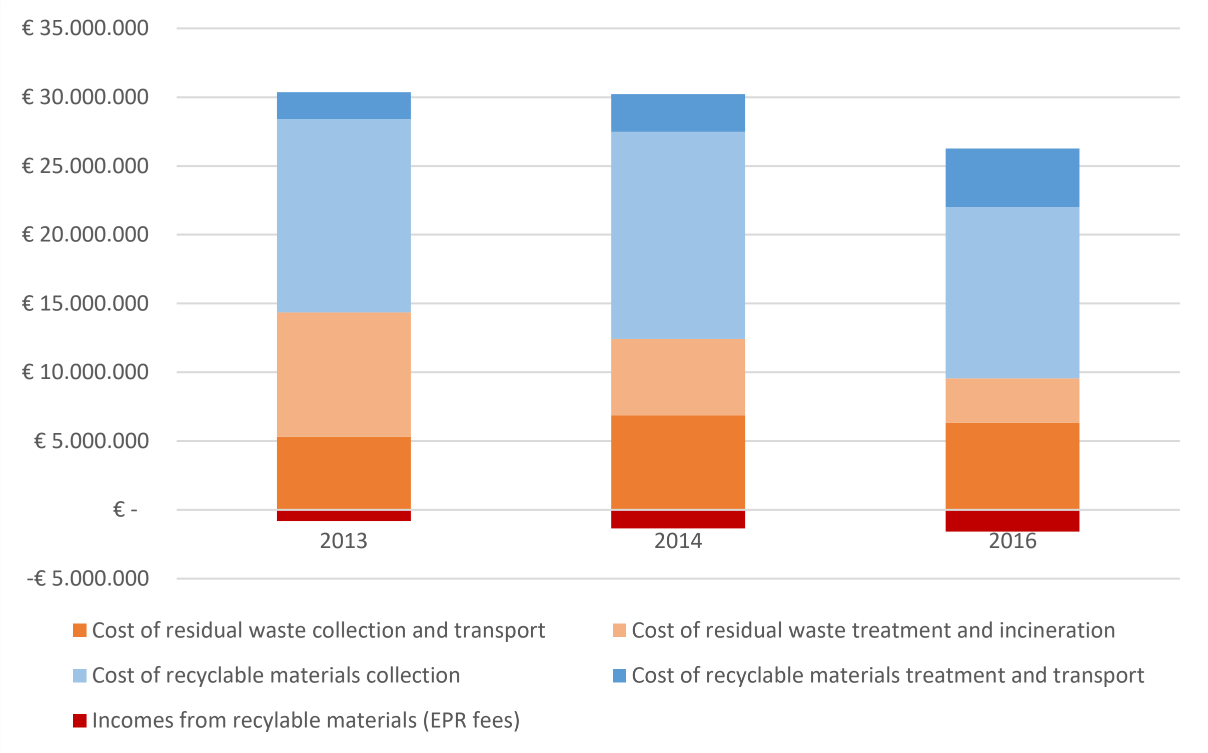


Figure 20 – Overview of total costs in Euros over three years for Parma

Figure 20 shows a drop in total operational costs since the implementation of the new separate collection systems and an increase in incomes from recyclable materials. The 2013 figures represent the previous comingled collection system, and 2014 and 2016 represent the new separate collection system.

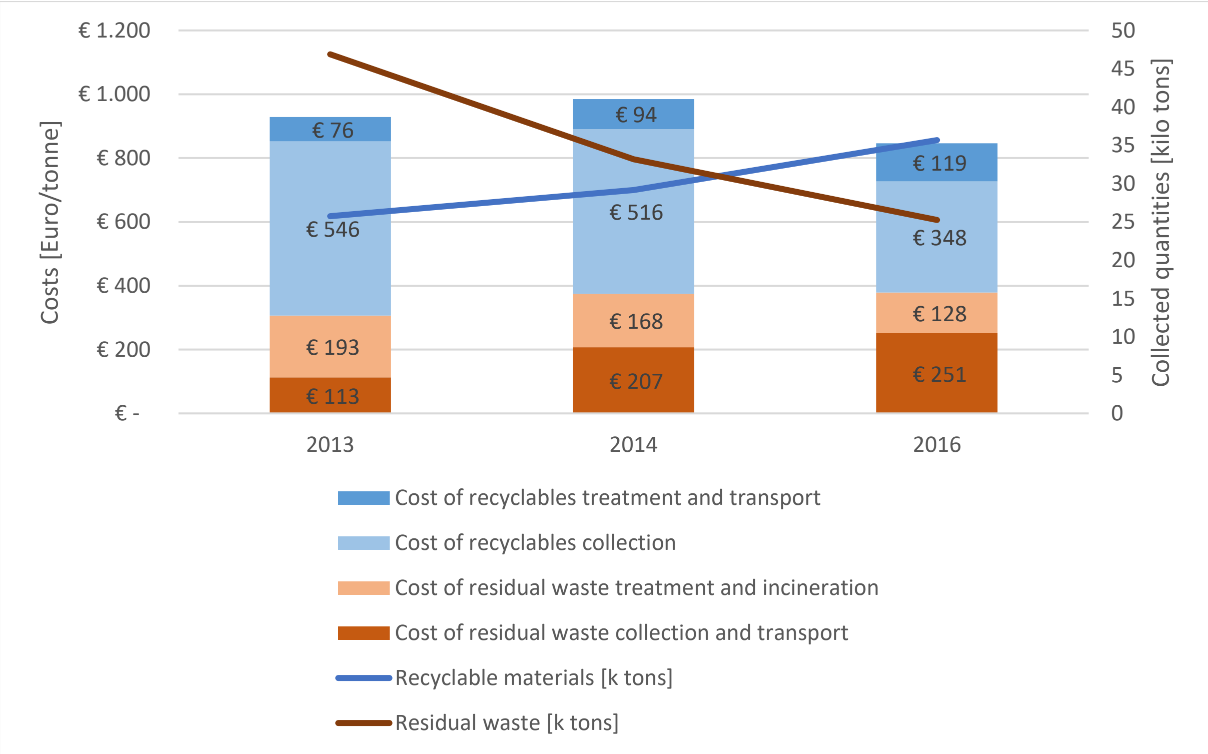


Figure 21 – Overview of total costs in Euros per ton and waste quantities over three years for Parma

From this data, it can be calculated that for every drop of 1000 tonnes of residual waste;

- The collection costs in Euro per ton increase with € 6.40, which could be explained by economies of scale (the lesser waste is collected, the more expensive it becomes per unit of mass);
- The treatment costs in Euro per ton decrease with € 3.01, which could be explained by the anticipated linear relationship due to fixed processing, incineration and landfilling costs and taxes per ton.

For every increase of 1000 tonnes in recyclables;

- The collection costs for recyclables in Euro per ton decrease with € 19.93, which again could be explained by economies of scale (the more waste collected, the cheaper it becomes per unit of mass);
- The treatment and transport costs in Euro per ton increase with € 4.37, which could be explained by increased complication of the plastics and PMD waste stream and therefore higher processing costs and increase in impurities.

WASTE FEE

Following from the assessment above, a separate collection systems can yield certain financial benefits. This could result in lower operational costs for a municipality, what ideally could translate into lower citizen waste fees. Looking at both Parma and Tubbergen, this is exactly what happened (for the other cases no detailed data is available). Due to the new waste collection system, Tubbergen has been able to decrease the waste fee from € 157 per household in 2011 to €121 per household in 2018, which is far below the Dutch average waste fee of € 243 per household in 2018. For Parma, the waste fee increased during the introduction of the new system, but has been coming back down to an average € 244 per household, which is one of the lowest tariffs in the area and below to the Italian average waste fee of € 302 per household.

	2011	2012	2013	2014	2015	2016	2017	2018
Tubbergen [€/hh]	157	153	147	146	143	138	130	121
Parma [€/hh]	248	261	260	267	249	244	244	-

Table 12 - Overview of the citizen waste fee for Tubbergen and Parma

OPPORTUNITY COSTS

To illustrate potential financial consequences from shifting to a new waste collection system, the table below gives an overview of two hypothetical scenario's; i) separate waste collection with 100% recycling and ii) no separate waste collection and 100% incineration of the plastic waste streams. A similar approach as presented in the *Cost-Effectiveness Analysis For Incineration Or Recycling Of Dutch Household Plastics* paper[40] is followed in this paragraph.

	Recycling [€/ton]	Incineration [€/ton]
Collection and transport	305	72
Net-treatment costs	223	107
Sub-total	*528*	*179*
Opportunity costs incineration	90	
Opportunity costs recycling		572
Total	*618*	*751*

Table 13 - Comparison of recycling vs incinerating the PMD packaging waste stream[41]

[40] A Cost-Effectiveness Analysis For Incineration Or Recycling Of Dutch Household Plastics, Gradus R., 2016
[41] Costs from benchmark reports in the Netherlands amongst 132 municipalities are used. NVRD Benchmark household waste in the Netherlands, 2014 - 2017

In the first row, the costs of collection and transport for both scenarios are presented. In case of comingled collection and subsequent waste incineration, the average collection and transport costs are estimated at € 72 per ton. In case of separate collection and recycling, the collection and transport costs are estimated at € 305 per ton. It can be noted that the collection and transport costs of separated PMD are substantially higher than for comingled household waste. This can be explained by the low density of plastics, i.e. more transport is required for a ton of PMD packaging than for a ton of residual waste due to the higher volume.

The second row presents the net-treatment costs. For PMD the treatment costs and the potential revenues from the sale of re-granulate products are estimated at € 223 per ton. For residual waste the revenues from incinerating the waste and selling electricity or heat minus the treatment and operational costs are € 107 per ton. It is assumed taxes for incineration are included in this number. Potential contributions for separate collection and recycling from producer responsibility organisations are not included here.

Thirdly, the missed opportunity of recycling in case of incineration, and energy recovery in case of plastic recycling are taken into account. When plastic is source-separated and no longer incinerated there is an energy deficit, which needs to be compensated. Alternatively, in case plastic is not source-separated and recycled but incinerated, there is a plastic or re-granulate deficit, which needs to be taken into account. It is assumed that in the case of plastic recycling an approximate energy deficit of € 90 Euro per ton is created – the equivalent energy value of the plastic that is separated at recycled, but would otherwise have been used for energy recovery[40]. In the case of plastic incineration, a deficit is created in the volume of recycled plastics. The value of recycled plastic that is lost due to incineration is estimated at € 572 per ton, which is calculated using plastic compositions analysis[42] and regrind plastic market prices[43].

Concluding, the net costs of incinerating one ton of plastic are considerable higher than for recycling. The total cost for recycling plastic is € 618 per ton and for energy recovery € 751 per ton. This means that, on average, € 134 is lost for every ton of plastics that is incinerated. For paper and cardboard, a similar assessment can be done resulting in an estimated loss of € 174 per ton of material incinerated[44]. This can be contributed to significantly lower collection and treatment costs, as well as lower opportunity costs for the recycled material[45]. Potential contributions for separate collection and recycling from producer responsibility organisations are not included here, and could further increase these numbers.

It must be noted that this analysis is based on Dutch data; however, it is expected that for the other four cases a similar result would be replicable. In addition, two fairly extreme scenarios are taken, 100% recycling and 100% incineration, which are not really realistic. In reality, these prices will not be fixed and will for a large extent be a dynamic product of the waste composition, quantity and quality. It is not possible to include all these aspects in this financial assessment, but one can imagine that increasing quantities will result in lower collection and processing costs on weight basis (economies of scale) and increasing quality of the waste stream will result in lower treatment costs and higher revenues. Similarly, decreasing residual waste quantities results in higher collection costs on weight basis and potentially decreasing revenues due to less caloric value in the residual waste. And assessment of these aspects is outside the scope of this report.

MARKET PRICES OF RECYCLATES

The revenues from secondary materials (waste materials or recyclates) can pay for a substantial part of the total cost of waste management schemes in EU Member States. Therefore understanding how the price of recylates,

---

[42] www.lckva.nl/publish/pages/124515/170150-01_lckva_samenstelling_kunststofpmd_fase_1def_pmd.pdf
[43] https://www.vraagenaanbod.nl/marktprijzen/id15315-Kunststofprijzen_week.html
[44] Incineration of glass and metal results generally results in ash products, and are therefore excluded.
[45] https://www.nedvang.nl/wp-content/uploads/2019/07/Factsheet-jaarvergoeding-2019.pdf

and therefore waste materials, changes over time is an important aspect of waste management. The graph below shows an overview of the average yearly prices per waste stream for the period 2013-2019[46,47].

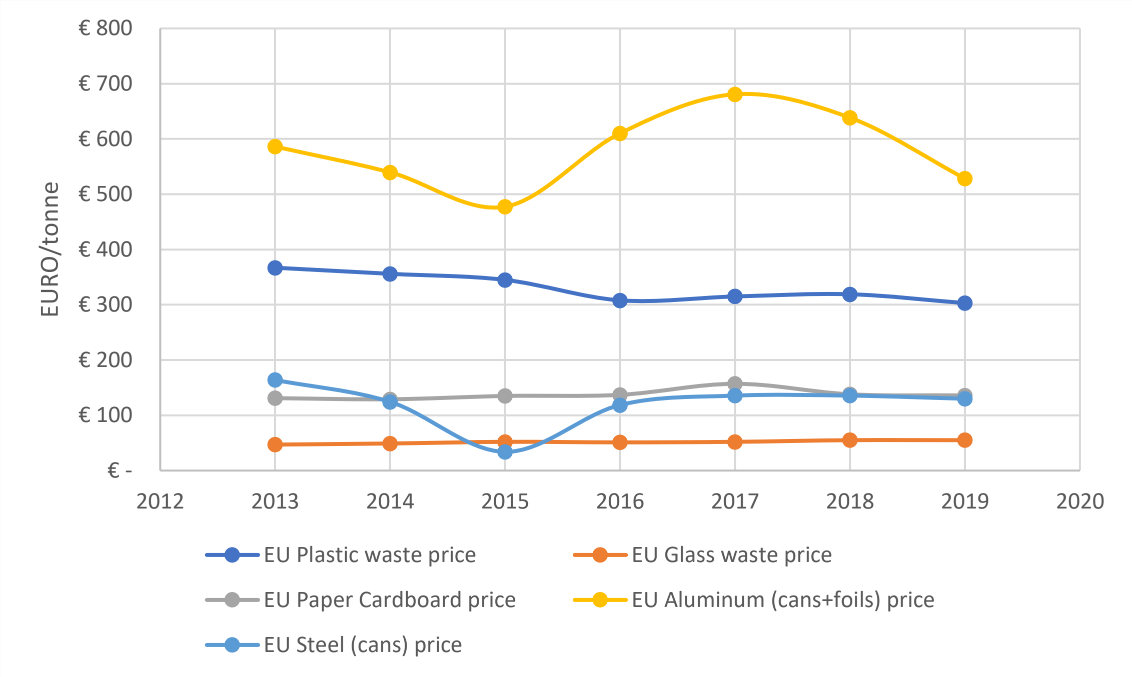


Figure 22 - Specific prices of total traded waste volumes in the EU

It can be seen that prices for glass and paper and cardboard waste are quiet constant, whereas plastic, steel and aluminium prices fluctuate over the years. In case no case specific information on revenues from material waste streams is available, these average European figures are used.

4.1.4. PROJECT DEFINITION

For all cases, the project is defined as the new implemented collection system. Obviously, the collection of PPW is a part of collection of the full range of household waste (which also includes organic waste, textiles, etc.). In the analysis, costs and benefits derived from these waste streams are discarded. This collection system is of course different for every case study. For each case the specific scope, the collection system and financial responsibilities are discussed in detail below.

4.2. COST-BENEFIT ANALYSIS PARMA

4.2.1. PROJECT DEFINITION PARMA

In 2013, Parma started to implement a separate waste collection system focused on the separate collection of paper and cardboard; glass; and plastic, metals and composites. The new collection system was implemented in various phases between June 2013 and September 2014. The Pay-As-You-Throw element was only implemented in July 2015.

In the new collection system, the residual waste, paper and cardboard, glass, and PMD waste streams are collected at the kerb, using home containers and bags. For glass collection, 1,304 bell containers are available throughout the city. Parma has four civic amenity sites run by Iren Ambiente, and thirteen automatic eco-

[46] Material prices for recyclates, Extraction from the Foreign Trade Statistics, 2019, https://ec.europa.eu/eurostat/web/waste/prices-for-recyclates
[47] Nonferrous and ferrous metal prices per category are obtained from Letsrecycle.com, 2019

stations where citizens can bring their (PPW) waste (ca. one bring point per 11,557 inhabitants). An important part of the new collection system are the new eco-stations bring points, implemented between 2015 and 2018.

Figure 23 - Eco-station in Parma[48]

Waste management: In Parma, the waste is collected and processed by Iren Ambiente. Iren Ambiente is subcontracted by the municipality to execute waste management (collection and corresponding processing). The collected residual waste is transported to the post sorting and incineration facility of Irens Ambiente, located in Parma. Paper waste is transported to the paper recycler Ghirardi in Parma and both the clear and coloured glass stream are sent to Furlotti. The PMD stream is post-separated in paper from the beverage cartons (Ghirardi); plastics; and metals, which are both send to the Oppimitti or Masotina recycling facility. The flowchart for the collection of PPW in Parma is presented in Figure 24.

[48] From https://parma.repubblica.it/cronaca/2017/03/01/news/rifiuti_a_parma_il_cassonetto_non_c_e_piu_le_ecostation_costano_mezzo_milione-159541133/

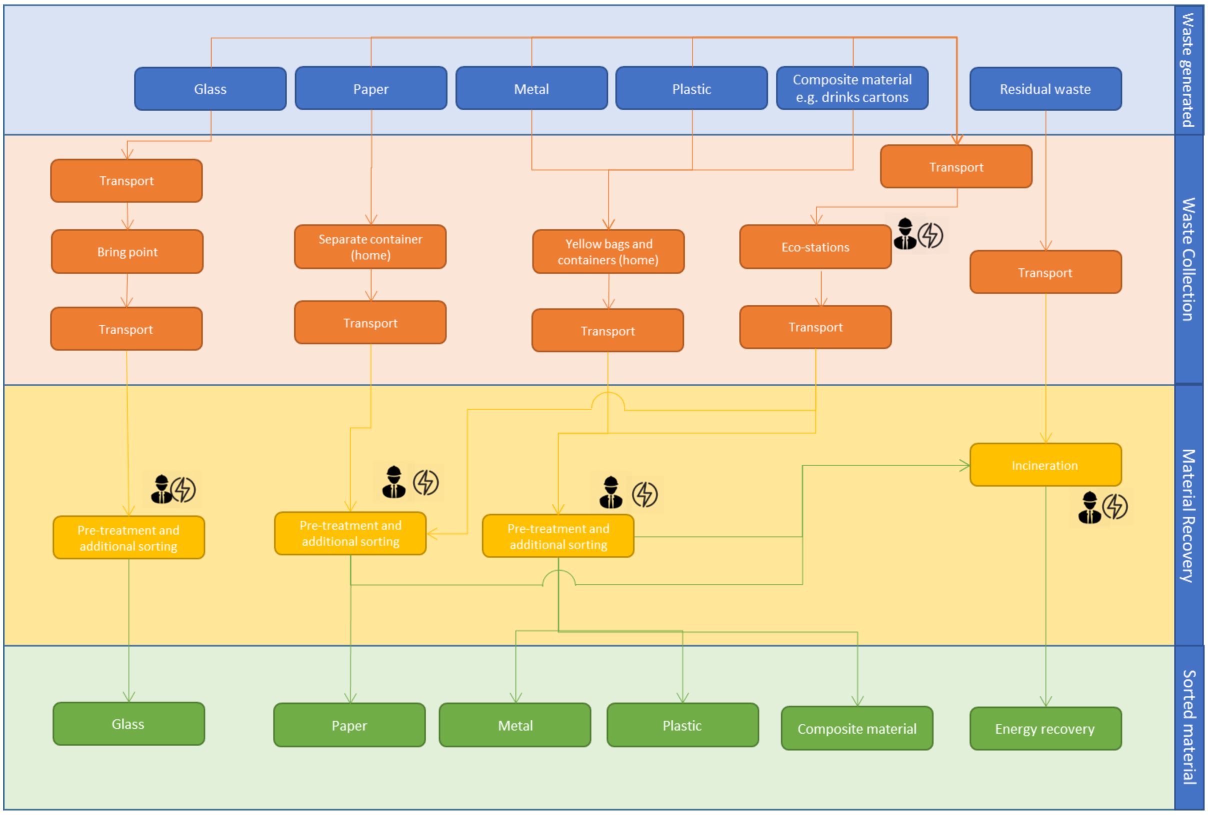


Figure 24 - Flowchart PPW Parma

Financial responsibilities: In 2015 the collection system was expanded with four eco-stations (automated CAS where citizens can bring all waste except residual). In 2017 four additional eco-stations were installed, followed by five mini eco-stations in 2018. These investments were done by the municipality of Parma. In addition, Parma invested in large information campaigns in the period of 2012 – 2015. Apart from the eco-stations, Iren Ambiente owns the waste management equipment, meaning operational costs and potential investments in equipment are directly made by Iren Ambiente. Iren Ambiente charges municipalities based on the quantities of waste collected. Revenues from material streams and incineration are collected by Iren Ambiente, and partly transferred to the municipality. Revenues from the EPR CONAI are collected by the municipality. Lastly, the municipality collects the waste fee from the citizens.

EPR scheme: CONAI, the private non-profit National Packaging Consortium. CONAI is a traditional EPR scheme, a system forming the response from private companies to a problem of collective interest, i.e. the environment, in accordance with the guidelines and objectives set by the Italian political system. 900,000 companies which produce or use packaging have joined CONAI. CONAI marked the transition from a management system based on landfills to an integrated system based on the prevention, recovery and recycling of six packaging materials: steel, aluminium, paper, wood, plastic and glass. CONAI collaborates with municipalities according to specific agreements governed by the ANCI-CONAI National Framework Agreement and serves as a guarantee to citizens that any materials from separate waste collections are fully used through proper recovery and recycling processes. Any companies that join the consortium pay a compulsory contribution which serves as a form of financing allowing CONAI to support separate waste collection and packaging waste recycling. CONAI directs the activities and guarantees the recovery results of 6 Consortia: steel (Ricrea), aluminium (Cial), paper/cardboard (Comieco), wood (Rilegno), plastic (Corepla) and glass (Coreve), ensuring the necessary link between these Consortiums and Public Administration[49]. As per 2018, CONAI is encouraging producers to use more recyclable

[49] CONAI, 2019, http://www.conai.org/en/about-us/what-is-conai/

packaging by linking their tariffs to the recyclability and quality of the packaging that's put on the market. CONAI implemented the following scheme[50];

- Level A: Sortable and recyclable packaging from the "Commerce & Industry" circuit – 150 €/t
- Level B: Sortable and recyclable packaging from the "Household" circuit – 208 €/t
- Level C: Packaging not sortable/recyclable with current technologies – 546 €/t.

4.2.2. IDENTIFICATION OF COSTS AND BENEFITS FOR PPW COLLECTION IN PARMA

The identification of costs and benefits consists of three categories; investment costs, operating costs, and revenues. These will be discussed in more detail below.

THE INVESTMENT COSTS

Investment costs refer to all fixed investments required for a waste collection system (e.g. land purchase, buildings, construction, transport, collection and sorting facilities) as well as other costs during the preparation and start-up phase of an investment action (e.g. planning & design fees, technical assistance, publicity, project supervision).

For this assessment however, it was found that Iren Ambiente (and therefore Parma) already had a large waste collection infrastructure in place. In addition, such investment costs would not be made by the municipality of Parma. Therefore, it has been decided to exclude these investment costs from the scope. It is however important to notice that the good practice in waste collection requires base line elements to operate successfully, being a PMD sorting and recycling installation, a paper sorting and recycling plant and a glass sorter and smelter. As can be seen in the table below, this is the case for Parma.

Sorting and Recycling facilities	Distance [km]
Paper and Cardboard	7
PMD	72
PMD	133
Glass	18

Table 14 - Sorting and recycling facilities in the vicinity of Parma

What has been included in the investment section, are the additional costs required for setting up the new waste collection system. These included costs for expanding the bring points with new Eco-stations, as well as communication campaigns, brochures, new smart bins and additional management.

Item	Assumption & data source	Cost
Startup costs for separate collection	Between 2012 and 2017 Parma invested in communication, delivery of new containers (bins with electronics), door to door information and brochures. The costs per year varied but totalled to € 1,672,922. The yearly average costs are € 418,231[51].	€ 418.231
Management of new collection sites	The management for additional collection sites (Eco-stations) is € 40,000 per year. In the first years, the costs were lower, at € 30,000[51].	€ 40,000
Eco-stations (standard)	The investment costs for a standard Eco-Station € 45,000[51]. Four Eco-stations have been installed in 2015, four additional stations were installed in 2017.	€ 45,000

[50] CONAI, 2018, http://www.conai.org/en/businesses/environmental-contribution/contribution-diversification/
[51] Data from interview with G. Folli, Deputy mayor for environment of Parma municipality, 2019

Eco-stations (mini)	The investment costs for a mini Eco-Station € 25,000[51]. Five mini Eco-stations have been installed in 2018.	€ 25,000

Table 15 - Assumptions and data for investment costs PPW Parma

OPERATING COSTS

The operational costs regarding the collection and processing of the PMD, paper and cardboard, glass and residual waste fractions are included. Also, regional taxes and opportunity costs are taken into account. The table below gives an overview of the assumptions and data sources.

Item	Assumption & data source	Unit cost
Collection of residual waste	In 2017, the cost for collection of residual waste using bins and bags is € 63.65 per inhabitant per year[52].	315.89 €/ton
	In 2017, the cost for collection of residual waste using family containers was € 28.35 per inhabitant per year[52].	
	In 2017, 8,369 inhabitants used bins for residual waste, 15,149 used bags, and 170,634 used family containers. [53]	
	At 194,152 inhabitants and 20,047 tonnes of total residual waste collected[63], this is equal to 315.89 €/ton.	
	The quantities collected for earlier years were taken from the same source[63], the collected quantities for later years (>2017) are assumed to stay fixed, however the expected increase in population is included.	
	The assumed allocated percentage for the relevant waste streams within the residual waste is 51.2%. This includes paper, cardboard, metal, plastics and glass; excluding textile, organic, wood, bulky and toxic waste.	
Collection of Plastics and Metal packaging materials	In 2017, Parma collected 9,011 tonnes of PMD was collected[63].	312.41 €/ton
	In 2017, the cost for collection of PMD material was € 14.50 per inhabitant per year[54].	
	In 2017, PMD waste was collected selectively for 194,152 inhabitants[53].	
	At 194,152 inhabitants and 9,011 tonnes of PMD material collected, this is equal to 312.41 €/ton.	
	The quantities collected for earlier years were taken from the same source[63], the collected quantities for later years (>2017) are assumed to stay fixed, however the expected increase in population is included.	
Collection of paper and cardboard	In 2017, the cost for collection of paper and cardboard waste at apartments was € 6.79 per inhabitant per year[54].	57.96 €/ton
	In 2017, the cost for selective collection of paper and cardboard waste was € 4.48 per inhabitant per year[54].	
	In 2017, paper and cardboard waste was collected selectively and at apartments for both 194,152 inhabitants[53].	
	At 194,152 inhabitants and 18,890 tonnes of paper and cardboard collected[63], this is equal to 57.96 €/ton.	
	The quantities collected for earlier years were taken from the same source[63], the collected quantities for later years (>2017) are assumed to stay fixed, however the expected increase in population is included.	

[52] Parma, Integrazione al Piano Finanziario Atersir degli interventi relativi al Servizio di Gestione dei Rifiuti Urbani per l'anno 2017 nel Comune di Parma. (2017) p. 25
[53] Integrazione al Piano Finanziario Atersir degli interventi relativi al Servizio di Gestione dei Rifiuti Urbani per l'anno 2017nel Comune di Parma p 37
[54] Parma, Integrazione al Piano Finanziario Atersir degli interventi relativi al Servizio di Gestione dei Rifiuti Urbani per l'anno 2017 nel Comune di Parma. (2017) p. 26

Collection of glass	In 2017, the cost for road collection of glass waste using bell containers was € 3.20 per inhabitant per year[54].	79.84 €/ton
	In 2017, the cost for door to door collection of glass waste was € 12.00 per inhabitant per year[54].	
	In 2017, 23,518 inhabitants used door to door glass waste collection and 194,152 inhabitants used road side bell containers for glass waste[53].	
	At 10,091 tonnes of glass collected[63], this is equal to 79.84 €/ton.	
	The quantities collected for earlier years were taken from the same source[63], the quantities for later years (>2017) are estimated to stay fixed.	
Processing costs PMD	The processing costs of PMD are unknown. Therefore, an average number for a medium sized city of a recent benchmark study in the Netherlands is taken[68].	229 € /ton
Processing costs paper and cardboard	Paper and cardboard requires little processing (sorting after collection) compared to the PMD waste stream. In addition, often paper waste processing is already a part of the paper recycling process. It is assumed the processing price is already included in the collection costs, and therefore a price of € 0 /ton is taken.	0 €/ton
Processing costs glass	Glass waste requires less processing compared to the PMD waste stream. It is assumed the processing price is already included in the collection costs, and therefore a price of € 0 /ton is taken.	0 €/ton
Processing costs residual waste	In 2017, the disposal and processing costs of residual waste were 128 €/ton[53]. It is assumed 68% of the residual waste is incinerated in Parma, therefore 32% of each material entering the residual waste is assumed to be incinerated with energy recovery[55].	128 €/ton
Street cleaning	In 2013, Parma spent € 5,908,646 on cleaning up littered waste and other services. It is assumed 25% of these costs are allocated specifically to littering, and 75% is other costs. Subsequently, it is assumed that 51.12% of all littered waste is packaging waste (which is the packaging fraction in the Parma's residual waste, and also corresponds to composition analysis data for littering from WRAP), therefore € 4.02 per in habitant is included for street cleaning. For 2014 also data is available and included. Data for the other years is assumed to be equal to 2013 and 2014 data.	4.02 €/inh
Ecotax	In Emilia-Romagna, a regional law (16/2015) states that municipalities should pay an Ecotassa, or Eco-tax. Per ton of waste landfilled or incinerated 15 €/ton is paid. With this eco-tax virtuous municipalities are rewarded. In 2016, Parma paid € 160,288[56].	€ 160.288
	For earlier and later years, no data is known. Therefore, a trend is estimated based on the residual waste quantities.	
Opportunity cost incineration	The missed opportunity costs by diverting plastic and paper/cardboard waste from incineration are assumed to be € 90 per ton[40]. Italy has no tax in place for the incineration of waste[73].	90 €/ton
	The metal fraction of the PMD stream is excluded, as metals can be easily post separated before/after the incineration process. On average, PMD contains 6% of metal[42].	
	PMD (excluding metal) and paper and cardboard that is separately collected is assumed to be diverted from incineration.	

Table 16 - Assumptions and data for operational costs PPW Parma

[55] Sustainability report 2018 Iren Ambiente, https://www.gruppoiren.it/iren_gruppo-theme/pdf-reader/web/viewer.html?file=/documents/21402/0/BDS+ENG+2018/67e1fc8b-914a-4a73-8f35-aee3db0857cf
[56] Presentation on the Eco-tax regional law in Emilia-Romagna, G. Folli, 2016.

REVENUES

The following financial revenues are identified for the Parma waste collection system:

- Citizen waste tax
- Potential value of recovered materials
- Environmental taxes (Ecotassa)
- Incineration benefits
- EPR fees packaging industry

In the table below the assumptions and data sources for the revenues are stated.

Item	Assumption & data source	Unit cost
Waste fees	The waste fee in Parma is calculated based on household and housing size, however the average tariff in 2015 was 248.67 €/household, which translates to roughly 115 €/inhabitant. For other years, the average fees are also available.	96.90 €/ hh
	This fee covers all household waste streams, therefore the allocated percentage is calculated. From the 2016 report on Waste management in Emilia-Romagna[57] it is found that 29.6% of the total costs of waste collection and management are appointed to the packaging waste streams. This includes paper, cardboard, metal, plastics and similar streams in the residual waste; excluding textile, organic, wood, bulky and toxic waste.	
Recovered paper and cardboard	The average price for paper and cardboard waste in Europe is € 137/ton[46].	137 €/ton
	It is assumed the paper and cardboard waste stream collected using a PAYT approach has an average recycling efficiency of 81%[58], meaning a total of 19% paper and cardboard material is lost in the process of collection, sorting and finally recycling.	
	It is assumed an additional volume of paper waste is coming from the PMD waste stream. The beverage carton (or tetra packs) collected in PMD consist of 75% of paper[59]. The PMD waste stream composition shows that 10% of the PMD waste is beverage cartons[60].	
	It is assumed 10% of the paper and packaging waste is rejected and not send to recycling[61].	
Recovered metals (ferro)	The unit price for ferrous metal waste is on average € 125/ton[46]. It is assumed the metal composition in PMD consists of 65% of ferrous metals and 35% of non-ferrous metals[62].	125 €/ton
	It is assumed the metal waste collected using PMD in a PAYT approach has an average recycling efficiency of 89%[58].	
	It is assumed the PMD waste stream composition consists of 10% metal packaging[51].	
	It is assumed 20% of all of the ferrous metal packaging waste is rejected, and the rest is send to recycling[61].	
Recovered metals (non ferro)	The unit price for non-ferrous metal waste in Europe is on average € 560/ton[46]. It is assumed the metal composition in PMD consists of 65% of ferrous metals and 35% of non-ferrous metals.	560 €/ton

[57] https://www.arpae.it/cms3/documenti/_cerca_doc/rifiuti/ReportRifiuti2016.pdf
[58] WUR, Rekenmodel grondstof uit afval (2018)
[59] The Alliance for Beverage Cartonnes and the Environment, Beverage cartons weight composition, link
[60] Eureco, WUR, Rapportage samenstelling ingezameld kunststof/PMD verpakkingen fase 1 (2017) ,link
[61] Packaging recovery in Italy: THE CONAI SYSTEM, http://www.conai.org/wp-content/uploads/2014/09/The-CONAI-System_-2017.pdf
[62] Rijkswaterstaat, Afvalmonitor (2017), https://afvalmonitor.databank.nl

	It is assumed the metal waste collected using PMD in a PAYT approach has an average recycling efficiency of 89%[58].	
	It is assumed the PMD waste stream composition consists of 4% non-ferrous metal packaging[59].	
	It is assumed 15% of all of the non-ferrous metal packaging waste is rejected, and the rest is send to recycling[61].	
Recovered glass	The average European unit price for glass waste is estimated at € 51/ton[46].	51 €/ton
	It is assumed the glass waste stream collected using a PAYT approach has an average recycling efficiency of 88%[58].	
	It is assumed 5% of all of the glass waste is rejected, and the rest is send to recycling[61].	
Recovered plastics	The unit price for plastic waste in Europe is on average € 325 per ton[46].	325 €/ton
	It is assumed 20% of all of the glass waste is rejected, and the rest is send to recycling[61].	
EPR fee Paper and cardboard	The unit price for collected paper is € 0.064 per kg[52].	29.91 €/ton
	The unit price for collected cardboard is € 0.017 per kg[52].	
	In 2017, Parma separately collected 19,124 tonnes of paper and cardboard waste[63]. From this, 3,795 was cardboard.	
EPR fee glass	The unit price for collected glass is € 0.03276 per kg[52].	€ 32.76/ton
	In 2017, Parma collected 10,111 kg of glass[63].	
EPR fee light weight packaging	The unit price for collected multi-material (plastic and metal cans) is € 0.10571 per kg[52].	€ 105.71/ ton
	In 2017, Parma collected 7,586,434 kg of multi material waste[63].	
Eco-tax	In Emilia-Romagna, the regional law (16/2015) states that municipalities pay an Ecotassa, or Eco-tax, based on the performance of the residual waste numbers per capita. With this eco-tax virtuous municipalities are rewarded. In 2016, Parma received € 709,715.	€ 709,715
Incineration	It is assumed 68% of Parma's residual PPW is incinerated[55], calculated based on the percentage waste landfilled of the total amount of waste. The rest is assumed to be landfilled, at no operational costs.	90 €/ton
	It is assumed that all recyclable waste that is in the residual waste stream is not post sorted, and goes to the incinerator. Also, it is assumed that 20% of all collected waste recyclable waste streams is rejected and ends up in incineration.	
	It is assumed that the incineration of packaging waste (paper and plastic) into energy and heat amount to a revenue of € 90 per ton[40].	

Table 17 - Assumptions and data on the revenues from PPW collection in Parma

4.2.3. CBA RESULTS PARMA

The overview of all costs between 2012 and 2021 are shown in the figure below. The following trends can be noticed;

- An increase in total costs during the implementation of the new collection systems (2014);
- Strongly increasing costs for collection of PMD after 2012, due to more and expensive separate collection of the PMD waste stream;
- Decreasing costs for residual waste collection and processing, due to a decrease in residual waste quantities;

[63] Catasto Rifiuti Sezione Nazionale, Parma, 2017. https://www.catasto-rifiuti.isprambiente.it/index.php?pg=mDetComune&aa=2016&regidb=08&nomereg=Emilia-Romagna&providb=034&nomeprov=Parma&regid=08034027&nomecom=Parma&cerca=cerca&&p=1&width=1536&height=864

- Fairly constant costs for collection of paper, cardboard and glass.

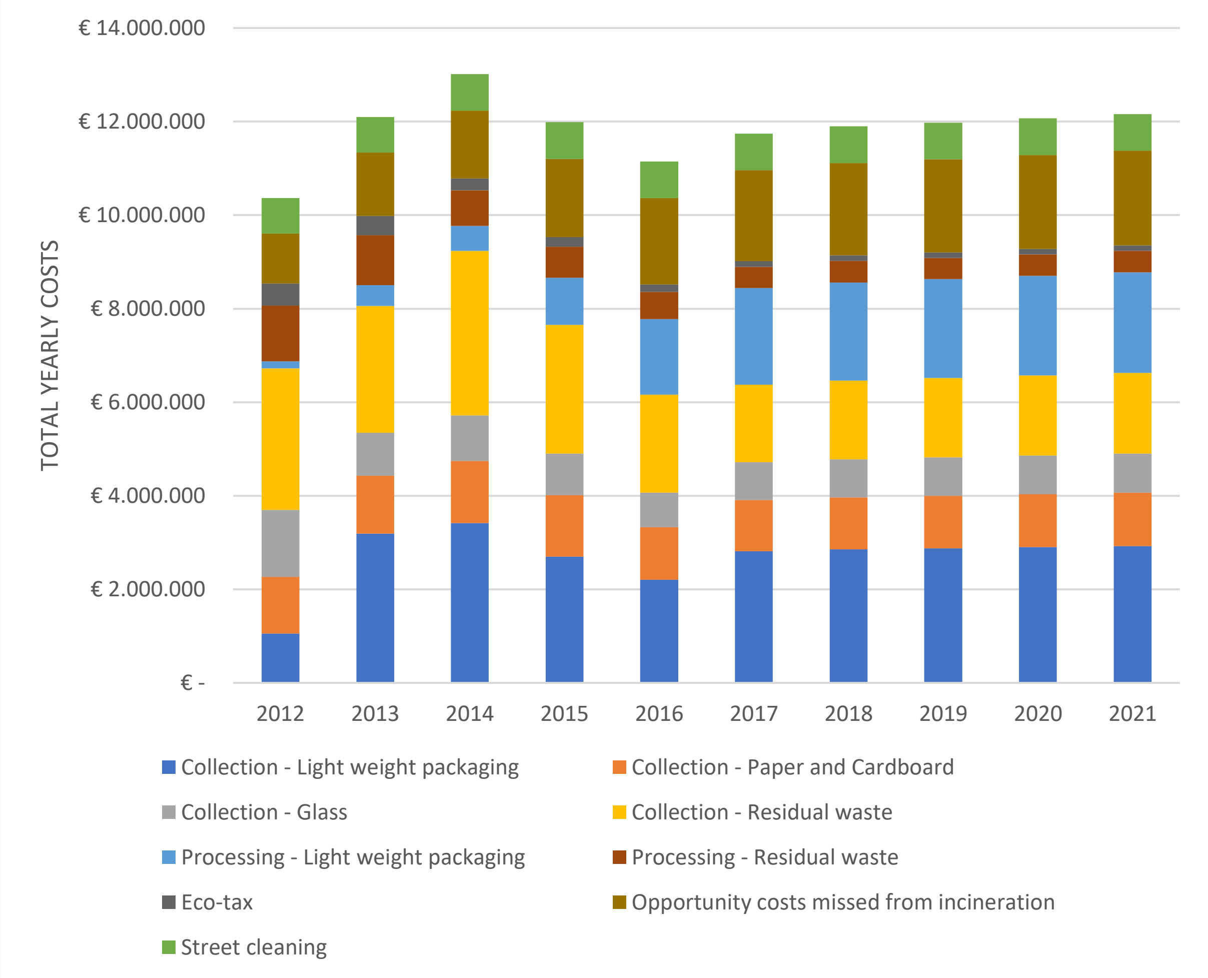


Figure 25 - Overview of total cost per year for Parma

The overview of all revenues between 2012 and 2021 are shown in the figure below. The following trends can be noticed;

- Waste fees cover the largest part of the costs (52% of total revenues);
- The received ecotax increased significantly and makes up for a large part of the total revenues;
- Revenues from recovered waste materials and EPR fees are relatively small;

Figure 26 – Overview of total revenues per year for Parma

In Figure 27 both the total costs and benefits are plotted, together with the Financial Net Present Value (FNPV). The FNPV is calculated taking into account a discount rate of 4%, and subtracting all costs from all benefits for every year. This approach is in line with the EC CBA guidelines. The first year is taken as the 'present year', as it is assumed this is the year the investment decision for the new waste collection system is made. This final overview shows that the total costs are in balance with the total revenues.

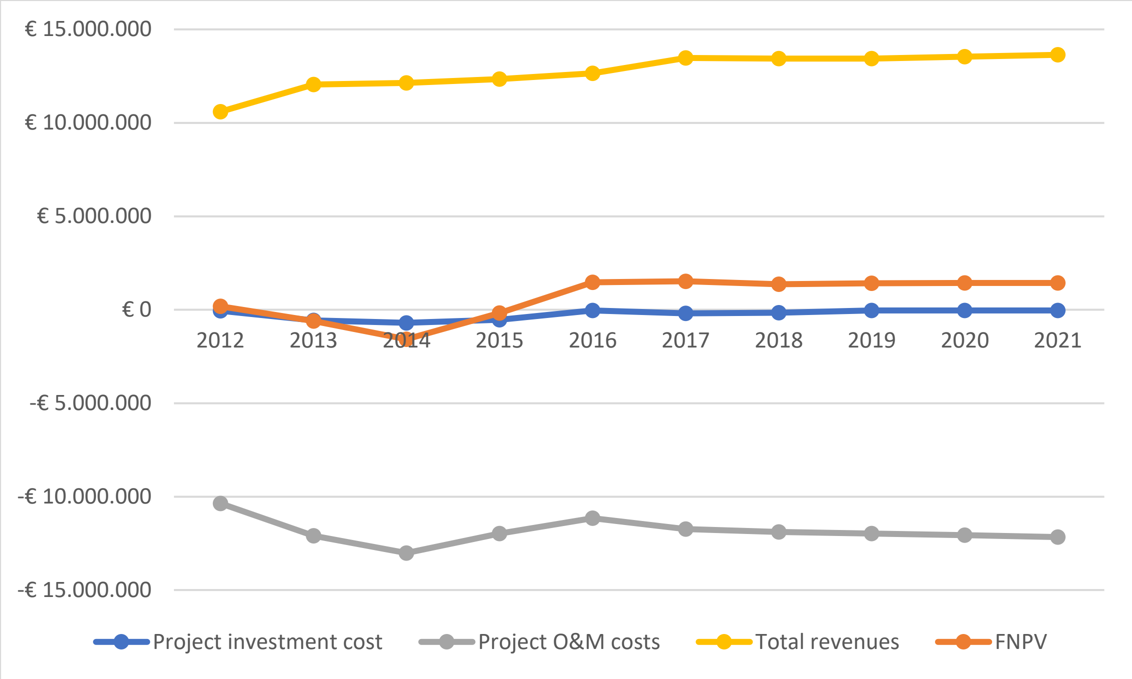


Figure 27 –Overview of costs, benefits and FNPV for Parma

4.2.4. SENSITIVITY ANALYSIS

In order to highlight uncertainties in the data, a sensitivity analysis has been performed on three parameters; i) the total operational costs; ii) the material prices, iii) the EPR fees and the total collected quantities. From all parameters these ones are deemed the most likely to change, and the most likely to have significant effect on the total financial viability.

For all scenario's the effect on the financial net present value and the benefit/cost ratio will be calculated. This will indicate how sensitive the results are to the change in the chosen parameters.

Operational costs

The scenario assessed in the sensitivity analysis, is a decrease of 10% in the total operational costs for all future years from 2017 onwards. These include the cost of collection, processing, transport, communication, etc.

Material prices

The scenario assessed in the sensitivity analysis, is an increase of 10% in the all material prices for all future years from 2017 onwards. Better waste collection practices are expected to increase the quality of the collected materials. With all required elements present, such a well-functioning recycling chain, the material prices might influence the end results significantly.

Producer fees

In all five countries Extended Producer Responsibility schemes are in place, presenting a financial lever for separate collection and producing high quality waste streams. The effect of this parameter is assessed with an increase of 10% for all future years from 2017 onwards.

Capture rate

Assuming the waste collection system manages to steer towards a 100% capture rate in the final project year (2021), it is analysed what the financial overview look like. In the assessment, the current capture rates for 2017 are taken, and between 2018 – 2021 a yearly 25% increase is assumed. For PMD, this means an additional 7297 tonnes of waste is separately collected in 2021, for paper and cardboard this means an additional 2887 tonnes is collected in 2021. The glass capture is already >90% and therefore not included in this assessment. The separately collected waste streams are subtracted from the residual waste stream.

In the table below the scenarios are drafted, and the effects on the FNPV and B/C ratio is shown.

Scenario	FNPV	Delta FNPV	B/C ratio	Delta B/C
Standard scenario	€ 5,213,312	-	1.079	-
Decrease of 10% in operational costs	€ 7,934,627	52.2%	1.112	3.1%
Increase of 10% in material prices	€ 6,292,149	20.7%	1.091	1.1%
Increase of 10% in EPR fees	€ 5,720,904	9.7%	1.084	0.5%
Increase in collected quantities	€ 3,737,835	-28.3%	1.038	-3.7%

Table 18 - Sensitivity analysis of Parma results

It can be concluded that the operational have the largest effect on the final results, for every 1% decrease in the operational costs, the FNPV goes up with 5.2% and the benefit/cost ratio goes up with 0.3%. The material prices have a significant effect as well, and the effect of the EPR fees is the smallest. The increase in capture rate results in a lower, however still positive FNPV and B/C ratio.

4.2.5. EVALUATION & CONCLUSIONS

Overall, looking at the average benefits it can be concluded that the most significant contribution (54%) is coming from the citizen waste fee; 24% comes from recovered materials; and 11% comes from the EPR fees. The rest is covered by incineration revenues and eco-tax benefits.

Waste fee: As can be seen in the graph below, Parma managed to improve their separate collection system by eventually even lowering the costs for its citizens. During the implementation the costs went up for a period of two years, only to come back down again in 2015. Comparing the waste fee in 2012 and 2016, we see a drop of 1.6%. Two possible explanations for the reduction in the waste fee are the foreseen producer fees that have been increasing from 2013 onwards; and the municipalities experience in the sharp decreasing in residual waste and the accompanied costs.

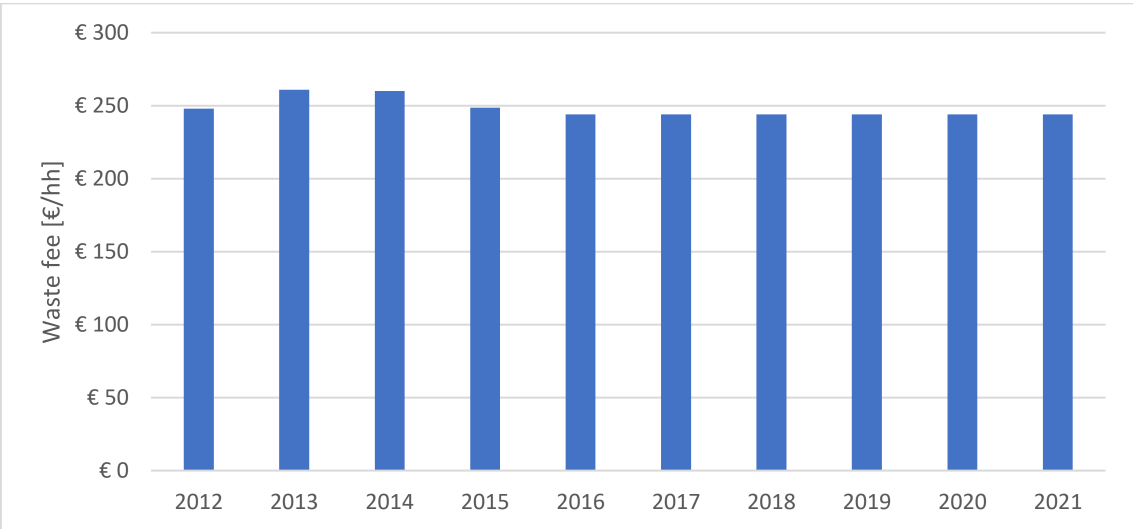


Figure 28 – Average waste fee in Parma per household (3person family in 100 m²)[39]

In order to present a quick overview of the shifting incomes, the items below are listed as a percentage of the total revenues (% of the total revenues);

- the waste fee is decreasing from 56% in 2012 to 49% in 2021;
- the revenues form incineration decrease from 16% in 2012 to 6% in 2021;
- the recovered materials are increasing from 18% in 2012 to 26% in 2021;
- the EPR fee contribution increases from 8% in 2012 to 12% in 2021;
- and the eco-tax is increasing from 2% in 2012 to 7% in 2021.

Investment: The total investment Parma made was in total € 2.4 million over the course of 2012 -2018, which comes down to € 12.30 per inhabitant.

Waste quantities: Parma realised a drop in collected residual waste quantities of 62%, going from 52 kilotonnes in 2012 to 20 kilotonnes in 2017. A corresponding increase of 53% in collected recyclable PPW waste has been found.

Operational costs: Due to less generated residual waste quantities, and more separately collected recyclable packaging waste, Parma has been able to decrease the operational costs per capita for both residual and recyclable waste stream.

Evaluation	
Assessed period	2012 - 2021
Waste fee drop	1.6%
Total investment	€ 2,387,922
Investment per inhabitant	€ 12,30
Drop in residual waste	62%
Increase in separate collected recyclable PPW waste	53%
Decrease in operational costs for residual waste EUR/inh	€ 57,09
Decrease in operational costs for separate PPW EUR/inh	€ 55,99

Table 19 - Evaluation of Parma results

4.3. COST-BENEFIT ANALYSIS GHENT

4.3.1. PROJECT DEFENITION GHENT

Ghent already has a separate PAYT-based waste collection system since 1998. The system remained largely unchanged over the last years and focuses on the separate collection of paper and cardboard; glass; and plastic, metals and composites.

Waste management: The intermunicipality of IVAGO serves both the city of Gent and the neighbouring municipality of Destelbergen. IVAGO has its own collection equipment, but works together with private company SUEZ to complement the collection services. IVAGO operates her own waste-to-energy plant, producing electricity and heat from residual waste.

In Ghent the waste management company has identified different zones for collection approaches; C-zones, Z-zones and Apartments and S-zones. Depending on the zone the waste is collected in containers, bags or at bring-points. The collection approaches per zone are also presented in the figure below. In case of door-to-door collection, citizens need to use a specific yellow bag for residual waste; and a blue bag for PMD waste. In addition, Ghent has six civic amenity sites were citizens can discard of their waste. The glass waste from Ghent transported to High 5 Glass sorting and GRL Glass Sorting for sorting. Ghent's Paper waste is sorted by Stora

Enso Paper Sorting[64]. The residual waste is sent to IVAGO's incinerator[3]. Lastly, PMD is sorted by Suez in the R&R BE North facility[64]. The flowchart for the collection of PPW in Ghent is presented in Figure 30.

Figure 29 - Different collection methods in Ghent (Yellow bag=residual waste; Green container = organic waste; Blue = PMD)[65]

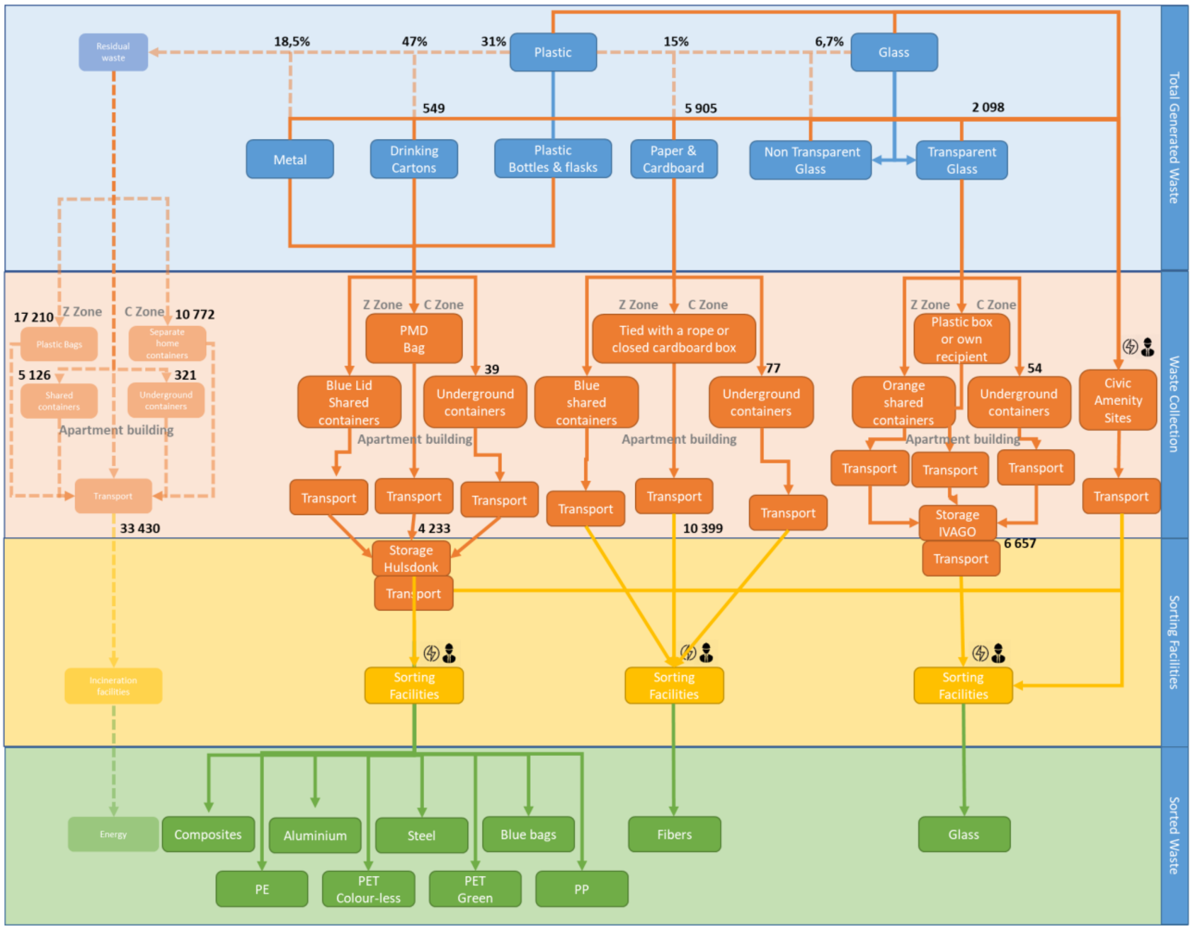


Figure 30 - Flowchart PPW Ghent

[64] Collectors Deliverable 2.4

[65] From https://stad.gent/nl/student-gent/op-kot/huisvuil-op-kot. Glass and paper and cardboard don't have a specific container or bag.

Financial responsibilities: Since the PAYT system has already been in place for a long time, no relevant investments have been identified and included in the assessment.

Since IVAGO owns the waste management equipment and fleet, operational costs and potential investments in equipment are directly made by IVAGO. IVAGO is a mixed intermunicipal association. The city of Ghent and the municipality of Destelbergen are the government partners. ECOV, a partnership between SUEZ and Indaver, is the private partner. Every year, IVAGO charges Ghent and Destelbergen for the collection, transport and treatment of the household waste. Revenues from material streams and incineration are collected by IVAGO. Revenues from the Belgian EPR Fostplus for packaging waste are collected by IVAGO. Lastly, the municipality collects the waste fee from the citizens[66].

EPR scheme: In Belgium, Fost Plus is responsible for promoting, coordinating and financing the selective collecting, sorting and recycling of household packaging waste in Belgium. A total of 11 million Belgian citizens in almost 600 municipalities have access to the selective collection of household packaging waste. More than 5,000 companies are Fost Plus members. In 2018 they declared 780,000 tonnes of packaging. Fost Plus recycled 724,000 tonnes of packaging in 2018, representing 92,8 % of all packaging materials brought onto the Belgian market by our members. This translates to about 29 kg of glass, 15 kg of PMD and 54 kg of paper and cardboard, including 17 kg of packaging per inhabitant. In 2018, Fost Plus had an annual budget of 190 million EUR, coming from member contributions and sales of the collected materials[67]. Fost Plus is part of PRO Europe (Packaging Recovery Organizations Europe), the umbrella group for packaging collection and recycling organizations. All the member organizations of PRO Europe use the Green Dot symbol (Groene Punten).

4.3.2. IDENTIFICATION OF COSTS AND BENEFITS FOR PPW COLLECTION IN GHENT

THE INVESTMENT COSTS

When assessing the investment costs, it was aimed to include the additional costs required for setting up a new waste collection system (e.g. expanding bring points, communication campaigns, brochures, new smart bins, etc.) However, Ghent has already been collection the waste separately for a long time. IVAGO was one of the first players to introduce the polluter pays principle in 1998, by implementing smart waste containers equipped with an electronic chip for monitoring and efficient waste managing purposes, underground waste containers and CNG trucks for collection. Since 1998 the waste collection in Ghent has evolved, and therefore, no recent relevant investment costs have been identified.

Similar to the Parma case, it is important to notice that the good practice in waste collection requires base line elements to operate successfully, being a PMD sorting and recycling installation, a paper sorting and recycling plant and a glass sorter and smelter. As discussed in the COLLECTORS Deliverable 2.4 report, this is the case for Ghent.

In light of comparability with the other cases, as well as availability of collection and financial data, the reference period for the Ghent case study is 2012 – 2023.

OPERATING COSTS

The operational costs regarding the collection and processing of the following fractions is included:

- PMD
- Paper
- Glass

[66] Beleidsnota 2014-2019, IVAGO

[67] Fost Plus, Key figures 2018 https://www.fostplus.be/en/about-fost-plus/organisation/numbers-and-charts

- Residual waste

As these waste streams have very different mass and volume flows, the collection costs vary significantly. Due to different characteristics and material compositions of the waste streams, the processing costs also vary largely. Since the separate waste collection system in Ghent has been in place for a long time, detailed information over the course of the years is available. The three graphs below show the collected amounts of the three packaging waste streams, combined with the costs of collection per year in euro per ton.

The PMD graph shows that despite the increasing quantities, no economies-of-scale-effect is taking place, as the technical costs go up together with the collected quantities.

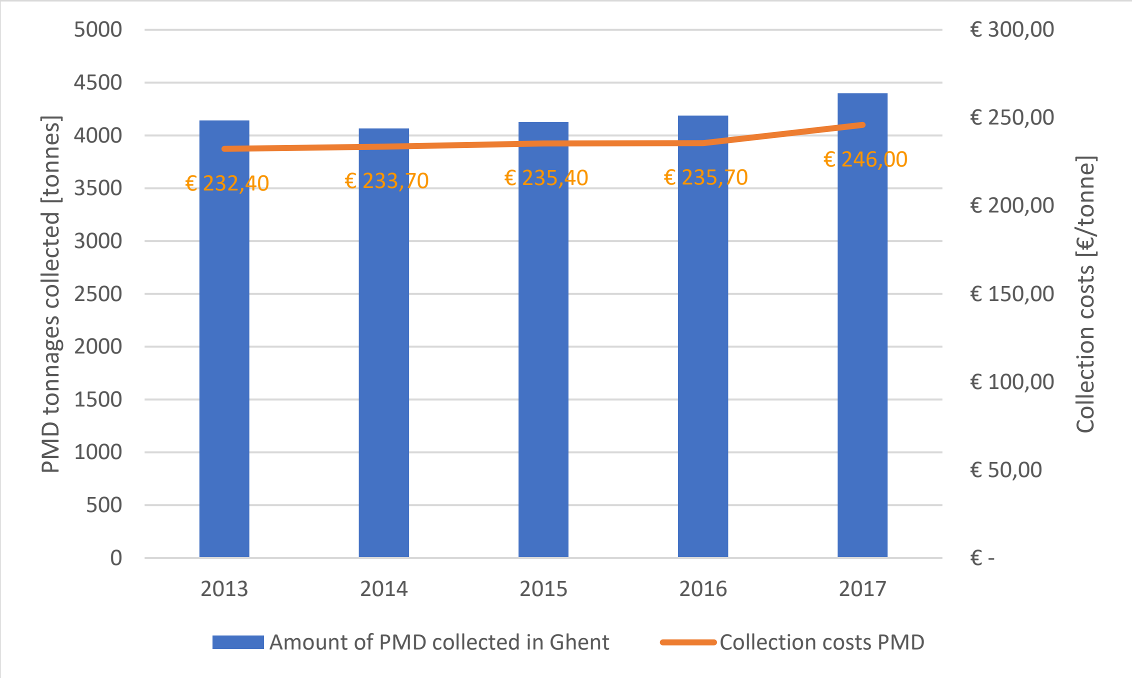


Figure 31 – Collected PMD quantities vs the cost of collection for Ghent [69,70]

The collection costs for paper and cardboard seem to increase with time, and the fluctuations in the collected quantities don't seem to influence the costs directly.

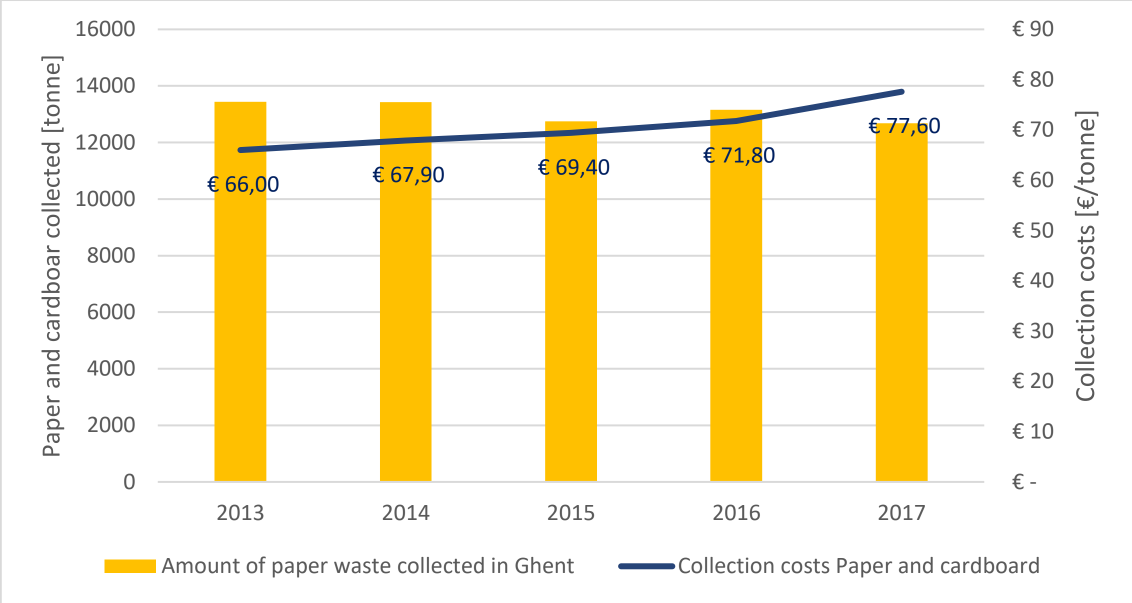


Figure 32 – Collected paper and cardboard quantities vs the cost of collection for Ghent [69,70]

In the graph depicting the glass figures, the years 2015 and 2017 seem to show some effect of economies of scale; in 2015 the collection costs drop which could be caused by the increase in collected amounts, and in 2017 the collection costs increase, possibly due to the small amounts of glass collected.

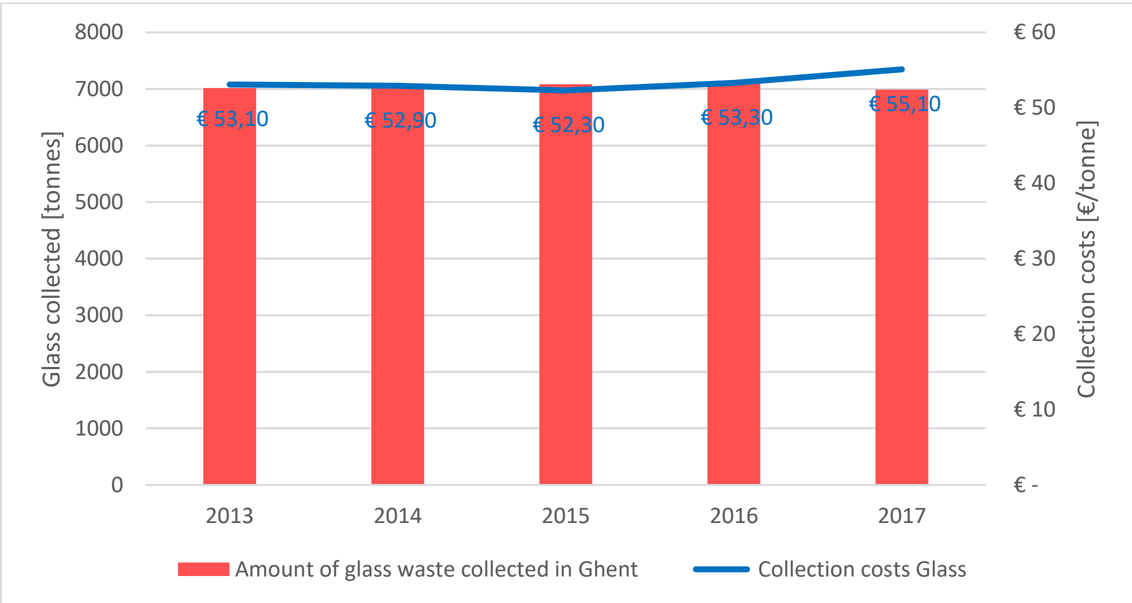


Figure 33 - Collected glass quantities vs the cost of collection for Ghent[69,70]

These dynamics are included in the assessment. Also operational costs for communication, cleaning up littered packaging waste, opportunity costs, taxes and social costs (financial contribution to poor households) are included.

The table below gives an overview of all assumptions and data sources.

Item	Assumption & data source	Unit cost
Collection of residual waste	For 2017, the collection cost for residual waste are estimated at 80€/ton[68].	80 € /ton
	In 2017, 172.2 kg/inhabitant of residual waste was collected in Ghent. At 258,845 inhabitants, this is 44,573 tonnes of residual waste[70].	
	The assumed allocated percentage for the relevant waste streams within the residual waste is 37%[36]. This includes paper, cardboard, metal and plastics and glass; excluding textile, organic, wood, bulky and toxic waste.	
	The quantities collected for earlier years were taken from the same source, the quantities for later years (>2017) are estimated to stay fixed.	
Collection of PMD waste	In 2017, the cost for collection of PMD waste were 246 €/ton[69].	246 €/ton
	In addition to the collection costs for 2017, the evolution of the costs for 2013-2016 are known[69].	
	In 2017, 4.272 tonnes of PMD material was collected in Ghent[70].	
	The quantities collected for earlier years were taken from the same source, the quantities for later years (>2017) are estimated to stay fixed.	
Collection of paper and cardboard	In 2017, the cost for collection of paper and cardboard waste were 77.60 €/ton[69].	77.60 €/ton
	In addition to the collection costs for 2017, the evolution of the costs for 2013-2016 are known[69].	
	In 2017, 49 kg/inhabitant was collected in Ghent. At 258,845 inhabitants, this is 12.683 tonnes of paper and cardboard [70].	
	The quantities collected for earlier years were taken from the same source, the quantities for later years (>2017) are estimated to stay fixed.	
Collection of glass	In 2017, the cost for collection of glass waste were 55.10 €/ton[69].	55.10 €/ton
	In addition to the collection costs for 2017, the evolution of the costs for 2013-2016 are known[69].	
	In 2017, 27 kg/inhabitant was collected in Ghent. At 258,845 inhabitants, this is 6,989 tonnes of glass[70].	
	The quantities collected for earlier years were taken from the same source, the quantities for later years (>2017) are estimated to stay fixed.	
Processing costs PMD	In 2017, the cost for processing PMD waste were 169 €/ton[69].	169 €/ton
	In addition to the collection costs for 2017, the evolution of the processing costs for 2013-2016 are known[69].	
Processing costs paper and cardboard	No data of an additional processing costs of paper and cardboard waste was available. It is estimated that due to little required processing the costs are € 0 /ton.	0 €/ton
Processing costs glass	No data of an additional processing costs of paper and cardboard waste was available. It is estimated that due to little required processing the costs are € 0 /ton.	0 €/ton
Processing costs residual waste	For 2017, the processing costs for residual waste are estimated at 98 €/ton[71].	€ 93 /ton

[68] NRVD Benchmark household waste in the Netherlands, 2016.
[69] FOST PLUS, cijfers en grafieken, 2018
[70] IVAGO activiteiten verslagen 2014-2017
[71] Interview with IVAGO, 2019

Taxes	In 2017, the tax on incineration of residual waste was 12.64 €/ton[72]. For all previous years the taxes are known, ranging between 8.09 – 13.26€/ton. It is assumed no waste is landfilled, as landfill of separately collected waste and combustible waste is banned in Belgium[73].	12.6 €/ton
Communication	In 2017, the costs for communication on collection and sorting were € 0.32 per inhabitant[69].	0.32 €/inh
Opportunity cost plastic incineration	The missed opportunity costs by diverting plastic, paper and cardboard waste from incineration are assumed to be € 90 per ton.	77.40 €/ton
	The waste tax paid over incineration waste, as mentioned above are deducted from the € 90 per ton.	
	The metal fraction of the PMD stream is excluded, as metals can be easily post separated before/after the incineration process. On average, PMD contains 6% of metal[42].	
	PMD (excluding metal), paper and cardboard that is separately collected is assumed to be diverted from incineration.	
Social contribution	In order to unburden poor households, the municipality charges less to no cost to circa 25,000 households, or roughly 50,000 inhabitants. It is assumed the full allocated waste fee (see Table 21) is withheld.	6.30 €/inh
Street cleaning	Littering cost the local and regional authorities an estimated € 17.51 per inhabitant[74]. It is assumed 37%[36] of these cost can be allocated to the packaging waste streams (fraction of the packaging waste in residual waste), therefore € 6.53 per in habitant is included for street cleaning.	6.53 €/inh

Table 20 - Assumptions and data for operational costs PPW Ghent

REVENUES

The following financial revenues are identified for the Ghent waste collection system:

- Citizen waste tax
- Potential value of recovered materials
- Incineration benefits
- EPR fees packaging industry

In the table below the assumptions and data sources for the revenues are stated.

Item	Assumption & data source	Unit cost
Waste fees	In 2017, the average waste fee per inhabitant was € 61.12 per household (waste fee for all waste streams)[71]. The waste fee for the packaging waste streams is estimated to be € 13.60 per household. Residual waste collection costs citizens 1.75€/bin of 60L, and PMD waste costs citizens 0.30€/bag of 75L. For collection of glass and paper and cardboard waste there is no fee.	13.60 €/hh
	A density of 130kg/m³ is assumed for residual waste, and a density of 55 kg/m³ for PMD material. It is assumed all bags and bins are 95% full.	
	The allocated mass percentage of the packaging waste streams within the residual waste is 37%, taken from the sorting analysis.	
	The average price for paper and cardboard waste in Europe is € 137/ton[46].	137 €/ton

[72] OVAM, milieuheffing, https://www.ovam.be/milieuheffingen
[73] Landfill bans and taxes, CEWEP project, 2017 http://www.cewep.eu/wp-content/uploads/2017/12/Landfill-taxes-and-bans-overview.pdf
[74] OVAM, Zwerfvuil en Sluikstort 2017, costs, https://www.ovam.be/sites/default/files/atoms/files/Zwerfvuil_Sluikstort_Studie_2017-DEF.pdf

Recovered paper and packaging	It is assumed the paper and cardboard waste stream collected using a PAYT approach has an average recycling efficiency of 81%[58].	
	It is assumed an additional volume of paper waste is coming from the PMD waste stream. The beverage cartons (or tetra packs) collected in PMD consist of 75% of paper[75]. The PMD waste stream composition shows that 10.1% of the PMD waste is beverage cartons[69].	
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
Recovered metals (ferro)	The unit price for ferrous metal waste is on average € 125/ton[46]. It is assumed the metal composition in PMD consists of 63% of ferrous metals and 37 % of non-ferrous metals[76].	125 €/ton
	It is assumed the metal waste collected using PMD in a PAYT approach has an average recycling efficiency of 89%[58].	
	It is assumed the PMD waste stream composition consists of 10% metal packaging[51].	
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
Recovered metals (non ferro)	The unit price for non-ferrous metal waste in Europe is on average € 560/ton[46]. It is assumed the metal composition in PMD consists of 88% of ferrous metals and 22% of non-ferrous metals.	560 €/ton
	It is assumed the metal waste collected using PMD in a PAYT approach has an average recycling efficiency of 89%[58].	
	It is assumed the PMD waste stream composition consists of 4% non-ferrous metal packaging[59].	
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
Recovered glass	The average European unit price for glass waste is estimated at € 51/ton[46].	51 €/ton
	It is assumed the glass waste stream collected using a PAYT approach has an average recycling efficiency of 88%[58].	
Recovered plastics	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	97.60 €/ton
EPR fee plastics	In 2017 the EPR fee, or Groene Punten tarieven, for separately collected plastics packaging material is € 210.7/ton[77]. Data for other 2013-2019 is available as well.	210.7€/ton.
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
EPR fee Paper and cardboard	The unit price for separately collected paper and cardboard is € 16.9/ton[77]. Data for other 2013-2019 is available as well.	16.9€/ton
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
EPR fee Glass	The unit price for separately collected glass is € 21.4/ton[77]. Data for other 2013-2019 is available as well.	21.4€/ton
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
EPR fee aluminium	The unit price for separately collected aluminium is € 32.6/ton[77]. Data for other 2013-2019 is available as well.	32.6€/ton
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	

[75] The Alliance for Beverage Cartonnes and the Environment, Beverage cartons weight composition, http://www.beveragecarton.eu/beverage-cartons/what-are-beverage-cartons

[76] FostPlus key figures 2018; https://www.fostplus.be/nl/over-fost-plus/organisatie/kerncijfers-en-jaarverslag

[77] Fost Plus, Groene Punten tarieven, 2017, https://www.fostplus.be/sites/default/files/Files/Bedrijven/GPtarieven/groenepunttarieven_nl_2017.pdf

EPR fee metal	The unit price for separately collected metals is € 124.4/ton[77]. Data for other 2013-2019 is available as well.	124.4 €/ton
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
EPR fee drinking cartons	The unit price for separately collected drinking cartons is € 245.5/ton[77]. Data for other 2013-2019 is available as well.	245.5 €/ton
	FostPlus recycled 92.8% of all packaging put on the market in 2018. It is therefore assumed the average rejected percentage of packaging waste is 7.2%[76].	
Incineration benefits	It is assumed that the revenues from burning mixed waste (residual, paper cardboard and plastic) are on average € 90 per ton.	90 €/ton
	It is assumed that all recyclable waste that is in the residual waste stream is not post sorted, and goes to the incinerator. Also, it is assumed that 20% of all collected waste recyclable waste streams is rejected and ends up in incineration.	
Tax savings	No environmental tax has to be paid over all waste that is not sent to incineration due to separate collection, therefore per ton of separately collected packaging waste 12.64 €/ton is saved.	12.64 €/ton

Table 21 - Assumptions and data on the revenues from PPW collection in Ghent

4.3.3. CBA RESULTS GHENT

The overview of all costs between 2013 and 2022 are shown in the figure below. Overall it can be noticed that most costs are fairly constant. Total collection costs for PMD, paper and cardboard and residual waste make up the biggest costs.

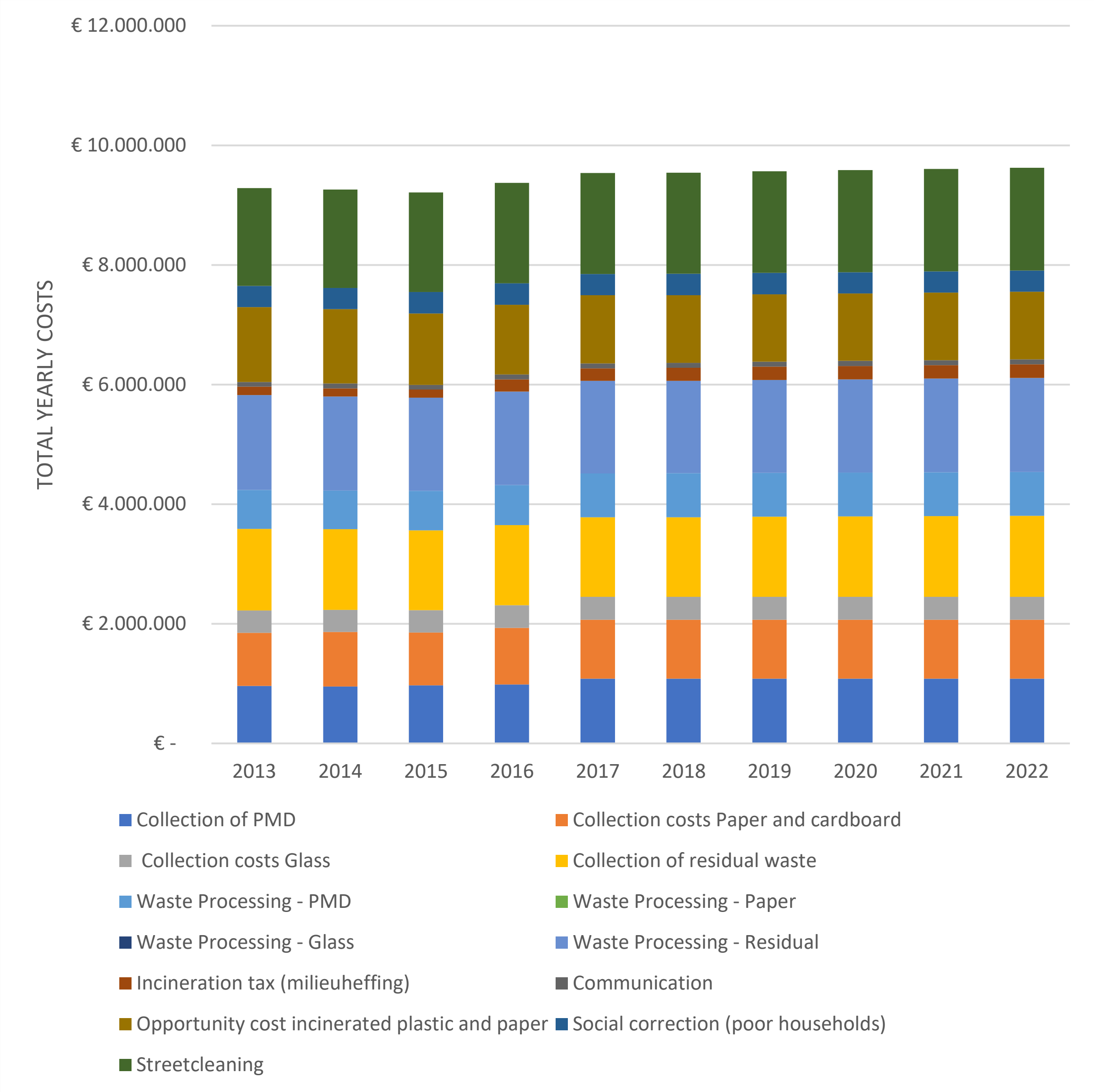


Figure 34 – Overview of total cost per year for Ghent

The graph on revenues shows that the citizen waste tax again plays a significant role, making up 24% of the total revenues. In addition, the EPR fees (especially plastic) play a large role. It can also be noted that the incineration benefits are quite high. Due to an significant increase in EPR fees for plastic packaging from 210 €/ton in 2017 to 375 €/ton in 2018 this revenue increased significantly. These fees are redefined every year based on the effective costs for the collection, sorting and recycling of the packaging. The fees have been fluctuating largely, especially over the last three years (see Figure 36). Overall, the combination of all EPR fees make up for 22% of the total revenues, and therefore are a significant contribution.

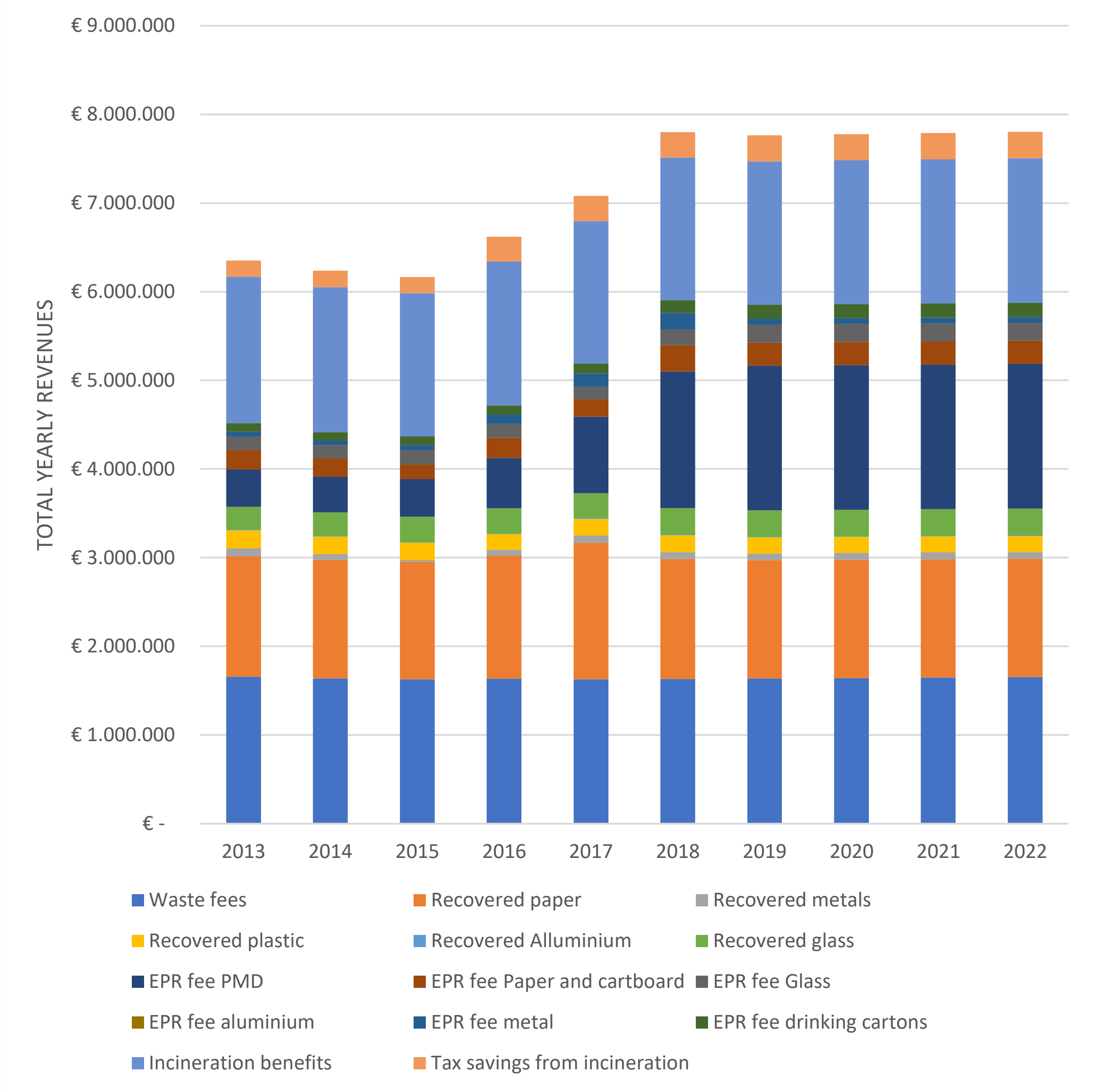


Figure 35 – Overview of total revenues per year for Ghent

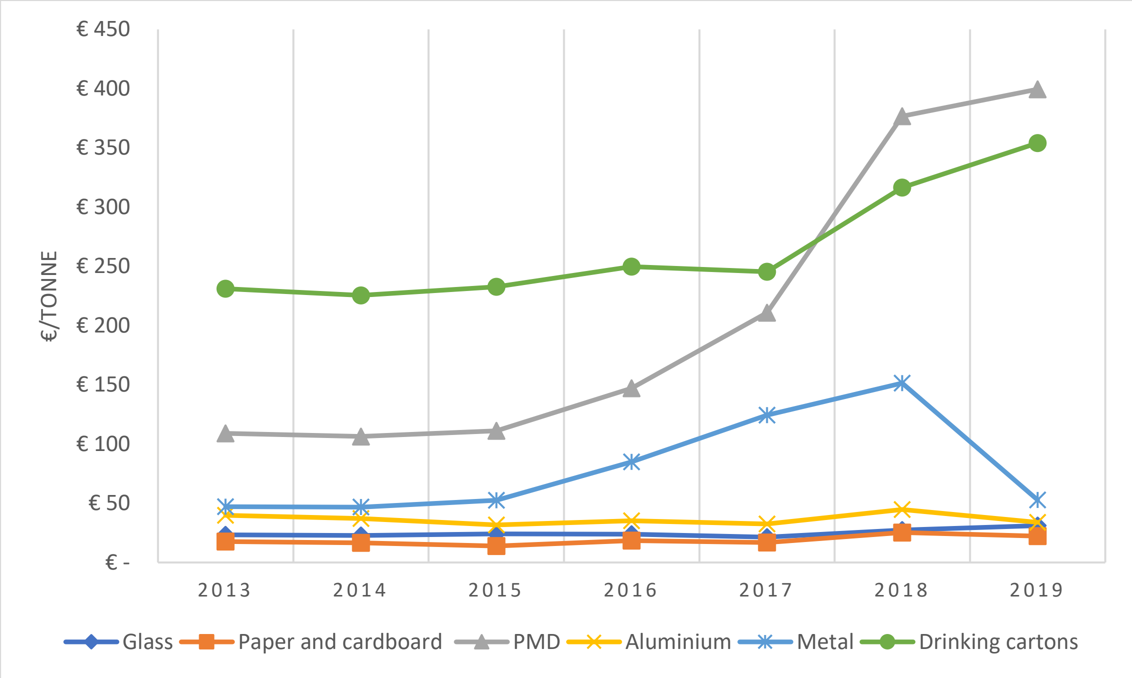


Figure 36 – Overview of Groene Punten tarieven from Fost Plus 2013 – 2019 [77]

All costs and benefits are calculated taking into account a discount rate of 4% - in line with EC CBA guidelines. The first year is taken as the 'present year'. The final overview of all costs, benefits and the financial net present value shows that the investment and operational costs are not in balance with the assessed revenues. The financial net present value is therefore negative, meaning the cost outweigh the benefits. Since only the packaging aspect of the waste collection system is assessed, this does not directly mean that the waste collection system is 'losing money'. Possibly, the missing costs are covered by revenues from other waste streams.

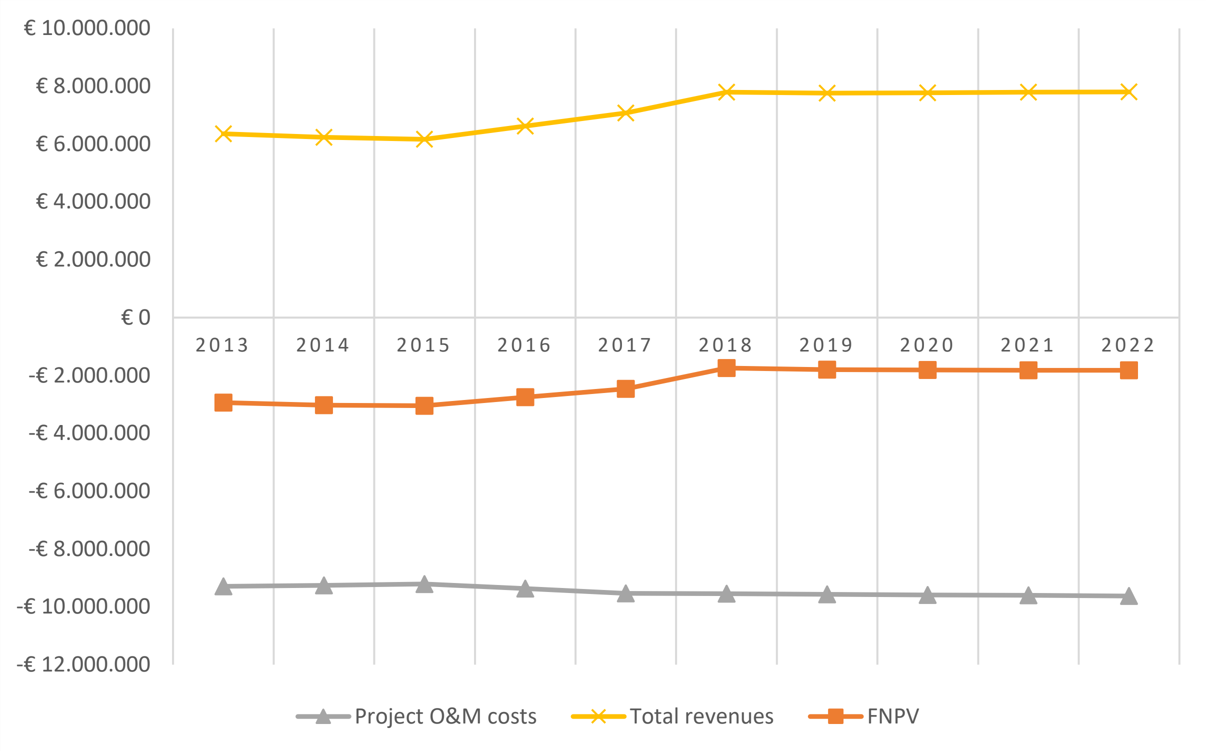


Figure 37 – Overview of costs, benefits and FNPV for Ghent

4.3.4. SENSITIVITY ANALYSIS

In order to highlight uncertainties in the data, a sensitivity analysis has been performed on the total operational costs, the material revenues, the EPR fees and collected quantities. An identical assessment as for the previous case has been performed. See also Chapter 3.3 for the methodology. For the capture rate the current capture rates for 2017 are taken, and increased systematically to a 100% capture rate in 2021.

In the table below the scenarios are drafted, and the effects on the FNPV and B/C ratio is shown.

Scenario	FNPV	Delta FNPV	B/C ratio	Delta B/C
Standard scenario	€ -19,967,805	-	0.7557	-
Decrease of 10% in operational costs	€ -17,052,493	14.6%	0.7874	4.2%
Increase of 10% in material prices	€ -19,325,246	3.2%	07647	1.2%
Increase of 10% in EPR fees	€ -19,165,243	4.0%	0.7669	1.5%
Increase in capture rate	€ -18,802,892	5.8%	0.7929	4.9%

Table 22 - Sensitivity analysis of Ghent results

It can be concluded that the operational costs have the largest effect on the results, for every 1% decrease in the operational costs, the FNPV goes up with 1.46% and the benefit/cost ratio goes up with 0.42%. The increase in material prices and EPR fees have a positive effect as well, however smaller compared to the decrease in operational costs. The increase in capture rate has a positive effect on the FNPV. The FNPV stays negative for all scenarios.

4.3.5. EVALUATION & CONCLUSIONS

Overall, looking at the benefits it can be concluded that – an average – merely 23% of these are coming from the citizen waste fee; 27% comes from recovered materials; and 23% comes from the EPR fees. The rest is covered by incineration revenues and tax savings.

Waste fee: As can be seen in the graph below, Ghent has a low waste fee of around € 60 per household. Comparing the waste fee in 2012 and 2018, we see an increase of 13%. This increase seems significant, however in absolute terms Ghent has one of the lowest fees from the assessed cases, and also the lowest absolute fluctuations. The total costs seem quite constant, however, the EPR fee for plastic waste increased significantly in 2017, which directly results in sharply increasing total benefits. Possibly, this resulted in a slightly lower waste fee after 2016.

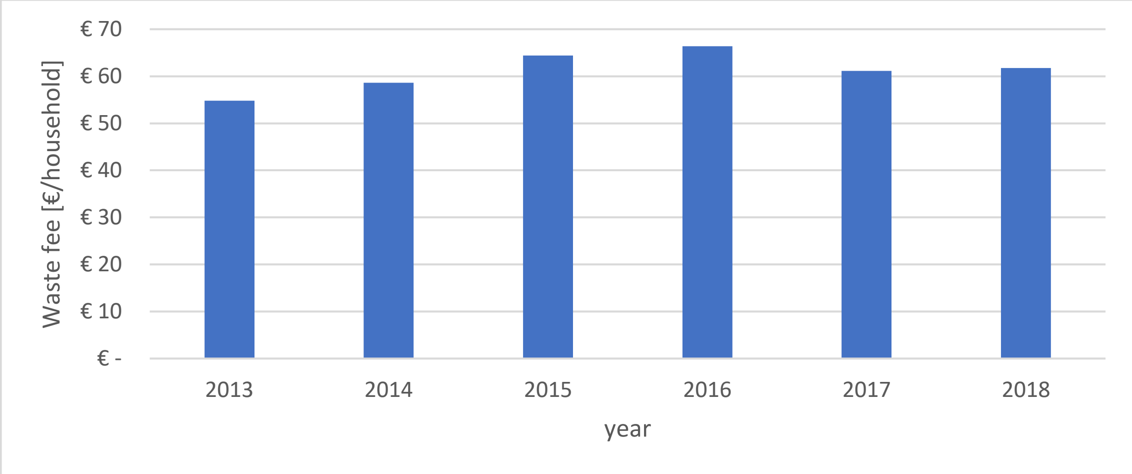


Figure 38 – Average waste fee in Ghent per household[70]

In order to present a quick overview of the shifting incomes, the items below are listed as a percentage of the total revenues (% of the total revenues);

- the waste fee is decreasing from 26% in 2013 to 21% in 2022;
- the revenues form incineration decrease from 26% in 2013 to 21% in 2022;
- the recovered materials are decreasing from 30% in 2013 to 24% in 2022;
- the EPR fee contribution increases from 15% in 2013 to 30% in 2022.

Investment: No recent investments have been identified.

Waste quantities: Despite the waste collection system already being in place for many years, Ghent still managed to realise a drop in residual waste quantities of 2%, going from 46 kilotonnes in 2012 to 44.5 kilotonnes in 2017. A corresponding increase of 2% in collected recyclable PPW waste has been found.

Operational costs: Due to less generated residual waste quantities, and more separately collected recyclable packaging waste, the corresponding operational costs per capita for residual waste decrease with 0.37€/inhabitant. The total operational costs for separate collection increased with 0.89€/inhabitant.

Evaluation	
Assessed period	2013 - 2022
Waste fee drop	-13%
Total investment	-
Investment per inhabitant	-
Drop in residual waste	2%
Increase in separate collected recyclable PPW waste	-2%
Decrease in operational costs for residual waste EUR/inh	€ 0,37
Decrease in operational costs for separate PPW EUR/inh	-€ 0,89

Table 23 - Evaluation of Ghent results

4.4. COST-BENEFIT ANALYSIS BERLIN

4.4.1. PROJECT DEFENITION BERLIN

In January 2013, Berlin was the first German federal state to introduce a model waste separation strategy, with a single recycling bin for light packaging together with similar materials[78]. A new recycling bin for PMD (plastic and metal packaging and beverage cartons) was introduced in Berlin, uniting the previously separate systems ("Yellow bin", "Yellow bin plus" and "Orange Box") into the Wertstofftonne (=recycling bin). In addition to light packaging, these bins are also used to collect equivalent non-packaging waste. Equivalent non-packaging recyclables include objects made of metal and/or plastics, e. g. watering cans, flower pots, plastic bowls, toys, pots and pans, tools, cutlery, etc. Collections from the new bins are carried out by BSR and by ALBA. The contents of the recycling bins are sorted at the ALBA Sorting Plant at Hultschiner Damm in Berlin-Mahlsdorf. In addition, paper and cardboard as well as glass are collected separately. Glass is collected separately (white, green, brown) and Berlin has ca. 6,000 bring points for glass waste. PMD is collected in yellow shared containers and door-to-door wheelie bins throughout the city. Residual waste is collected bi-weekly using household containers. Additionally, it is possible to get specific household waste bags (6€ per bag) at civic amenity sites, which can be ordered in case of an unusual higher amount of waste.

Figure 39 – Separate glass collection for brown, white and green glass (L) and Berlins new recycling bin[78]

Waste management: Based on the 'Kreislaufwirtschafts- und Abfallgesetz Berlin', it is the public authority's responsibility to collect waste from households and other sources. The collection is organised and carried out by the Berliner Stadtreinigungsbetrieben (BSR). This does also include the waste fractions considered for the ""Dual System"", which are recycables such as paper and cardboard, glass and light packaging. BSR and the firm ALBA share the responsibility for emptying the recycling bins, whereas BSR empties a fifth of the recycling bins in Berlin. The BSR was founded in 1951 as a municipal enterprise of Land Berlin. BSR is one of the largest waste management companies in Europe. It has around 5,300 employees and a fleet of some 1,600 vehicles.

BSR operates 15 civic amenity sites in Berlin. The flowchart for the collection of PPW in Berlin is presented in Figure 40. A possible first entry point for paper waste is the sorting facility WUB Wertstoff-Union Berlin GmbH, where the collected paper can be sorted. Different fractions are for example cardboard, mixed paper and de-inking capable paper. During this step, all non-paper materials are also removed[5]. Plastic waste from the PMD entry point can be transported to the sorting facility ALBA Recycling GmbH, which is conducting a separation of recyclables and which is providing these recyclables to the market for subsequent recycling steps[5]. Glass waste is handled fully by the dual systems. The residual waste is sent to one of Berlins' waste incinerators[79].

[78] www.berlin.de/senuvk/umwelt/abfallwirtschaft/downloads/siedlungsabfall/Abfall_Broschuere_engl.pdf
[79] Berliner Stadtreinigungsbetriebe, BSR-Entsorgungsbilanz 2017

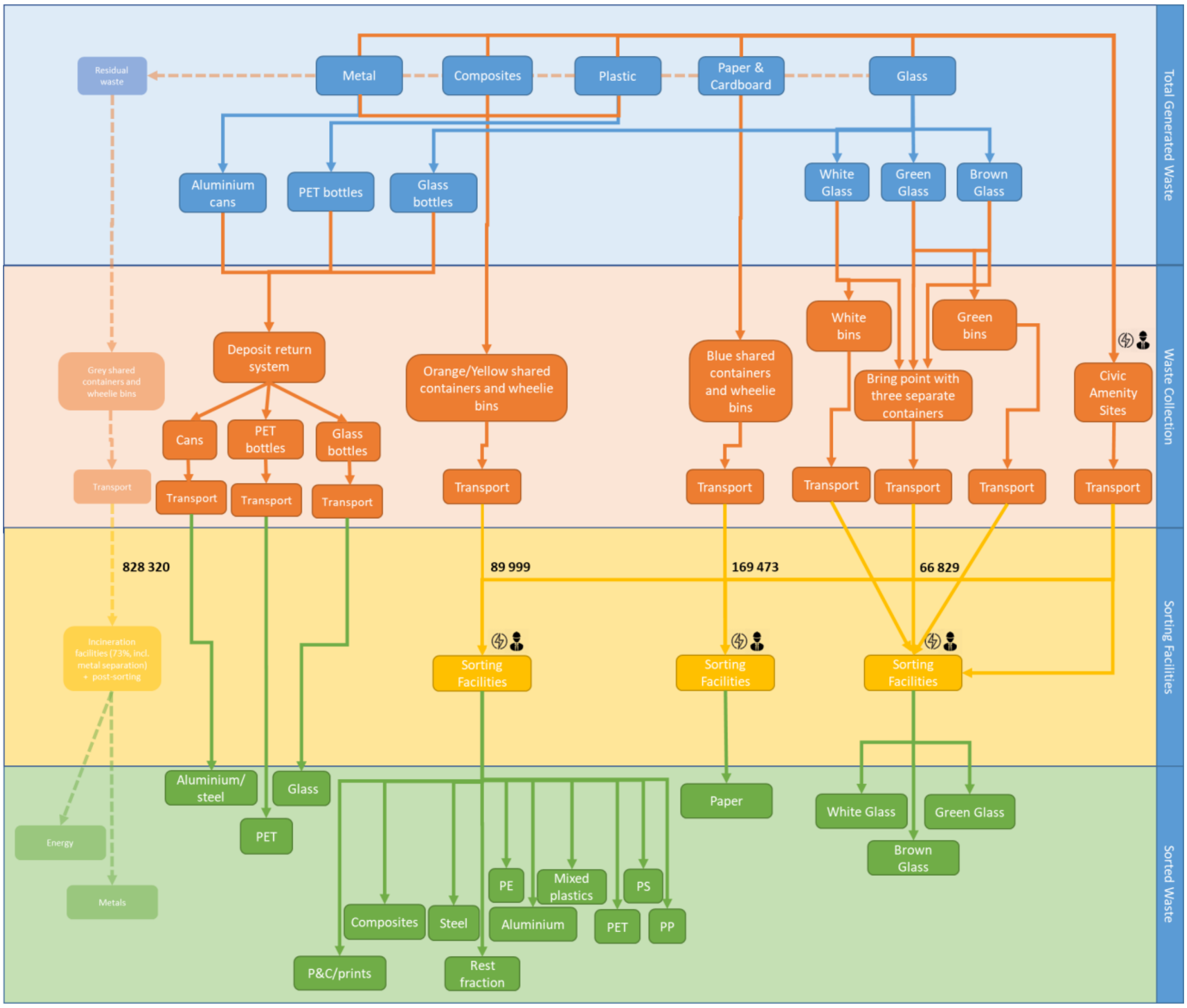


Figure 40 - Flowchart PPW Berlin

Financial responsibilities: Despite the change in collection approach to comingled collection of packaging materials and equivalent non-packaging packaging materials in the Wertstofftonne, no detailed information on investment costs has been found. Since the 'previously used yellow and orange bins' area still in use, it is assumed no additional investments have been made. Therefore, it has been assumed that no investments costs have been made.

BSR is 100% owned by the State of Berlin and as a public legal entity it is organized like a public limited company (management board, supervisory board) since 1994[80]. BSR owns the waste management equipment for Berlin and finances itself from the collection fees and other charges for services (cost recovery principle) but it does not generate profits and cost reductions directly benefit the fee-payers[81]. Potential investments in equipment will be made by BSR. Revenues from material recovery, incineration and from the EPR scheme (dual system) are collected by BSR.

EPR scheme: Der Grüne Punkt is Germanys producer responsibility for the packging industry, founded in 1990 as the first dual system. As the first system of its kind worldwide, it has been providing nationwide collection of used sales packages and obtains raw materials from them for the closed-cycle economy[82]. The dual system fees in Berlin are payed on a weight basis, producers have been incentivised to use less materials. Where in 1991 a

[80] www.innovatoripa.it/sites/default/files/bmas_resch_19022014.pdf
[81] www.berlin.de/senuvk/umwelt/abfallwirtschaft/downloads/siedlungsabfall/Abfall_Broschuere_engl.pdf
[82] Der Gruner Punkt, https://www.gruener-punkt.de/en/company/der-gruene-punkt.html

yogurt cup weighted 7.2 grams, nowadays in 2016 it weighs 4.7 grams. Also the system managed to increase the recycling rate from plastic recycling rates of 3% in 1991 to 54% in 2016.

4.4.2. IDENTIFICATION OF COSTS AND BENEFITS FOR PPW COLLECTION IN BERLIN

THE INVESTMENT COSTS

BSR already has a large waste collection infrastructure in place. In assessing the investment costs, it was aimed to include the additional costs required for setting up the good waste collection practice elements (e.g. expanding bring points, communication campaigns, brochures, new smart bins, etc.) In January 2013, Berlin was one of the first German federal states to introduce a model waste separation strategy, with a single recycling bin for light packaging together with similar materials. However, no data on the implementation and costs for the change in waste collection approach and the introduction of the Wertstofftonne[83], or recycling bin were found. In other sources this information has been discussed shortly and classified as confidential[84]. Therefore, these costs were excluded from the analysis.

Again, it is important to notice that the good practice in waste collection requires base line elements to operate successfully, being a PMD sorting and recycling installation, a paper sorting and recycling plant and a glass sorter and smelter. As discussed in the D2.2 report, this is the case for Berlin. The first entry point for paper waste is the sorting facility WUB Wertstoff-Union Berlin GmbH, where the collected paper is sorted. Different fractions are for example cartonnage, mixed paper and de-inking capable paper. During this step, all non-paper material are also removed. Both plastic and glass waste go to the sorting facility of ALBA Recycling GmbH, providing the material to the market for subsequent recycling steps.

OPERATING COSTS

The table below discusses the assumptions and data sources of the operational costs for collection and processing of the packaging waste streams.

Germany has no tax in place for the incineration or landfilling of waste[73].

Item	Assumption & data source	Unit cost
Collection of residual waste	In 2016, the collection costs for residual waste were € 70.80 per inhabitant[85]. For no other years the costs are known, therefore a fixed waste of € 70.80 over all years is assumed (given the rather limited PAYT element this seems a fair assumption).	218.63 €/ton
	In 2016, Berlin had 3,574,830 inhabitants.[86] This translates to € 218.63 per ton of residual waste.	
Collection PMD	In 2016, biweekly collection in Berlin costs € 288.38 per ton[87]. It assumed this holds for lightweight packaging.	288.38 €/ton
	In 2016, 88,107 tonnes of lightweight packaging material is collected[88]. Information on collected amounts for 2012 – 2017 is available.	

[83] Geschäftsbericht 2013 - Unterwegs mit der Berliner Stadtreinigung, BSR, 2013
[84] Berlin, Capital factsheet on separate collection, 2014, https://www.municipalwasteeurope.eu/sites/default/files/DE%20Berlin%20Capital%20factsheet.pdf
[85] Geschäftsbericht 2016, BSR
[86] Statistics on demography, Statistik Berlin, 2017, https://www.statistik-berlin-brandenburg.de/publikationen/stat_berichte/2018/SB_A01-01-00_2017q04_BE.pdf
[87] Müllgebühren im Vergleich Die 100 größten deutschen Städte, IW Consult, 2016, https://www.iwconsult.de/fileadmin/user_upload/downloads/public/pdfs/Muellgebuehrenranking_2016_Haus_Grund_Deutschland.pdf
[88] Abfallbilanz 2013-2017; https://www.berlin.de/senuvk/umwelt/abfall/bilanzen/de/archiv.shtml

Collection of paper	No financial information on the collection of paper waste is available. Therefore, the average collection costs for a large city from the Dutch benchmark are used. The average costs between 2015-2017 are € 102/ton.	102 €/ton
	In 2016, 169,797tonnes of paper waste is collected[88]. Information on collected amounts for 2012 – 2017 is available.	
Collection glass	No financial information on the collection of glass waste is available. Therefore, the average collection costs for a large city from the Dutch benchmark are used. The average costs between 2015-2017 are € 55/ton.	55 €/ton
	In 2016, 64.877 tonnes of glass is collected[88]. Information on collected amounts for 2012 – 2017 is available.	
Processing costs residual waste	In 2012, the average costs for processing and incineration of residual waste is € 146.55[89]. It is assumed no waste is landfilled, as landfill for untreated waste is banned in Germany[89].	146.55 €/ton
Processing costs PMD, paper, cardboard and glass	In Berlin, the BSR is responsible for the disposal of all waste from private households - with one exception; packaging waste. This is collected and recycled on behalf of the Dual Systems (Grüner Punkt)[90]. The Grüner Punkt buys recyclable waste, processes this, and sells or trades recyclates on the market. It is assumed the processing of recyclables (PMD, paper, cardboard and glass) is done by the Dual Systems (Gruner Punkt), and therefore the costs are not charged to the municipality or the BSR.	€ -
Street cleaning	The operational costs for street cleaning are € 38.10 per inhabitant. It is assumed packaging waste streams play a significant role here. The allocated cost to street cleaning of packaging waste is estimated to be 39.40% (total amount of the packaging waste streams on mass basis)[91].	15 €/inh
Opportunity cost plastic incineration	It is assumed that in case of plastic and paper/cardboard recycling an energy deficit of € 90 Euro per ton is created – the equivalent energy value of the plastic that is separated at recycled, but would otherwise have been used for energy recovery.	90 €/ ton
	The metal fraction of the PMD stream is excluded, as metals can be easily post separated before/after the incineration process. On average, PMD contains 6% of metal[42].	
	PMD (excluding metal) that is separately collected is assumed to be diverted from incineration.	

Table 24 - Assumptions and data for operational costs PPW Berlin

REVENUES

The following financial revenues are identified for the Berlin waste collection system:

- Citizen waste tax
- Incineration benefits
- EPR fees packaging industry.
- In Berlin, the city of Berlin cleaning is responsible for the disposal of all waste from private households - with one exception; the packaging. The municipal public services are responsible for the non-recyclable and organic waste, whereas paper, cardboard, lightweight packaging and glass falls under

[89] Kosten und Gebühren der Müllverbrennung in Deutschland nach Unternehmen im Jahr 2010 (pro Tonne Müll), 2012, https://de.statista.com/statistik/daten/studie/219745/umfrage/kosten-und-gebuehren-der-muellverbrennung-in-deutschland-nach-unternehmen/
[90] The disposal system of the BSR, https://www.bsr.de/das-entsorgungssystem-der-bsr-22619.php
[91] Abfalbillanz BSR 2015, mass basis of PMD, paper and cardboard, glass and residual packaging waste

the Dual System's Producers responsibility[92]. The recyclable streams are collected and recycled on behalf of the Dual Systems (Grüner Punkt)[90]. The Grüner Punkt buys recyclable waste, processes this, and sells or trades recyclates on the market. The benefits from recovered materials are therefore excluded, as these don't fall under the responsibility of the BSR and/or the municipality.

In the table below the assumptions and data sources for the revenues are stated.

Item	Assumption & data source	Unit cost
Waste fees	In 2016, the average waste tax per household was € 126[85].	49.65 €/hh
	The packaging waste makes up only a part of the residual waste. From the sorting analysis, the total amount of packaging waste is 39.4%. Therefore € 49.65 per household is taken.	
	In 2016, the BSR served 1.8 million household[85].	
EPR fee packaging industry Glass	The national tax rate, or weight-based fees for glass is € 76/ton[93]. These figures are crosschecked with the packaging volume fee calculator from Lizenzero[94], which gives similar prices as the tax database.	76 €/ton
	The glass recycling rate from GrunePunkt in 2016 was 85.6%[92].	
	It is assumed that this is largely due to impurities in the waste stream.	
Fee Packaging industry Paper	The national tax rate, or weight-based fees for paper, board and cardboard is € 206/ton[113]. These figures are crosschecked with the packaging volume fee calculator from Lizenzero[94], which gives similar prices as the tax database.	206 €/ton
	The paper and cardboard recycling rate from GrunePunkt in 2016 was 81.1%[92].	
	It is assumed that this is largely due to impurities in the waste stream.	
Fee Packaging industry Drinking cartons	The national tax rate, or weight-based fees or composite cartons (LPB) is € 775 /ton[113]. These figures are crosschecked with the packaging volume fee calculator from Lizenzero[94], which gives similar prices as the tax database.	790 €/ton
	The beverage carton recycling rate from GrunePunkt in 2016 was 77.6%[92].	
	It is assumed that this is largely due to impurities in the waste stream.	
Fee Packaging industry Plastic	The national tax rate, or weight-based fees for plastic is € 1,400/ton[113]. These figures are crosschecked with the packaging volume fee calculator from Lizenzero[94], which gives similar prices as the tax database.	1,400 €/ton
	The paper and cardboard recycling rate from GrunePunkt in 2016 was 53%[92].	
	It is assumed that this is largely due to impurities in the waste stream.	
Fee Packaging industry Metal (non ferro and ferro)	The national tax rate, or weight-based fees for aluminium and other metals which are part of the complete pack of a product is € 756 /ton[113]. These figures are crosschecked with the packaging volume fee calculator from Lizenzero[94], which gives similar prices as the tax database.	756 €/ton
	The metal recycling rate from GrunePunkt in 2016 was 90.5%[92].	
	It is assumed that this is largely due to impurities in the waste stream.	

[92] EPR for Packaging in Germany – Der Grüne Punkt, 2017, https://www.grontpunkt.no/media/2866/2017-11-22-denison-dsd-oslo-final.pdf

[93] Database on Policy Instruments for the Environment, https://pinedatabase.oecd.org/

[94] Lizenzero is Interseroh's dual system licensing system. Packaging volume fee calculator is found at https://www.lizenzero.de/en/packaging-volume-calculator/

Incineration benefits	It is assumed that the revenues from burning mixed waste (residual, paper cardboard and plastic) are on average € 90 per ton. It is assumed that all recyclable waste that is in the residual waste stream is not post sorted, and goes to the incinerator. Also, it is assumed that a weighted average of 19.9% of all separately collected recyclable waste is rejected and ends up in incineration[92].	90 €/ton
Tax savings from incineration	Germany has a landfill ban on untreated waste, but has no incineration tax in place.	0 €/ton

Table 25 - Assumptions and data on the revenues from PPW collection in Berlin

4.4.3. CBA RESULTS BERLIN

For Berlin, a period from 2012 to 2021 has been chosen. In the graphs below the results can be seen.

For the collection and processing costs, it can be seen that from 2012 to 2013 the processing costs for residual waste collection have decreased largely. This can be explained by the high costs for residual waste processing, and the large drop in the tonnage of residual waste collection due to the new separate waste collection system introduced in 2013. The total cost for collection of the packaging streams are limited compared to the collection costs for residual waste.

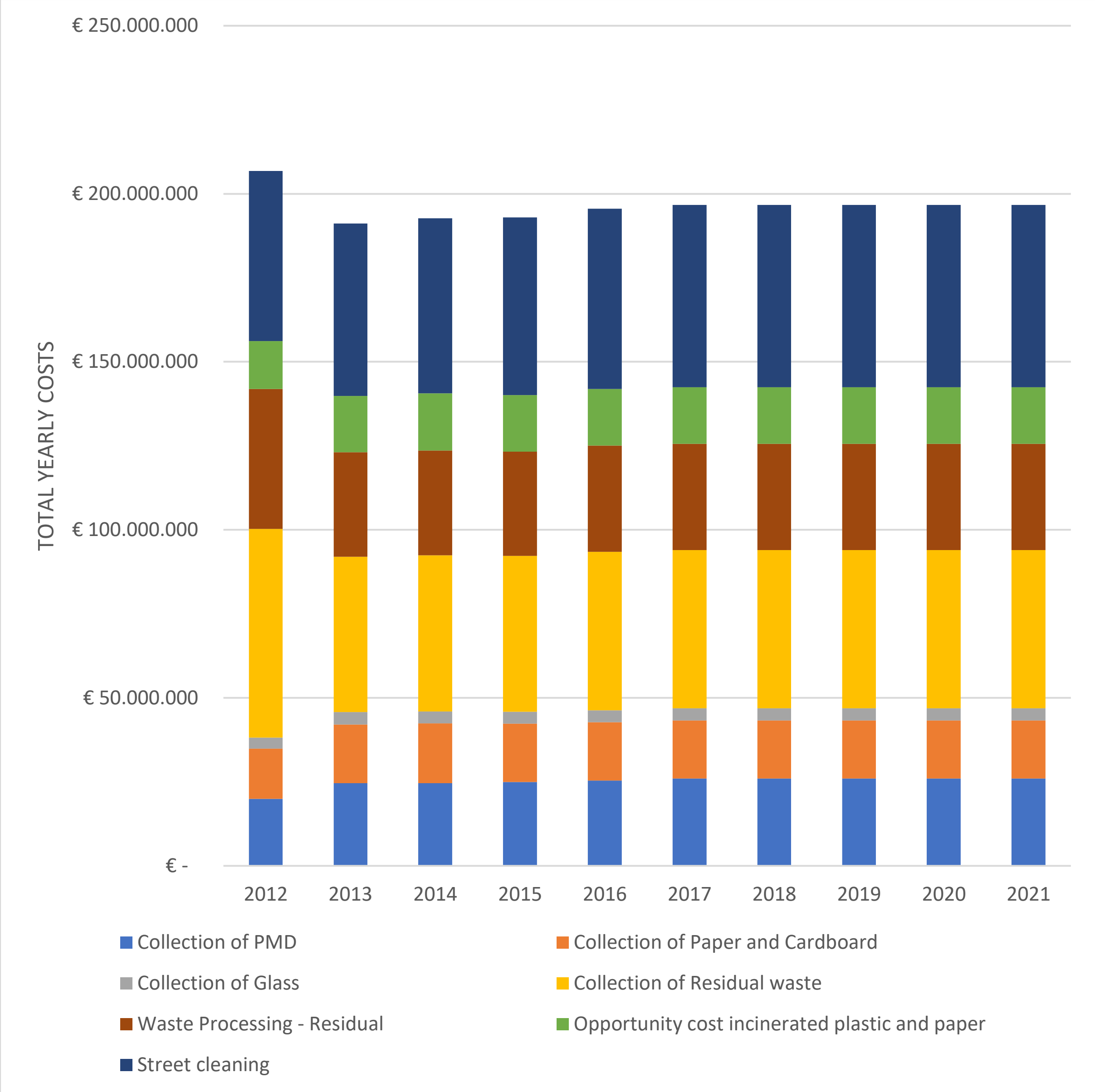


Figure 41 – Overview of total costs per year for Berlin

The graph with revenues shows that the citizen waste tax is by far the largest income and makes up for 38% of all revenues. The EPR fee for plastic (at € 1,400 per ton of collected plastic) is also a significant part of the revenues at 33%. .

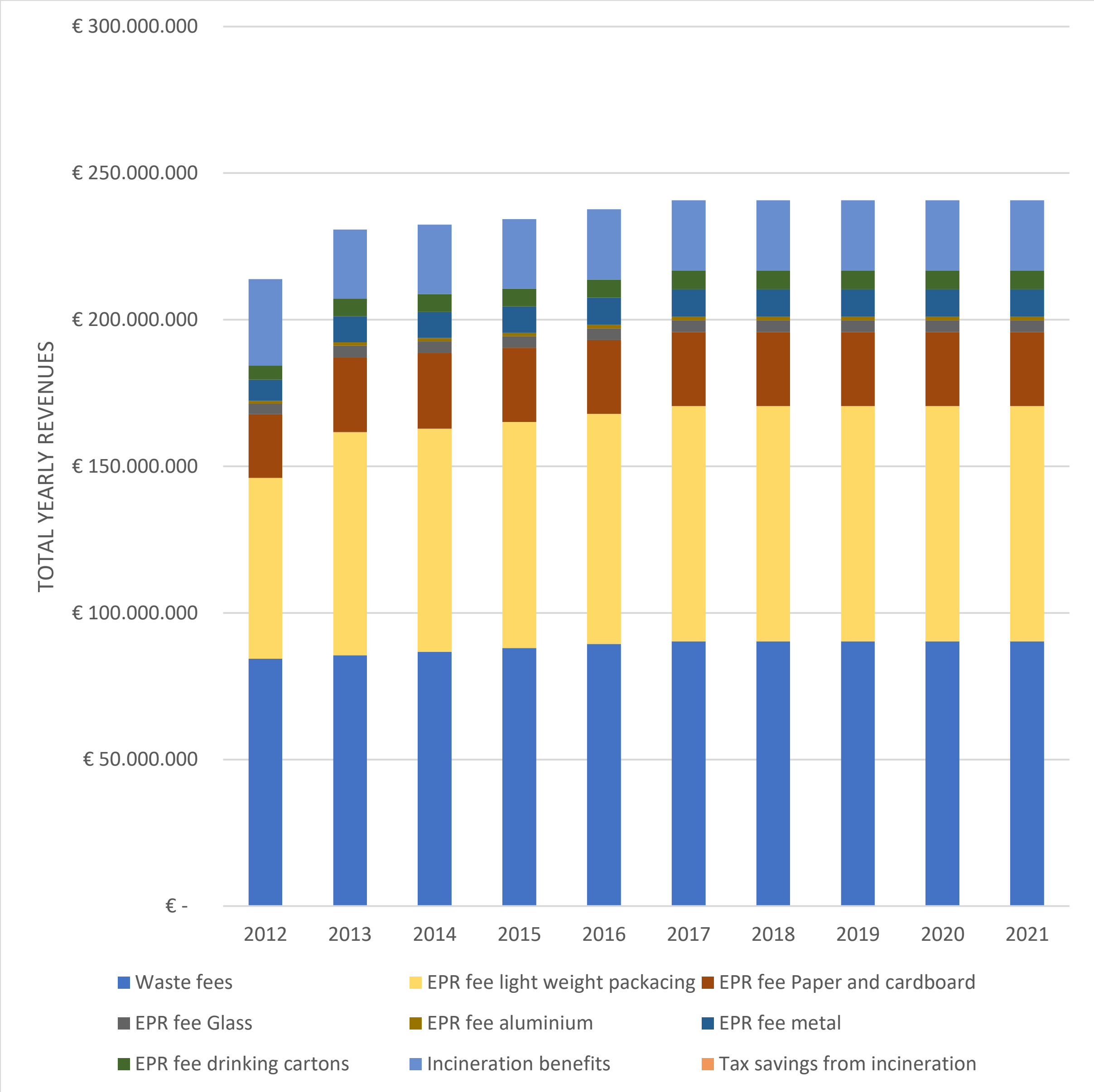


Figure 42 - Overview of total revenues per year for Berlin

The final overview of all costs, benefits and the financial net present value (FNPV) shows that the investment and operational costs are in balance with the assessed revenues. The first year is taken as the ‘present year’. All costs and benefits are calculated taking into account a discount rate of 4% - in line with EC CBA guidelines. The

FNPV is positive, meaning that the system receives more benefits than costs. This could mean that the 'beneficial' packaging system pays for collection and recycling of other less-profitable waste streams.

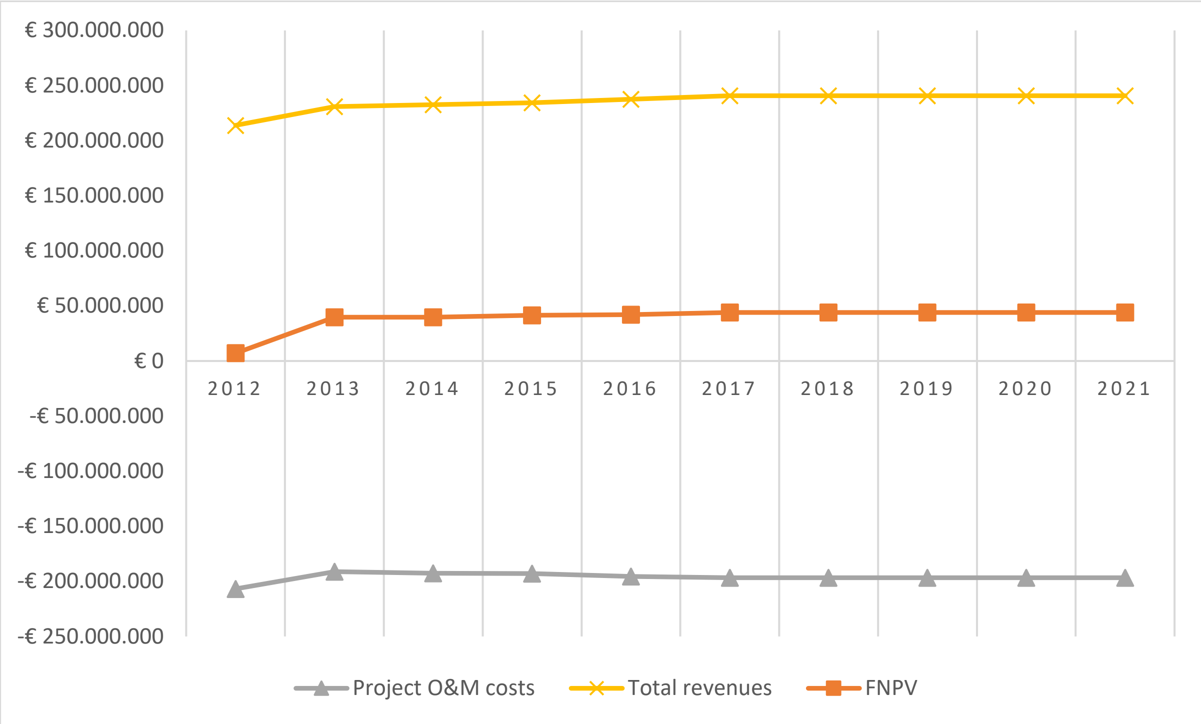


Figure 43 - Overview of costs, benefits and FNPV for Berlin

4.4.4. SENSITIVITY ANALYSIS

In order to highlight uncertainties in the data, a sensitivity analysis has been performed on the total operational costs and the EPR fees. An identical assessment as for the previous case has been performed, again taking the current capture rates for 2015 – 2017, and increasing systematically a 100% capture rate in 2021. As discussed, the material revenues are processed through the Dual Systems and therefore not included in the sensitivity assessment.

In the table below the scenarios are drafted, and the effects on the FNPV and B/C ratio is shown.

Scenario	FNPV	Delta FNPV	B/C ratio	Delta B/C
Standard scenario	€ 322,204,612	-	1.199	-
Decrease of 10% in operational costs	€ 375,851,745	16.7%	1.244	3.8%
Increase of 10% in material prices	-	-	-	-
Increase of 10% in EPR fees	€ 359,907,309	11.7%	1.225	2.1%
Increase in capture rate	€ 464,345,911	44.1%	1.289	7.5%

Table 26 - Sensitivity analysis of Berlin results

It can be concluded that the increase in capture rate has a significant effect on the results, as for every 1% decrease in the operational costs, the FNPV goes up with 1.67% and the benefit/cost ratio goes up with 0.38 %. The effect of the EPR fees shows that for every 1% of increase in the fees, the FNPV increases with 1.2% and the B/C ratio with 0.21%. The increase in capture rate has the largest effect; improving both the FNPV and B/C ratio.

4.4.5. EVALUATION & CONCLUSIONS

Overall, looking at the benefits it can be concluded that an average of 38% of these are coming from the citizen waste fee; 52% comes from the EPR fees; and ca. 10% comes from incineration benefits.

Waste fee: Unfortunately, limited information on Berlins waste fee development is available. However, the BSR does claim to have relatively low operational costs and therefore can charge low waste fees to her citizens. For instance, in the tariff period 2015-2016, only Munich charged slightly lower waste fees than Berlin. Due to the lack of data, the waste fee is assumed to be stable for all years.

In order to present a quick overview of the shifting incomes, the items below are listed as a percentage of the total revenues (% of the total revenues);

- the revenues form incineration decrease from 14% in 2012 to 10% in 2021;
- the EPR fee contribution increases from 47% in 2012 to 52% in 2021.

Two aspects that can be evaluated are the significant drop in residual waste and increase in recyclable packaging collection after implementing the new selective collection system, of respectively 24% and 19%.

Evaluation	
Assessed period	2012 – 2021
Waste fee drop	-
Investment	-
Investment per inh	-
Drop in residual waste PPW	24%
Increase in separate collected PPW waste	19%
Drop in operational costs for residual PPW EUR/inh	-
Increase in operational costs for separate PPW EUR/inh	-

Table 27 - Evaluation of Berlin results

4.5. COST-BENEFIT ANALYSIS TUBBERGEN

4.5.1. PROJECT DEFINITION TUBBERGEN

In 2015, Tubbergen shifted to a PAYT based waste collection system. PMD, paper and cardboard and glass are collected separately. PMD, paper and cardboard and residual waste are all collected using either mini containers or shared containers. Glass is collected using 42 communal containers.

Waste management: In the Netherlands, waste collection is usually carried out by local authorities either through their own collection services/in collaboration with a group of municipalities or through publicly owned companies, 100% of whose shareholders are the municipalities concerned (this was intended to encourage a more commercial approach to management and reduce costs)[95]. In Tubbergen, ROVA[96] collects all packaging waste streams and transports the PMD and metal to Attero in Wijster, the residual waste to Twence in Hengelo, and the paper and cardboard to Remondis and Peute in Rotterdam. In addition, paper and cardboard waste is periodically collected in the Tubbergen municipality by associations and schools (raising money with the paper and cardboard revenues). The flowchart for the collection of PPW in Tubbergen is presented in shown below in Figure 44.

[95] https://ec.europa.eu/environment/waste/studies/pdf/euwastemanagement_annexes.pdf
[96] ROVA is a public service provider and works for 23 municipalities with a working area of approximately 850,000 inhabitants.

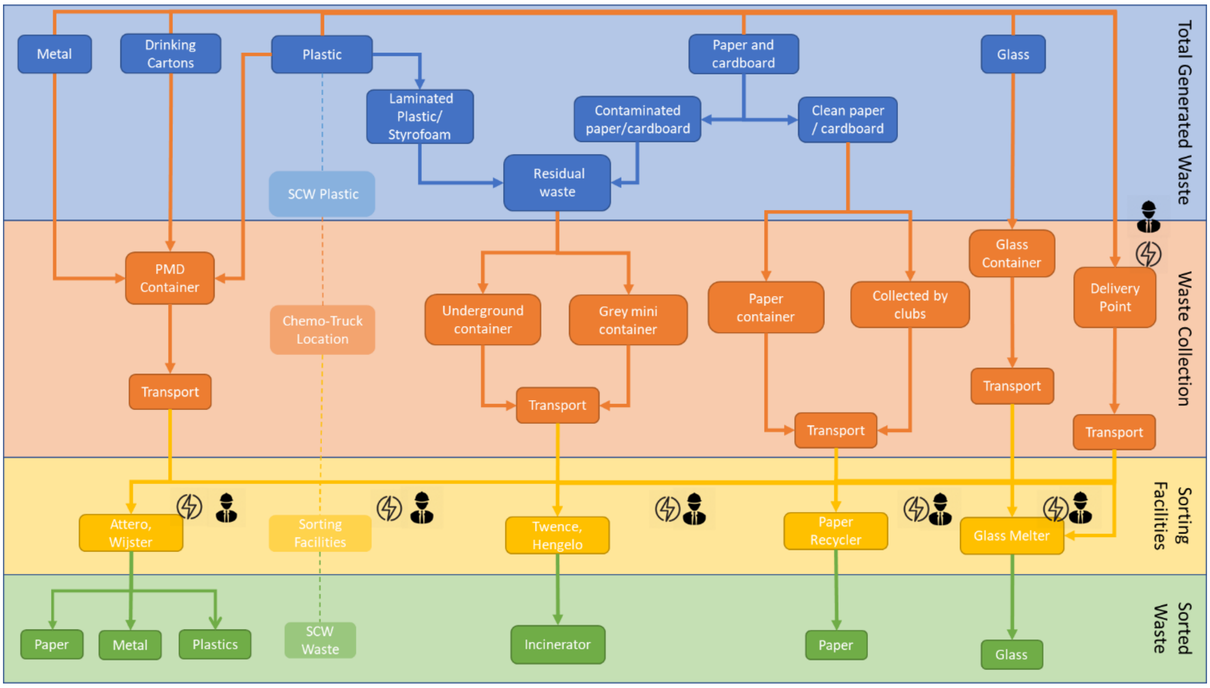


Figure 44 - Flowchart PPW Tubbergen

Financial responsibilities: ROVA is an intermunicipal association, owned by the 23 municipalities it is serving. ROVA owns the waste management equipment and fleet, therefore operational costs and potential investments in equipment are directly made by ROVA. Since ROVA has been operating in Tubbergen for quite some time, the required investments in equipment were very limited. The municipality Tubbergen invested mainly in communication campaigns, and in new (electronic) containers. Both the citizen waste fees and EPR compensation from Afvalfonds Verpakkingen is paid to the Tubbergen municipality. Revenues from material streams and incineration are collected by ROVA. ROVA charges Tubbergen for a waste management and organisation fee; covering the collection, transport, treatment and analysis of the waste for the PAYT system.

EPR scheme: In the Netherlands, the 'Afvalfonds Verpakkingen' reimburses waste collection companies in order to meet the legal requirements for collection and recycling on behalf of producers and importers. The Afvalfonds is financed by the waste management contribution of the packaging industry. Through this contribution the activities of the Packaging Waste Fund, but also those of the organizations involved, Nedvang, Nederland Schoon, Verpakkings chain BV (VPKT) and the Sustainable Packaging Knowledge Institute (KIDV) are funded. VPKT takes care of the sorting and recycling of (plastic) packaging by entering into contracts with post-separators, sorters, recyclers, transporters and storage and transfer stations. Every year, the Afvalfonds receives and distributes approximately € 200 million.

Starting in 2019, Afvalfonds started implementing lower tariffs for easily sortable and recyclable plastics. A similar incentive has been running for biodegradable plastics between 2013 – 2018.

4.5.2. IDENTIFICATION OF COSTS AND BENEFITS FOR PPW COLLECTION IN TUBBERGEN

INVESTMENT COSTS

In assessing the investment costs, it was found that ROVA (and therefore Tubbergen) already had a large waste collection infrastructure in place. The basic requirements for a well-functioning waste collection system such as containers, bring banks, civic amenity site(s), collection trucks, storage facilities and standard monitoring equipment were already available, and are therefore not included as investment costs.

In addition to the collection equipment, base line elements such as PMD sorting and recycling facilities, a paper sorting and recycling plant and a glass sorter and smelter are available to ROVA (see also Deliverable 2.4). ROVA brings the PMD packaging waste to Attero (ca. 60km), the glass waste to Maltha Glasrecycling (ca. 230 km), the residual waste to Twence (ca. 25km) and ROVA treats the paper waste herself. Investment costs for these facilities are excluded as they are beyond the scope of this project. Deliverable 2.4 of the Collectors project reflects further on this topic.

The additional investment costs required when setting up the new waste collection system are included in the assessment. These were costs for the implementation of the new PAYT system, such as new container management, new 'smart' containers with chips and a communication plan. These costs are shown below in Table 28.

Item	Assumption & data source	Unit cost
PAYT elements	For the implementation of the new PAYT system, Tubbergen invested in new container management, new 'smart' containers with chips and a new communication plan. These costs were budgeted at € 175,000, as indicated by the municipality of Tubbergen[97].	€ 175,000

Table 28 - Assumptions and data for investments costs PPW Tubbergen

OPERATING COSTS

For the operational costs of paper and packaging waste collection in Tubbergen the Dutch NVRD benchmark analysis[41] is used, which gives detailed insight in the collection and processing costs per waste stream, per collection method and per urban category (4 categories: A: 50-100% highrise, B: 30-49% highrise, C: 20-29% highrise, D:0-19% highrise). Tubbergen falls under category D, as a rural area with limited high-rise buildings. The disaggregated data is not available, however, the collection- and processing costs stated in the benchmark report are as follows: "….included are the personnel, material and / or outsourced costs that are allocated to the collection, storage and transfer and processing. Potential processing revenues are already included; the reimbursements from the Packaging industry/Afvalfonds are not".

ROVA indicated that, despite the change from a co-mingled to separate system in 2013, the increase in transport costs was limited. Thanks to 'vulgraadmetingen' – fill-level sensors in the containers – enable ROVA to collect efficiently without a significant increase in transport costs[98].

Also, the missed opportunity costs from waste diverted from incineration is included. The graph below shows the collected quantities over the years for residual waste (PPW fraction), PMD, paper and cardboard and glass. Looking at the changes in the collection numbers for Tubbergen, especially a significant change can be noted in the collected residual waste and PMD can be noted. Therefore, the opportunity costs (see also Chapter 4.1.3) of diverting PMD from incineration has been included as an indirect cost (as neither Tubbergen nor ROVA directly pay for this).

[97] Interview with waste policy advisor of Tubbergen municipality, 13/03/2019
[98] Interview with ROVA, 03/01/2019

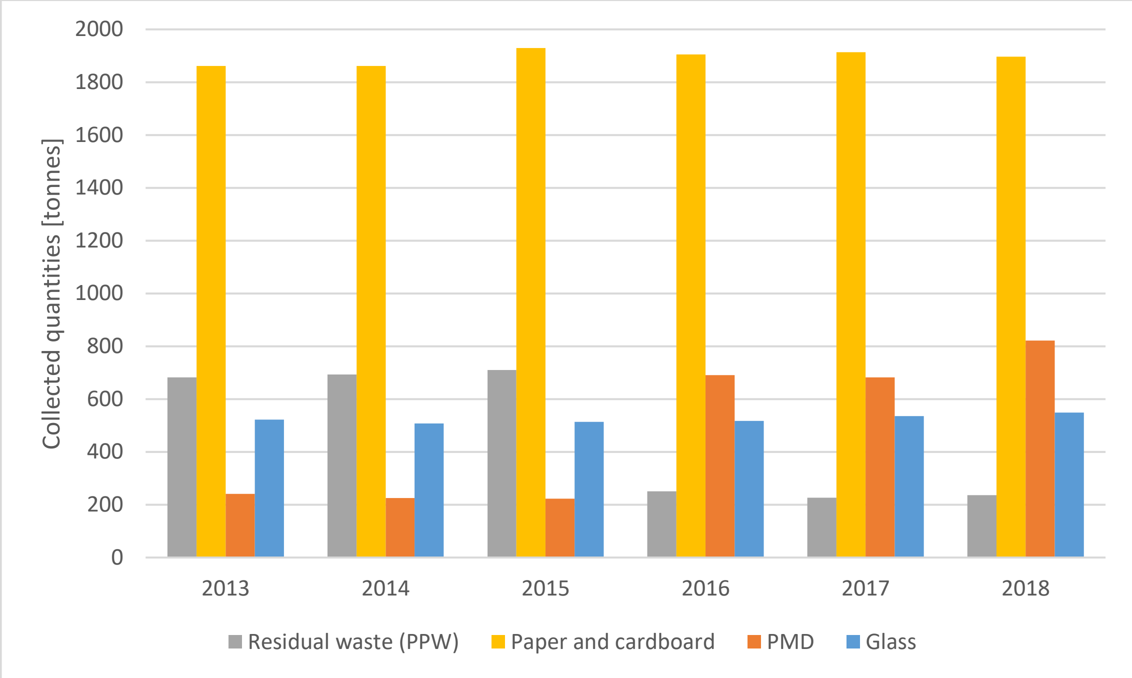


Figure 45 – Collected quantities Tubbergen 2013 – 2018

Lastly, waste taxes and street cleaning costs are also included. The table below gives an overview of the assumptions and data sources.

Item	Assumption & data source	Unit cost
Collection and processing of residual waste	Collection costs taken from 'Prestaties Fijn restafval – urban category D (rural) ' from the NVRD Benchmark Huishoudelijk Afval, which, which gives an overview of the average collection costs per waste stream, per urban category, per collection method for the Netherlands. Of these costs € 69 per ton is required for the collection, and € 116 per ton is required for the processing[99]. It is assumed any potential revenues are already included in the processing costs. Data for 2014 – 2017 is available and included in the assessment.	185 €/ton
	In 2016, there was 1,473 ton of residual waste collected in Tubbergen[100]. For the previous years, the collected amounts are known. From 2019 onwards, the collected amounts per inhabitant for 2018 are taken and multiplied with the expected number of inhabitants.	
Collection and processing of PMD	Collection costs taken from 'Prestaties PMD – urban category D (rural) ' from the NVRD Benchmark Huishoudelijk Afval, which, which gives an overview of the average collection costs per waste stream, per urban category, per collection method for the Netherlands. Of these costs € 326 per ton is required for the collection, and € 260 per ton is required for the processing. Data for 2014 – 2017 is available and included in the assessment.	586 €/ton
	In 2016, there was 691 ton of lightweight packaging material collected in Tubbergen[100]. For the previous years, the collected amounts are known. From 2019 onwards, the collected amounts per inhabitant for 2018 are taken and multiplied with the expected number of inhabitants.	

[99] Afvalstoffenheffing 2017, Processing rates Twence for household waste
[100] Rova, Afvalmonitor gemeente Tubbergen (2017)

<table>
<tr><td rowspan="2">Collection and processing of paper</td><td>Collection costs taken from ‘Prestaties Oud papier en kartonne – urban category D (rural) ’ from the NVRD Benchmark Huishoudelijk Afval, which, which gives an overview of the average collection costs per waste stream, per urban category, per collection method for the Netherlands. Data for 2014 – 2017 is available and included in the assessment. For paper and cardboard waste no breakdown of collection and processing costs is available, and the revenues are already included. The market prices for paper waste are decreasing, and between 2017 and 2019 the prices have been halved.</td><td rowspan="2">4 €/ton</td></tr>
<tr><td>In 2016, there was 1905 ton of paper and cardboard material collected in Tubbergen[100]. For the previous years, the collected amounts are known. From 2019 onwards, the collected amounts per inhabitant for 2018 are taken and multiplied with the expected number of inhabitants.</td></tr>
<tr><td rowspan="2">Collection and processing of glass</td><td>Collection costs taken from ‘Prestaties Glassverpakkingen – urban category D (rural) ’ from the NVRD Benchmark Huishoudelijk Afval, which, which gives an overview of the average collection costs per waste stream, per urban category, per collection method for the Netherlands. Data for 2014 – 2017 is available and included in the assessment. For glass waste no breakdown of collection and processing costs is available.</td><td rowspan="2">47 €/ton</td></tr>
<tr><td>In 2016, there was 517 ton of glass collected in Tubbergen[100]. For the previous years, the collected amounts are known. From 2019 onwards, the collected amounts per inhabitant for 2018 are taken and multiplied with the expected number of inhabitants.</td></tr>
<tr><td>Waste incineration tax</td><td>In 2016, the waste tax for residual waste was € 13.07 per ton. The waste tax was introduced in 2014 at € 17 per ton, and increased to € 32.12 per ton in 2019[101]. It is assumed no waste is landfilled, as landfilled is banned in the Netherlands[73].</td><td>13.07 €/ton</td></tr>
<tr><td rowspan="4">Opportunity cost plastic and paper incineration</td><td>The missed opportunity costs by diverting plastic and paper and cardboard waste from incineration are assumed to be € 90 per ton.</td><td rowspan="4">76.89 €/ton</td></tr>
<tr><td>The waste tax paid over incineration waste, as mentioned above are deducted from the € 90 per ton.</td></tr>
<tr><td>The metal fraction of the PMD stream is excluded, as metals can be easily post separated before/after the incineration process. On average, PMD contains 6% of metal[42]. Glass is a non-combustible material, it is not included.</td></tr>
<tr><td>PMD (excluding metal), and paper and cardboard that is separately collected is assumed to be diverted from incineration.</td></tr>
<tr><td>Street cleaning</td><td>No case specific costs for street cleaning are available. The average operational costs for street cleaning in Netherlands are estimated to be € 15 per inhabitant (of which 77% is paid by municipalities, the other 23% is paid by national or nature organisations)[102]. The allocated cost to street cleaning of packaging waste in Tubbergen is estimated to be 17 % (fraction of PPW in residual waste).</td><td>1.97 €/inh</td></tr>
</table>

Table 29 - Assumptions and data for operational costs PPW Tubbergen

[101] Afvalstoffenbelasting, belastingdienst, 2019, https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/zakelijk/overige_belastingen/belastingen_op_milieugrondslag/tarieven_milieubelastingen/tabellen_tarieven_milieubelastingen

[102] Deloitte, Report on the costs of littering in the Netherlands, 2010, http://www.svzo.nl/kostenzwerfafval.pdf

REVENUES

The following financial revenues are identified for the Tubbergen waste collection system:

- Citizen waste tax
- Revenues from collected materials. These are collected and further processed/sold by ROVA. These revenues are included in the processing costs[98], and therefore excluded to prevent double counting.
- Incineration benefits
- EPR fees packaging industry
- Tax savings

In the table below the assumptions and data sources for the revenues are stated.

Item	Assumption & data source	Unit cost
Waste fees	In 2016, the fixed waste fee in Tubbergen equals € 100 per household[103]. Depending on the container, either € 5.60 (120L) or € 9.20 (240L) is paid per emptying. The average waste fee per household in 2016 was € 138 per household. In 2016, Rova served 7876 households[104] in Tubbergen[105]. Data on the average fee for 2013 – 2019 is available and included for the assessment.	36.06 €/hh
	The assumed allocated percentage for the relevant waste streams (Including paper, cardboard, metal, plastics and the packaging residual waste; excluding textile, organic, bulky waste and toxic waste) is 26.13%[106]. This comes down to 36.06 € per household.	
Contribution packaging industry Glass	The Dutch 'Afvalfonds Verpakkingen' reimburses waste collection companies in order to meet the legal requirements for collection and recycling on behalf of producers and importers. Tariffs for 2013 - 2019 are available[107]. In 2016, the fee was 0.0595 €/kg.	56 €/ton
Contribution Packaging industry Paper	The Dutch 'Afvalfonds Verpakkingen' reimburses waste collection companies in order to meet the legal requirements for collection and recycling on behalf of producers and importers. 2013-2019 values are available[107]. In 2016, the fee was 0.022€/kg. It should be noted that the EPR fees for paper and cardboard have been decreasing the last few years.	22 €/ton
Contribution Packaging industry Drinking cartons	The Dutch 'Afvalfonds Verpakkingen' reimburses waste collection companies in order to meet the legal requirements for collection and recycling on behalf of producers and importers. 2013-2019 values are available[107]. In 2016, the fee was 0.18 €/kg.	180 €/ton
Contribution Packaging industry Plastic	The Dutch 'Afvalfonds Verpakkingen' reimburses waste collection companies in order to meet the legal requirements for collection and recycling on behalf of producers and importers. 2013-2019 values are available[107]. In 2016, the fee was 0.64 €/kg. It should be noted that the EPR fees for plastic have been more and more under pressure the last few years.	640 €/ton

[103] Verordening op de heffing en invordering van de afvalstoffenheffing 2016, http://decentrale.regelgeving.overheid.nl/cvdr/xhtmloutput/Actueel/Tubbergen/CVDR391814.html
[104] https://noaberkracht.incijfers.nl/jive
[105] Rova, annual report 2017, 2017
[106] Kostenverdeling per afvalstroom, NVRD, Benchmark Huishoudelijk Afval peiljaar 2016
[107] Tarieventabel Afvalfonds Verpakkingen, 2017, https://afvalfondsverpakkingen.nl/verpakkingen/alle-tarieven

Contribution Packaging industry Metal (non ferro and ferro)	The Dutch 'Afvalfonds Verpakkingen' reimburses waste collection companies in order to meet the legal requirements for collection and recycling on behalf of producers and importers. 2013-2019 values are available[107]. In 2016, the fee was 0.02 €/kg.	20 €/ton
Incineration benefits	It is assumed that the revenues from burning mixed waste (residual, paper cardboard and plastic) are on average € 90 per ton. It is assumed that all recyclable waste that is in the residual waste stream is not post sorted, and goes to the incinerator. It is also assumed that the impurities in the packaging waste streams are sent to incineration. For 2018 these were as follows; - Glass = 2.72% - Papier = 0.5% - Plastic = 8.3 -11.3% - Aluminium = 15% - Steel = 4%[108]; Coming to a weighted average of 2.4% of separately collected materials sent to incineration.	90 €/ton
Tax savings	Since a lot of plastic, paper and cardboard waste is diverted from incineration, no tax for incineration has to be paid. The tax savings are calculated with the sum of separately collected PMD, paper and cardboard and the waste tax as discussed in Table 29.	13.07 €/ton

Table 30 - Assumptions and data on the revenues from PPW collection in Tubbergen

4.5.3. CBA RESULTS TUBBERGEN

For the collection and processing costs, it can be seen that from 2013 onwards, the costs for residual waste collection and processing have been decreasing sharply. Similarly, the total costs for PMD collection and processing have been increasing strongly. The opportunity cost from incineration are significant, but are decreasing due to higher incineration tax rates from 2019 onwards.

[108] Monitoring Afvalfonds 2018, https://afvalfondsverpakkingen.nl/a/i/Monitoring-Verpakkingen-Resultaten-inzameling-en-recycling-2018.pdf

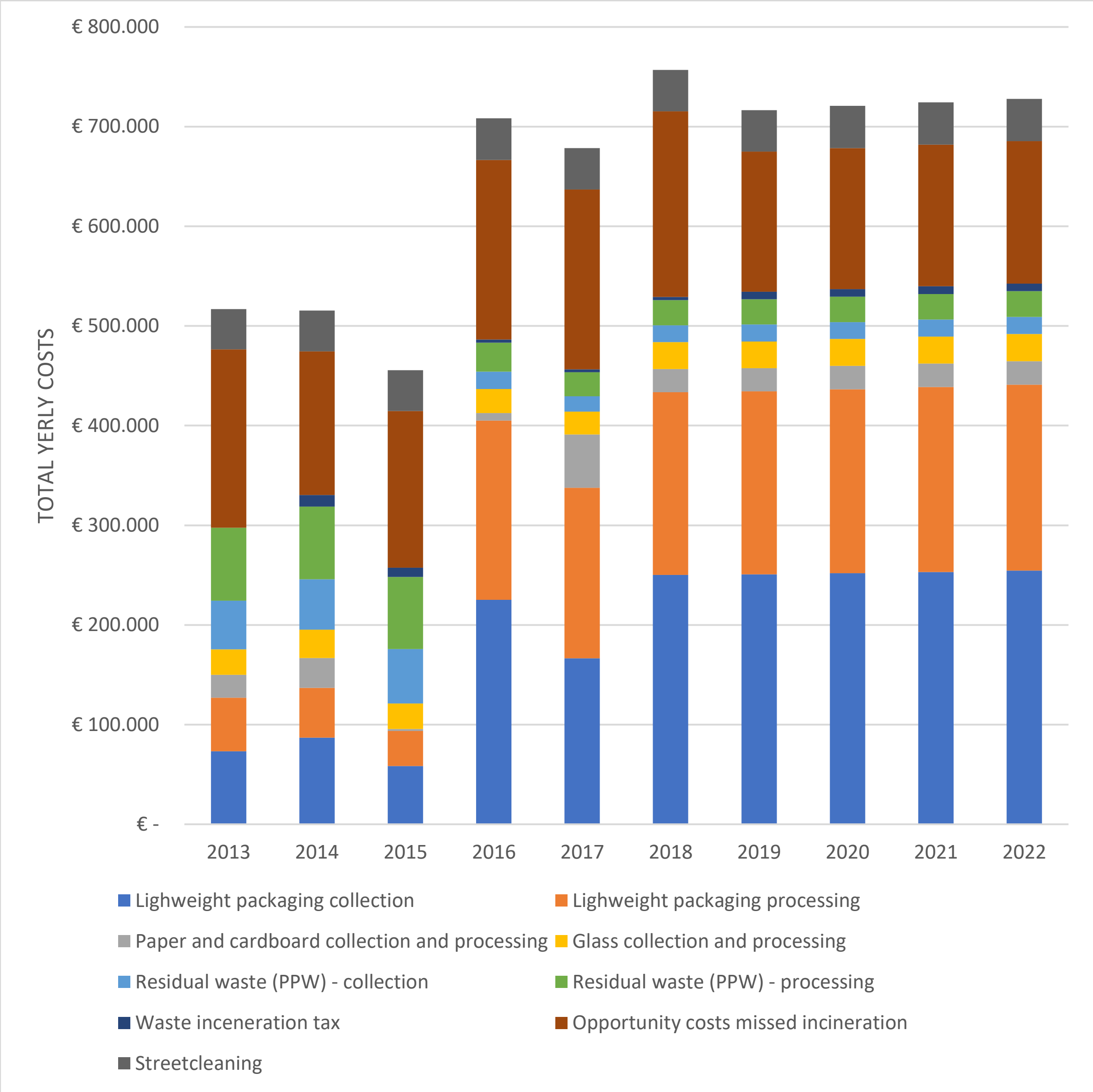


Figure 46 – Overview of total cost per year for Tubbergen

The graph with revenues shows that the citizen waste tax is by far the largest income, making up 42% of the total revenues. The EPR fee for separate plastic collection is also significant, especially since the producer fee went up to € 640 per ton of plastic put on the market. The large increase in total costs between 2015 and 2016 is largely caused by the large increase in PMD collection, more than doubling in 2016.

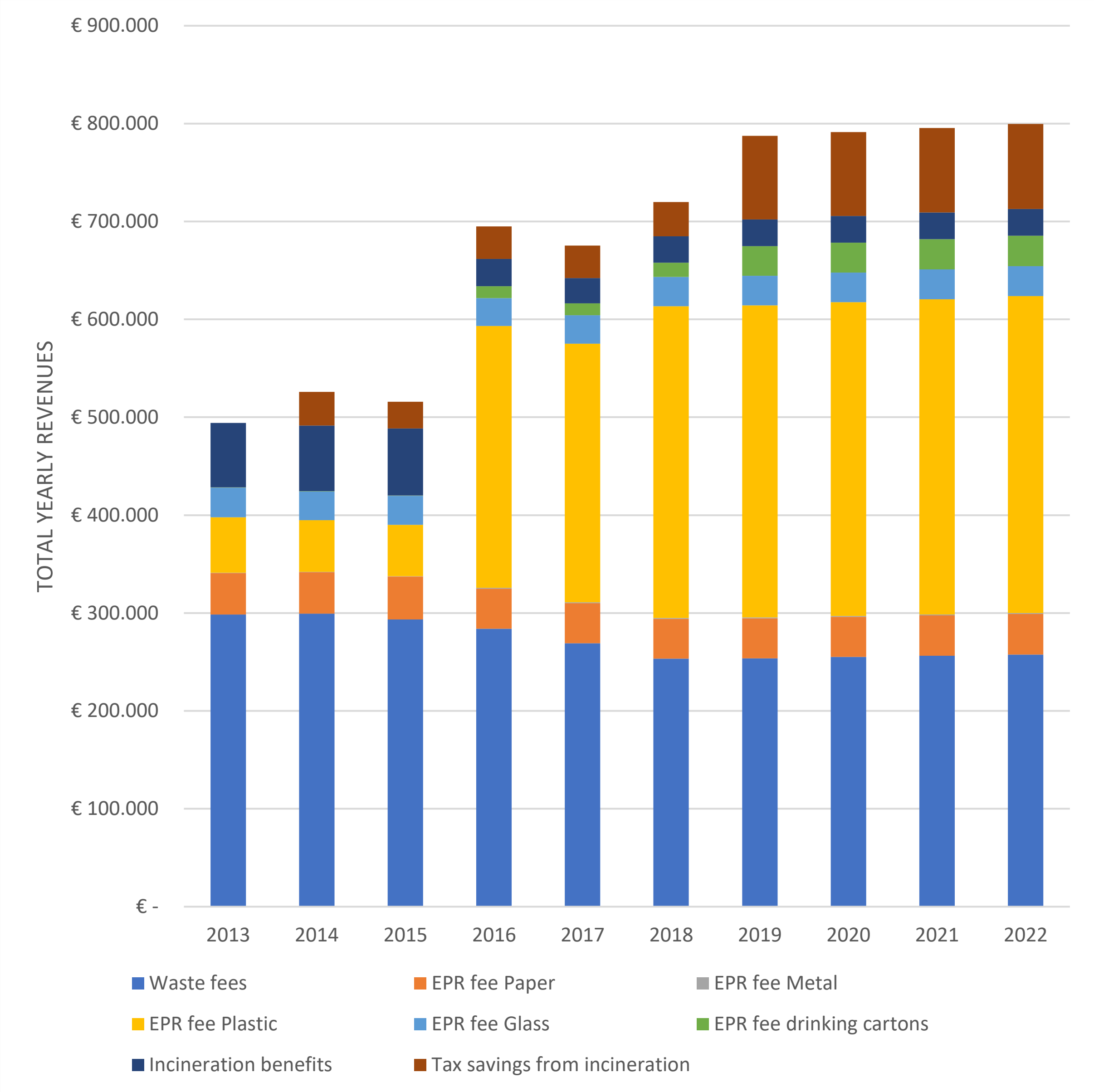


Figure 47 – Overview of total revenues per year for Tubbergen

Since the EPR fees contribute to no less than 40% of all benefits in the Tubbergen waste collection system, a closer look to these tariffs is shown in Figure 48. The increase in revenues is largely based on the EPR fee from separately collected plastics (yellow bar).

The fees from the AfvalfondsVerpakkingen are based on the actual required costs to meet the producer responsibility requirements for each type of material, consisting out of: i) the net costs of a material calculated as the cost for collection, processing and marketing minus the (positive or negative) revenue, and ii) the general system costs such costs for as monitoring, litter prevention and research. In the last years, especially the fees for separately collected plastic and beverage cartons increased. The sharp increase from 2015-2016 is enforced by the AfvalfondsVerpakkingen; The collection and recycling of plastic packaging and beverage cartons is a success, increasing the total costs. In order to be able to continue to bear their responsibilities, the fees are increased. If these costs were to go down, this could influence the financial performance of the waste collection system significantly.

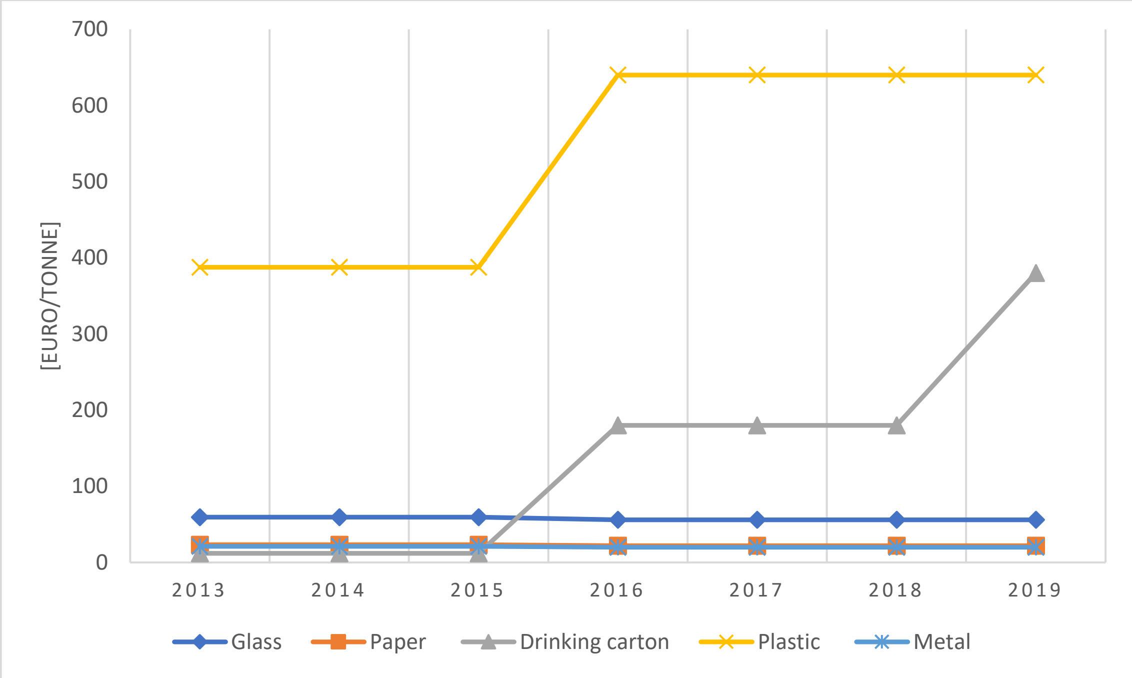


Figure 48 – EPR fees in Euro per ton for the Dutch packaging industry 2013 - 2019[107]

In the graph below, all costs and benefits are calculated considering a discount rate of 4% - in line with EC CBA guidelines. The first year is taken as the 'present year', as it is assumed this is the year the investment decision for the new waste collection system is made. Both the costs and benefits increased starting in 2015. The orange line shows that on average, the costs and benefits are in balance, as the FNPV is slightly positive.

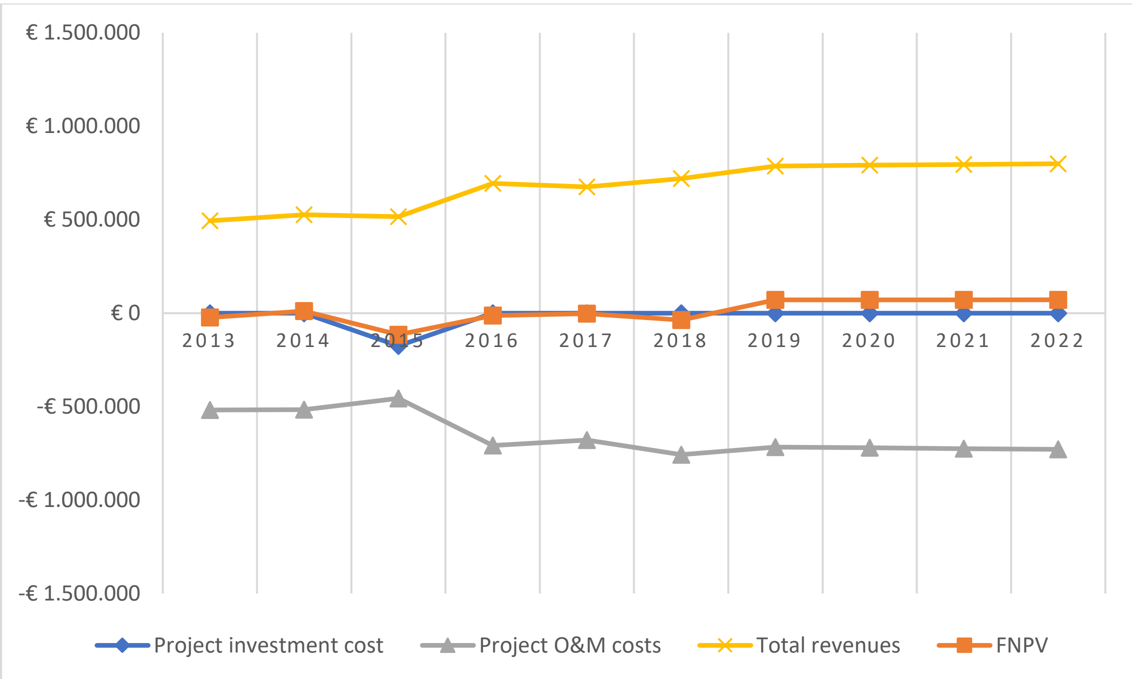


Figure 49 – Overview of costs, benefits and FNPV for Tubbergen

4.5.4. SENSITIVITY ANALYSIS

In order to highlight uncertainties in the data, a sensitivity analysis has been performed on the total operational costs and the EPR fees. An identical assessment as for the previous case has been performed, again taking the current capture rates for 2016 – 2018, and increasing systematically to a 100% capture rate in 2022.

The financial feasibility of the project depends on several variables and assumptions. In the sensitivity analysis the effect of the most crucial parameters as well as the uncertainties will be assessed.

In order to highlight uncertainties in the data, a sensitivity analysis has been performed on the total operational costs and the EPR fees. Since the material revenues are already included in the operational prices, this element is excluded from the sensitivity assessment.

In the table below the scenarios are drafted, and the effects on the FNPV and B/C ratio is shown.

Scenario	FNPV	Delta FNPV	B/C ratio	Delta B/C
Standard scenario	€ 48,583	-	1,043	-
Decrease of 10% in operational costs	€ 266,171	447.9%	1,091	4.6%
Increase of 10% in material prices	-	-	-	-
Increase of 10% in EPR fees	€ 208,431	329.0%	1,075	3.1%
Increase in capture rate	€ 42,517	-12.5%	1,041	-0.2%

Table 31 - Sensitivity analysis of Tubbergen results

It can be concluded that the operational have the largest effect on the results, for every 1% decrease in the operational costs, the FNPV goes up with 45% and the benefit/cost ratio goes up with 0.5%. The EPR fees also have a significant effect; for every 1% increase the FNPV increases with 33%, and the benefit/cost ratio with 0.3%. The increase in capture rate has a negative effect on the FNPV and B/C ratio, however still results in positive values.

4.5.5. EVALUATION & CONCLUSIONS

Overall, looking at the benefits it can be concluded that an average of 42% of these are coming from the citizen waste fee; 45% comes from the EPR fees; and ca. 6% comes from incineration benefits.

Waste fee: As can be seen in the graph below, Tubbergen managed to implement a separate collection system by eventually even lowering the costs for its citizens. During and after the implementation the waste fee has been decreasing. Comparing the waste fee in 2011 and 2017, we see a drop of 23%. As can be seen in Figure 47, the sharp increase in benefits from producer fees from plastics possibly enabled Tubbergen to reduce her waste fees. In addition, a decrease in collection and processing costs for residual packaging waste is happening between 2014 – 2015, however, this is largely counter balanced by the increase in costs for collection of PMD. Lastly, the increase in incineration tax from € 13.21 per ton in 2018 to € 32.12 per ton in 2019, will also have significant effects on the balance, but since Tubbergen has very low quantities of residual waste, this hardly shows in Figure 46.

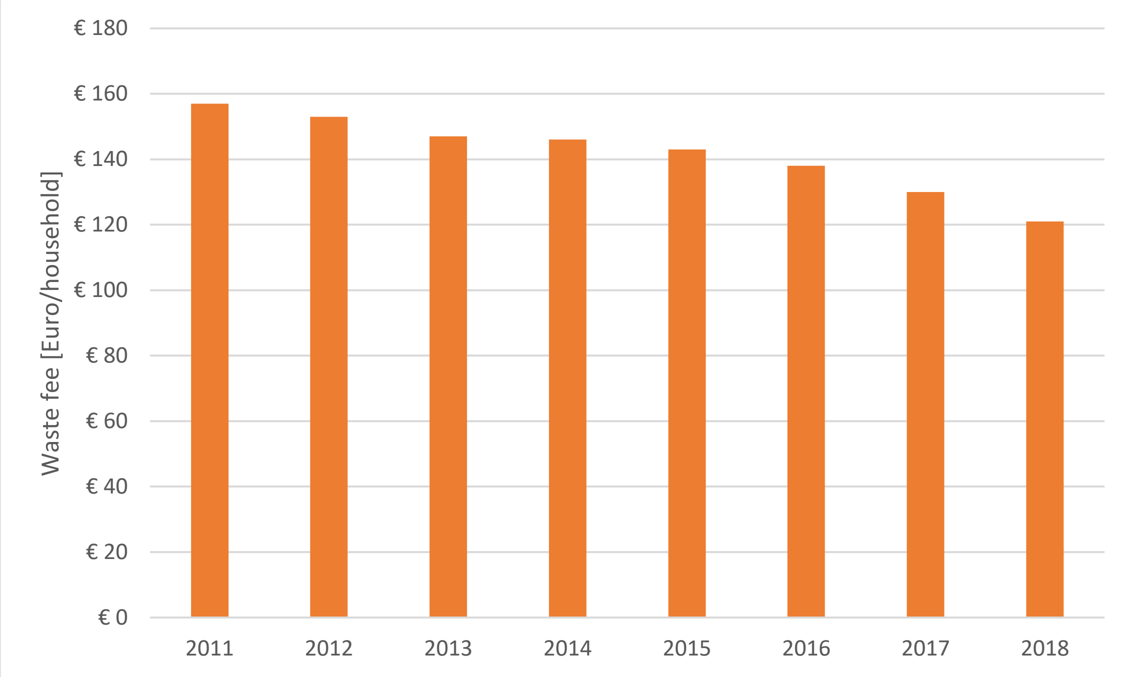


Figure 50 – Average waste fee in Tubbergen per household

In order to present a quick overview of the shifting incomes, the items below are listed as a percentage of the total revenues (% of the total revenues);

- the waste fee is decreasing from 60% in 2013 to 32% in 2022;
- the revenues form incineration decrease from 13% in 2013 to 3% in 2022;
- the EPR fee contribution increases from 26% in 2013 to 53% in 2022.

Investment: The total investment Tubbergen made was in total € 175,000, which comes down to € 8.27 per inhabitant.

Waste quantities: Tubbergen realised a drop in collected residual waste quantities of 65%, going from ca. 4,000 tonnes in 2013 to 1,003 tonnes in 2017. A corresponding increase of 24% in collected recyclable PPW waste has been found.

Operational costs: Due to less generated residual waste quantities, and more separately collected recyclable packaging waste, Tubbergen has been able to decrease the operational costs per capita for residual waste collection and processing. The operational costs for the recyclable packaging waste stream increased with ca. € 10 per inhabitant.

Evaluation	
Assessed period	2013 - 2022
Waste fee drop	16%
Investment	€ 175,000
Investment per inhabitant	€ 8,27
Drop in residual waste PPW	65%
Increase in separate collected PPW waste	24%
Drop in operational costs for residual PPW EUR/inh	€ 4,66
Increase in operational costs for separate PPW EUR/inh	-€ 10,37

Table 32 - Evaluation of Tubbergen results

4.6. COST-BENEFIT ANALYSIS RENNES

4.6.1. PROJECT DEFINITION RENNES

Rennes has been selected by the French ministery as pilot areas of the national programme on zero waste. The national waste programme set a 10% reduction of waste generated per inhabitants from 2010 to 2020. During this time Rennes reorganised their waste collection system, participated in the LIFE+ Miniwaste project to reduce biowaste, and invested largely in communication campaigns on reducing waste as well as additional containers and bringpoints.

Waste management: In Rennes, waste collection is managed by Rennes Métropole ("Direction des déchets et des réseaux d'énergie") and operated in collaboration with various subcontractors such as Sita Ouest for household and recyclable waste and Tribord for door-to-door vegetable and bulky waste. Glass waste is separately collected at bring points. Paper, newspapers and magazines from households are collected co-mingled with plastic, metal and composite packaging. Yellow bins collected door to door or bring points have been implemented for collecting those recyclables ("Multi-matériaux"). The Métropole operates 18 civic amenity sites (24,381 inhabitants per CAS). In July 2017, the list of recyclables to be included in the yellow bins or bring points was extended to all plastic packaging and small aluminium. Important communication campaigns followed this scope extension. The flowchart for the collection of PPW in Rennes is presented in shown below in Figure 51.

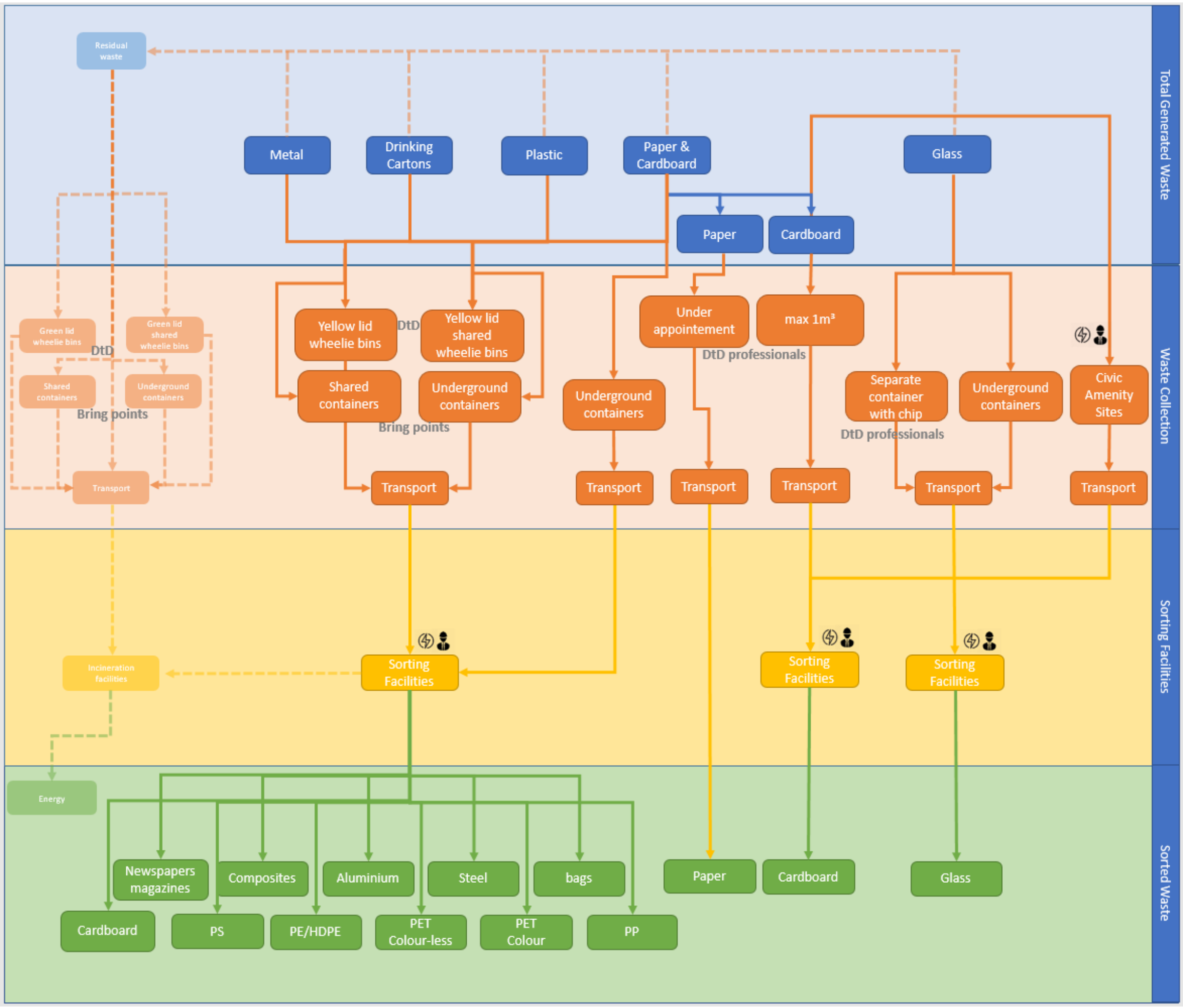


Figure 51 - Flowchart PPW Rennes

Financial responsibilities: Specific equipment investments can be done by both Rennes Metropole and the subcontractors. In 2013, Rennes Metropole invested in the acquisition of new containers, bring points and underground waste containers and construction of new waste disposal centres new equipment for treatment such as grinders and shredders. The citizen waste fee (TEOM) is collected by Rennes Metropole, as well as potential government or industry (EPR) support.

EPR scheme: CITEO (previously Eco-Emballages) is non-profit company and a collective EPR scheme for household packaging waste in France. It was the first French eco-organisation and was founded in 1992[109]. The scheme applies to all packaging consumed by households as end-users and affects all companies, producers and importers responsible for placing packaged products on the French market which then become household packaging waste. CITEO concludes contracts with municipalities, and covers 80% of the waste management costs. The figure below shows an overview of the CITEO costs.

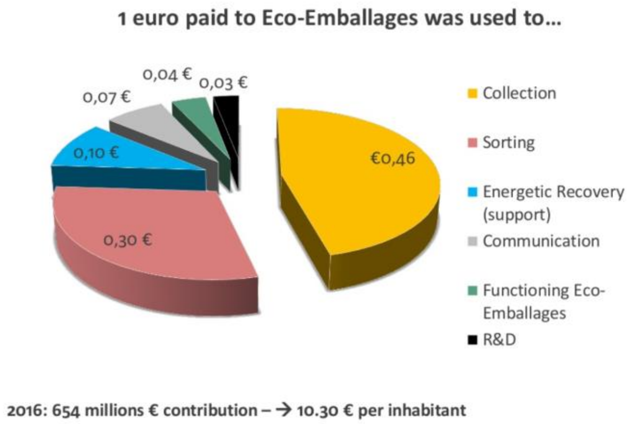


Figure 52 - Overview of CITEO costs[110]

4.6.2. IDENTIFICATION OF COSTS AND BENEFITS FOR PPW COLLECTION IN RENNES

THE INVESTMENT COSTS

For this assessment however, it was found that the Rennes Metropole already had a large waste collection infrastructure in place. The basic requirements for a well-functioning waste collection system such as containers, bring banks, civic amenity site(s), collection trucks, storage facilities and standard monitoring equipment were to a large extent already available.

It was aimed to include the additional costs required for setting up a new waste collection system (e.g. expanding bring points, communication campaigns, brochures, new smart bins, etc.) However, Rennes has already been collection the waste separately for a long time. Already in 2003, Rennes renewed the collection, sorting and management system for the waste disposal sites. In addition, separate collection was started in most peripheral municipalities. Following in 2005 Rennes defined a waste prevention policy and later in 2010 Rennes reorganized the complete collection system and launched the local waste prevention program[112]. An investment in a completely new waste system therefore is not the case. In 2013 however, Rennes Metropole did invest in new containers (bins and kiosks), voluntary contribution and bring points, the construction and compliance of waste

[109] EPR in the EU Plastics Strategy and the Circular Economy: A focus on plastic packaging, Institute for European Environmental Policy, 2017
[110] Extended Producer Responsibility: International Experiences, Cyclos 2018, https://www.slideshare.net/AgenceANGED/responsabilit-largie-du-producteur

disposal centres. These expenses are financed, with time differences, by the proceeds of the VAT compensation fund, equipment grants, and capitalized operating surplus.

It is however, important to notice that the good practice in waste collection requires base line elements to operate successfully, being a PMD + paper and cardboard sorting and recycling installation and a glass sorter and smelter. As discussed in Deliverable 2.4 of the Collectors project, this is the case for Rennes. Investment costs for these facilities are excluded as they are beyond the scope of this project.

Item	Assumption & data source	Unit cost
Containers and bins	In 2013, Rennes metropole invested in new chipped containers and bins[112].	€2,772,000
Bring points and underground containers	In 2013, Rennes metropole invested in new bring points and underground waste containers[112].	€ 1,118,000
Civic amenity sites	In 2013, Rennes metropole invested in new civic amenity sites facilities[112].	€ 1,100,000
Treatment equipment	In 2013, Rennes metropole subsidized neighbouring municipalities for investments in new treatment equipment such as grinders and shredders[112].	€ 213,000
Allocation on weight basis	These investment costs are covering all collected waste streams in Rennes, as well as some household and professional waste. Based on the total quantities in 2013[112] and 2017[111], household packaging waste is 34% of the total waste collected. Therefore 34% of the investment costs are allocated to the packaging waste streams, which comes down to a total of € 1,759,015 in 2013.	€ 1,759,015

Table 33 - Investment costs

OPERATING COSTS

The total operational costs in Rennes include costs for the infrastructure, communication, prevention, collection, transport and treatment. The operational costs of the following fractions are included:

- PMD +PC (plastics, metal, drinking cartons and paper and cardboard)
- Glass
- Packaging fraction of the residual waste

As these waste streams have different densities, mass flows and material compositions, the operational costs vary significantly. For the waste Rennes Metropole waste collection system detailed information for two years is available. The graph below shows the collected amounts combined with the costs of collection per year in euro per ton.

Overall this graph shows that the collected amounts increased slightly, which is caused by an increase in all three waste streams. A drop can be noted in the operational costs for residual waste; however, it seems this cannot directly be linked to the collected quantities. For both glass and PMD + paper and cardboard the operational costs increased, together with the collected amounts.

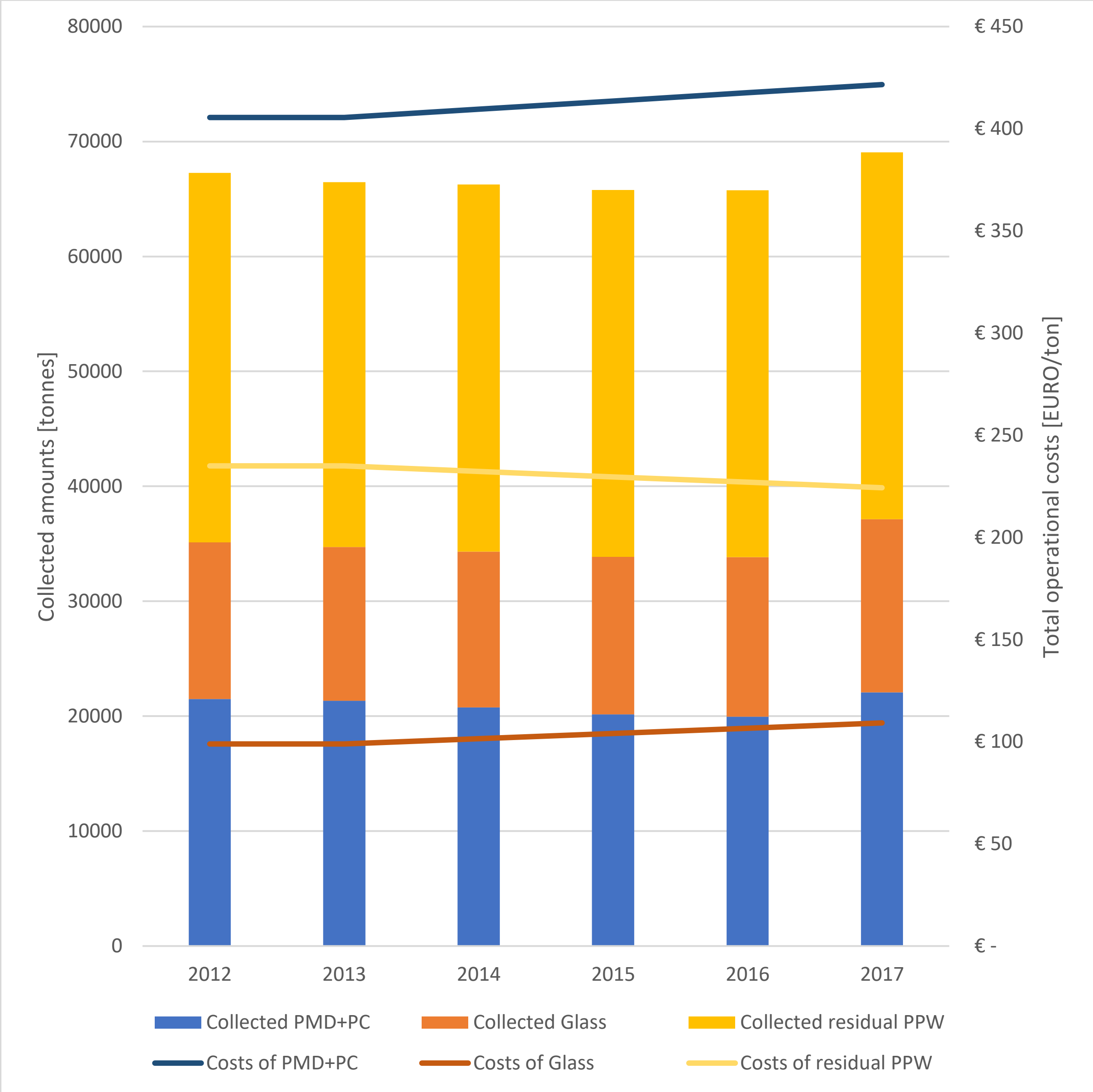


Figure 53 – Overview of collected amount and operational costs

The table below gives an overview of the assumptions and data sources.

Item	Assumption & data source	Unit cost
Total operational costs for plastic, metal, paper and cardboard packaging collection and processing	The total operational costs for the infrastructure, communication, prevention, collection, transport and treatment of lightweight packaging, metal, paper and cardboard waste is € 421.60 per ton in 2017. The largest elements of these costs are the collection costs, at € 247.50 per ton, and the treatment costs at € 146.30 per ton[111].	421.60 €/ton

[111] Rapport 2017 Sur Le Prix Et La Qualité Du Service Public De Prévention Et De Gestion Des Déchets, Metropole Rennes, 2017

	In addition, the total operational costs for 2013 are known[112]. These costs are included as well. For the other years, a linear trend is assumed.	
	In 2017, the Rennes metropole collected 21,609 tonnes of lightweight packaging material from households[111]. 18,871 tonnes is collected door-to-door, and 2,738 ton using bring points.	
Total operational costs for glass collection and processing	The total operational costs for the infrastructure, communication, prevention, collection, transport and treatment of glass waste is € 109.20 per ton in 2017[111]. The largest element of these costs are the collection costs, at € 100.80 per ton. In addition, the total operational costs for 2013 are known[112]. These costs are included as well. For the other years, a linear trend is assumed.	109.20 €/ton
	In 2017, the Rennes metropole collected 32 kg/inhabitant, or 15,602 tonnes of glass from households at 438.865 inhabitants[111]; 634 ton is collected door to door and 14,428 tonnes using bring points.	
Total operational costs residual waste collection and processing	The total operational costs for the infrastructure, communication, prevention, collection, transport and treatment of residual waste is € 224.30 per ton in 2017[111]. The largest elements of these costs are the collection costs, at € 106.10 per ton and the treatment costs at € 97 per ton. In addition, the total operational costs for 2013 are known[112]. These costs are included as well. For the other years, a linear trend is assumed.	224.30 €/ton
	Based on the sorting analysis of the household waste, only 37.80% of the household waste is from the packaging waste streams.	
	In 2017, the Rennes metropole collected a total of 84,430 tonnes of residual waste[111]; 69.286 tonnes is collected door to door and 15,148 tonnes using bring points. Of this amount 31,916 tonnes is residual packaging waste (37.80% of the residual waste is packaging waste[38]).	
Street cleaning	It is assumed the operational cost for street cleaning are already included in the above-mentioned costs.	-
Incineration tax	France has an environmental tax in place on landfilling and incinerating residual waste[113], EUR 7/t in 2009 to EUR 14/t in 2015. However, incineration with energy recovery and high energy efficiency are subject to a tax break (EUR 1.5/t in 2009 to EUR 3/t in 2015). It is worth noting that more than 90 % of all operators' subject to the landfill tax and incineration tax benefit from a tax break, potentially reducing the strength of these instruments[114]. Therefore an average tax of 11 € per ton is assumed.	11 €/ton
	All residual household waste is incinerated[111].	
Opportunity cost residual waste recycling	The missed opportunity costs by diverting plastic, paper and cardboard waste from incineration are assumed to be € 44 per ton[111]. On average, Rennes received € 44 per ton of residual waste sent to recycling.	44 €/ton
	The glass and metal waste fraction from the separately collected waste is assumed to be excluded, as well as the fraction that is sent to incineration after sorting (16.2%)[111].	

Table 34 - Assumptions and data for operational costs PPW Rennes

[112] Rapport annual 2013 sur le prix et la qualité du service public d'élimination des déchets, Metropole Rennes, 2013

[113] Database on Policy Instruments for the Environment, https://pinedatabase.oecd.org/

[114] Municipal waste management in France, European Environment Agency, 2013

REVENUES

The following financial revenues are identified for the Rennes waste collection system:

- Citizen waste tax
- Materials sold to recycling. For packaging waste material sold to recycling, French local authorities have access to various possibility: either decide where and to who they sell them, contract with material federation, or get the EPR standard price and entrust them with the sales. From the available information, it is unclear which exact option Rennes Metropole opts for.
- Government and industry support; no specific information on the France EPR fees for Rennes is available, only the total price received for material sold to third (recycling) parties. In addition, data on government and industry support is available, which is assumed to include EPR fees (industry support).
- Waste prevention fee ADEME. ADEME is active in the implementation of public policy in the areas of the environment, energy and sustainable development. ADEME provides expertise and advisory services to businesses, local authorities and communities, government bodies and the public at large, to enable them to establish and consolidate their environmental action. As part of this work the agency helps finance projects, from research to implementation, in its areas of action.
- Tax compensation

In the table below the assumptions and data sources for the revenues are stated.

Item	Assumption & data source	Unit cost
Waste fees	The waste tax for citizens (TEOM) in Rennes is based on the property value. These are difficult to calculate, and often combined with other local tax rates. For Rennes, the TEOM is known per waste stream for both 2013 and 2017. The total waste fee in 2017 was € 61.61 per inhabitant. Specifically for lightweight packaging, paper and cardboard, glass and residual waste the fee combined was € 44.50 per inhabitant[111]. For 2013, the waste fee distribution is also known[112]. For the other years, the waste fee is assumed to be a linear trend.	44.50 €/inh
Lightweight packaging, paper and cardboard sold to recycling	In 2017, Rennes received € 95.40 per ton from materials sent to recycling[111]. For 2013 also data is known[112]. For the other years, a linear trend is assumed.	95.40 €/ton
Glass materials sent to recycling	In 2017, Rennes received € 22.50 per ton from glass materials sent to recycling[111]. For 2013 also data is known[112]. For the other years, a linear trend is assumed.	22.50 €/ton
Residual waste materials sent to recycling	In 2017, Rennes received € 44.50 per ton from residual waste sent retrieved from recycling[111]. This is mainly from materials used for road construction (20,000+ tonnes) and retrieving metals (450 tonnes of ferrous metal, and 420 tonnes of non-ferrous metals were valued). For 2013 also data is known[112]. For the other years, a linear trend is assumed.	44 €/ton
Government and industry (EPR) support	On 25 November 2009, Rennes Métropole signed one of first local waste prevention programs with the Agency for the Environment and Energy Management (ADEME).The initiative ran for five years, from 2010 to 2014, with the goal to reduce the annual production of household waste per capita with 7%, from 319 kg to 296 kg. Successful implementation of measures could count on financial support from ADEME of more than 400,000 €/year[112].	5,640,219 €/y
	The total amount of industry support received in 2017 varies per waste stream; € 223.60/ton of lightweight packaging material, € 7.80 per ton of glass, and €6.00 per ton of residual waste[111]. Taking the tonnages into account, this comes to a total of € 5,455,836 in 2017.	

	The total amount of subsidies received in 2017 varies per waste stream; € 0.90/ton of lightweight packaging material, € 0.30 per ton of glass, and € 1.90 per ton of residual waste[111]. Taking the tonnages into account, this comes to a total of € 184,383 in 2017.	
	Combining these amounts to a total of € 5,640,219. For 2013 similar data is known[111]. For the other years, a linear trend is assumed.	
Redevance Speciale	Rennes metropole also takes charge of the waste collection of professional or non-household waste. Companies or private parties have to pay the 'redevance speciale' fee, which Rennes uses as a revenue to complement their financial model. In 2013, this fee was € 12.90 per ton of residual waste, in 2017 this decreased to € 8.10 per ton[111].	8.10 €/ton
Incineration benefits	It is assumed Rennes does not benefit directly from incineration revenues, as they sell the material to third parties for processing, recycling or incineration (see above).	-

Table 35 - Assumptions and data on the revenues from PPW collection in Rennes

4.6.3. CBA RESULTS RENNES

For Rennes, the total costs and revenues between the period 2012 to 2021 are presented. In the graphs below the results can be seen. The operating costs show a downwards trend from 2012 to 2016, mostly caused by the decrease in collected quantities. Due to the increased amount of collected quantities in 2017, the costs also increased.

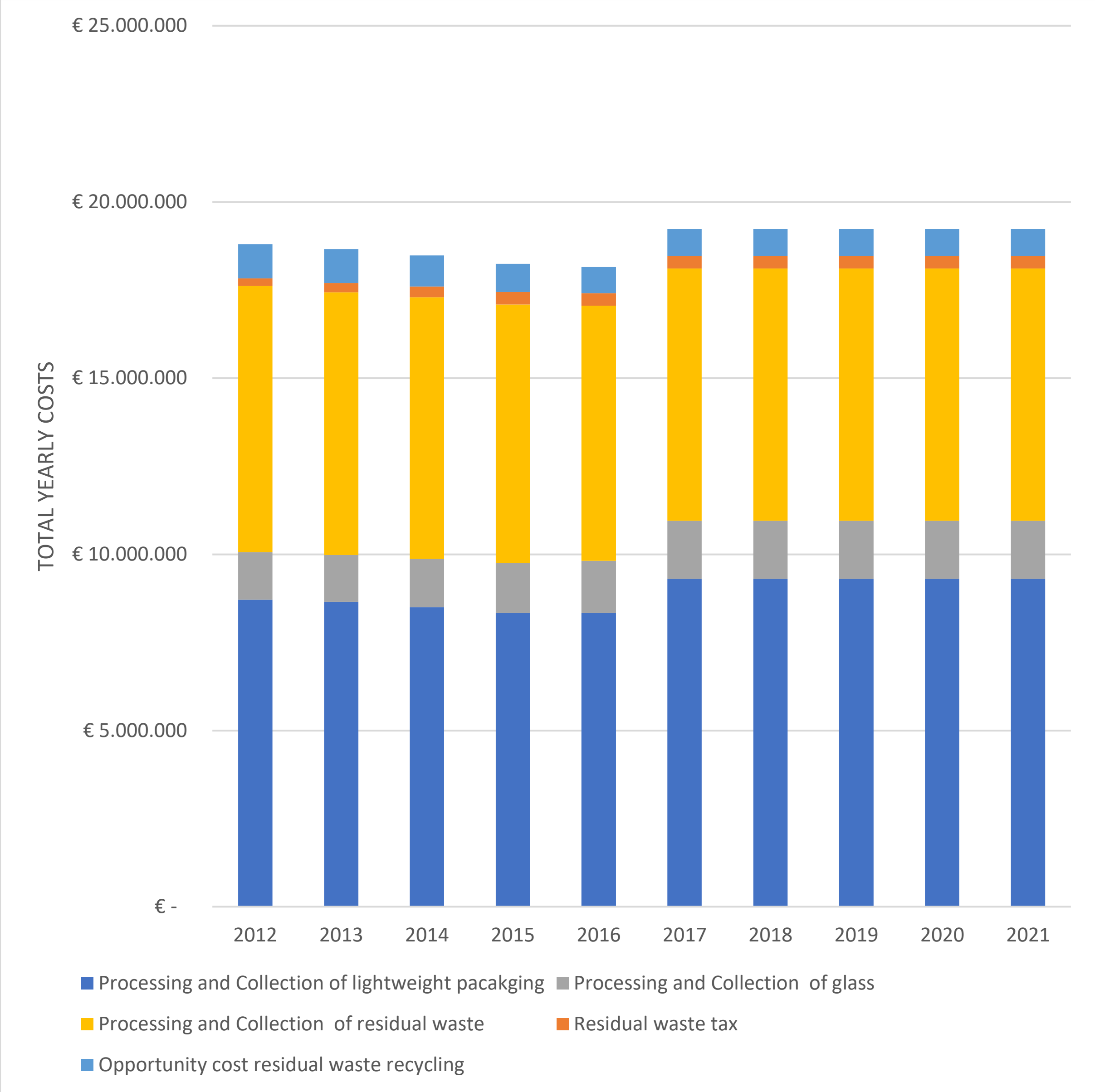


Figure 54 – Overview of total costs per year for Rennes

The graph with revenues shows that the citizen waste tax is by far the largest income, making up 52% of the total revenues. The benefits from government support are also significant, making up 21% of the total income.

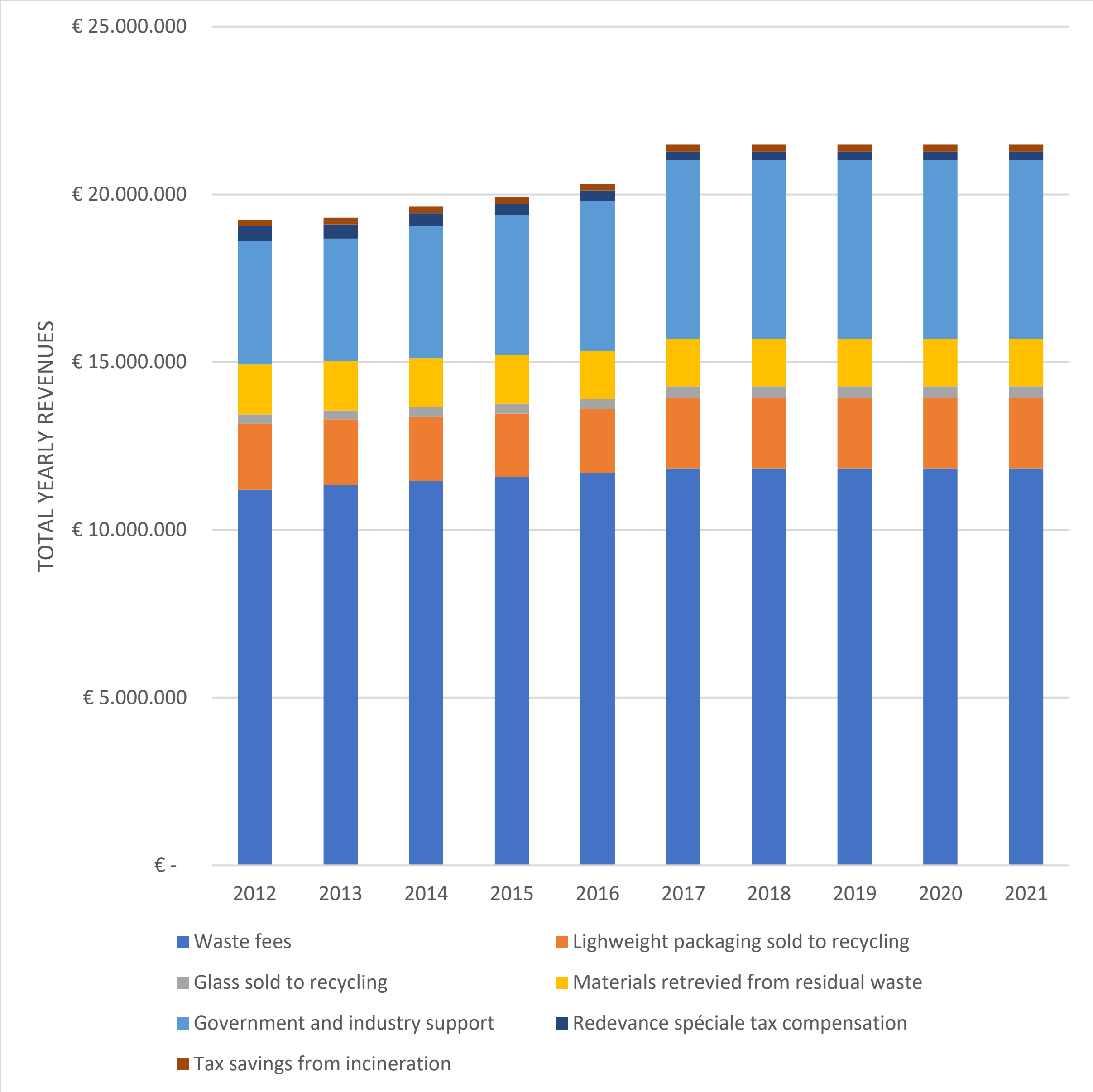


Figure 55 – Overview of total revenues per year for Rennes

In Figure 56 both the total costs and benefits are plotted, together with the Financial Net Present Value (FNPV). The FNPV is calculated taking into account a discount rate of 4%, and subtracting all costs from all benefits for every year. The first year is taken as the 'present year', as it is assumed this is the year the investment decision for the new waste collection system is made. This final overview of all costs, benefits and the financial net present value shows that the investment and operational costs are in balance with the assessed revenues, as the FNPV is slightly positive.

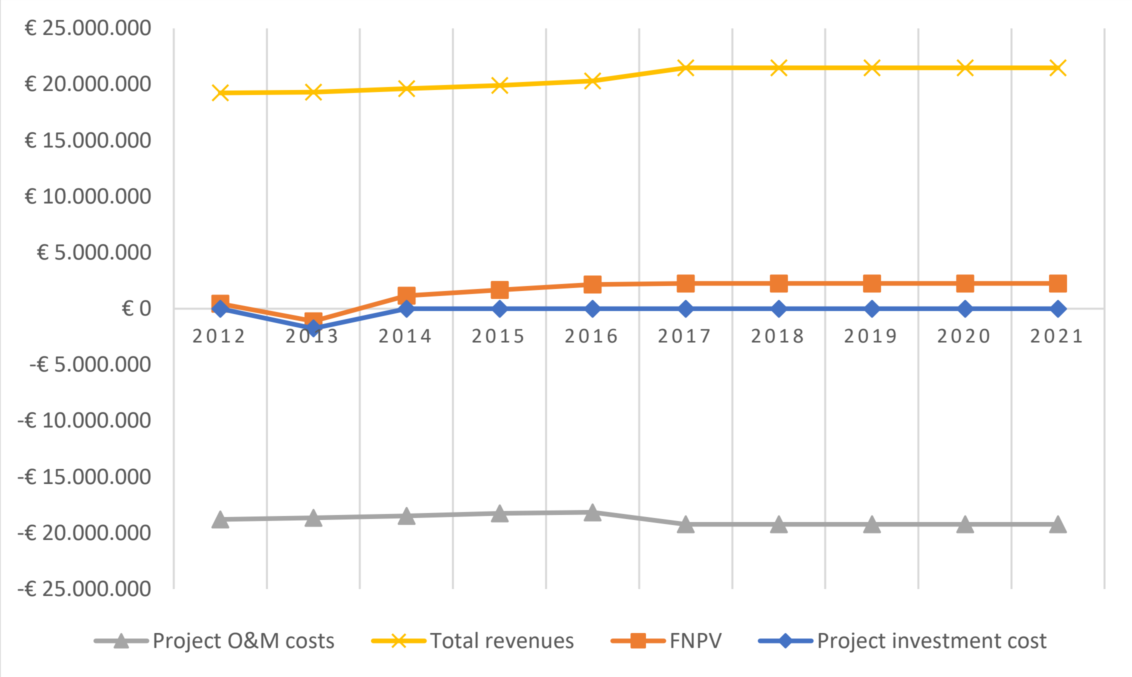


Figure 56 – Overview of costs, benefits and FNPV for Rennes

4.6.4. SENSITIVITY ANALYSIS

In order to highlight uncertainties in the data, a sensitivity analysis has been performed on the total operational costs and the material prices. As discussed above, no specific information on the Rennes EPR fees is available, therefore, this element is excluded from the sensitivity assessment.

In the table below the scenarios are drafted, and the effects on the FNPV and B/C ratio is shown.

Scenario	FNPV	Delta FNPV	B/C ratio	Delta B/C
Standard scenario	€ 12,339,982	-	1.092	-
Decrease of 10% in operational costs	€ 17,743,603	43.8%	1.136	4.0%
Increase of 10% in material prices	€ 13,488,467	9.3%	1.100	0.7%
Increase of 10% in EPR fees	€ 13,930,387	12.9%	1.103	1.0%
Increase in capture rate	€ 9,100,238	-26.3%	1.060	-2.9%

Table 36 - Sensitivity analysis of Rennes results

It can be concluded that the operational have the largest effect on the results, for every 1% decrease in the operational costs, the FNPV goes up with 4.4% and the benefit/cost ratio goes up with 0.4%. The increase in material prices and EPR fees have a significant effect as well. Increasing the capture rate to a 100%, has a negative effect on the FNPV, however maintains positive.

4.6.5. EVALUATION & CONCLUSIONS

Overall, looking at the benefits it can be concluded that an average of 57% of these are coming from the citizen waste fee; 23% comes from government and industry (EPR) support; and 18% comes from materials sold to recycling. The rest is coming from tax savings from not incinerating waste.

Waste fee: As can be seen in the graph below, Rennes managed to keep a stable and slowly decreasing waste fee for its citizens. Comparing the waste fee in 2011 and 2017, we see a drop of 4%. Looking at the total costs and benefits figures, we see that the costs have more or less stabilized over the years, whereas the benefits have been slowly increasing which is largely due to more government and industry support.

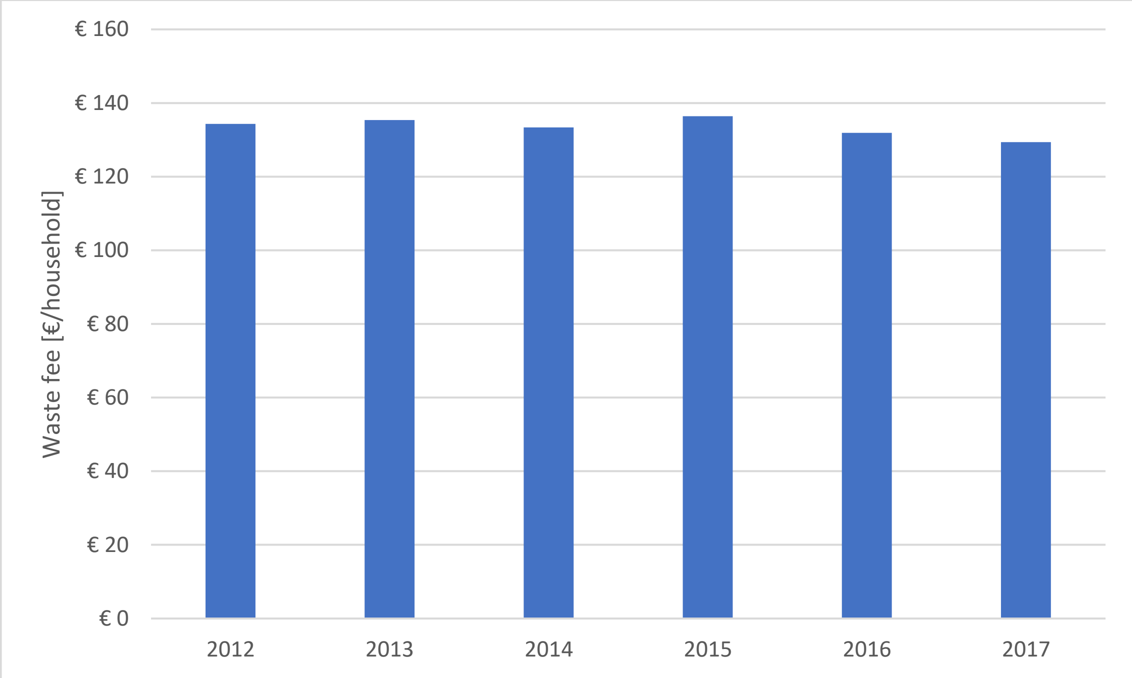


Figure 57 – Average waste fee in Rennes per household

In order to present a quick overview of the shifting incomes, the items below are listed as a percentage of the total revenues (% of the total revenues);

- the waste fee is decreasing from 58% in 2012 to 55% in 2021;
- the revenues from recovered materials are fairly stable and only decrease from 19% in 2012 to 18% in 2021;
- the government and industry support increases from 19% in 2012 to 25% in 2021.

Investment: The total investment Rennes made was in total € 1.76 million, which comes down to € 4.20 per inhabitant.

Waste quantities: Rennes Metropole realised a drop in collected residual waste quantities of 1%, and a corresponding increase of 6% in collected recyclable packaging waste has been found.

Operational costs: Due to less generated residual waste quantities, and more separately collected recyclable packaging waste, Rennes has been able to decrease the operational costs per capita for residual waste collection and processing with € 1.52 per inhabitant. The operational costs for the recyclable packaging waste stream increased with ca. € 1.11 per inhabitant.

Evaluation	
Assessed period	2012 - 2021
Waste fee drop	4%
Investment	€ 1,759,015
Investment per inhabitant	€ 4,20
Drop in residual waste PPW	1%
Increase in separate collected PPW waste	6%
Drop in operational costs for residual PPW EUR/inh	€ 1,52
Increase in operational costs for separate PPW EUR/inh	€ 1,11

Table 37 - Evaluation of Rennes results

4.7. CONCLUSIONS ON THE PPW STUDY

In this final paragraph the case results will be compared amongst each other. As indicated earlier in the report, the comparability of the cases is limited (see also Chapter 3.2). Below a comparison of the collection and processing costs; the waste fees; the producer fees and the financial good practices will be given.

COLLECTION AND PROCESSING COSTS

The costs for waste collection are in all five cases a significant part of the operational costs; ranging from 40% of total costs for Tubbergen, to 65% of total costs for Parma. Figure 58 below shows the collection and processing costs in Euro per ton of collected material. For each case similar trends can be seen;

- Collection of PMD materials is most expensive per unit of mass, which could be related to the high volume and the fact the waste stream cannot be compressed due to the necessity of post-separation;
- Both paper and cardboard and glass collection is fairly cheap per unit of mass, in all cases cheaper than collection of residual waste.

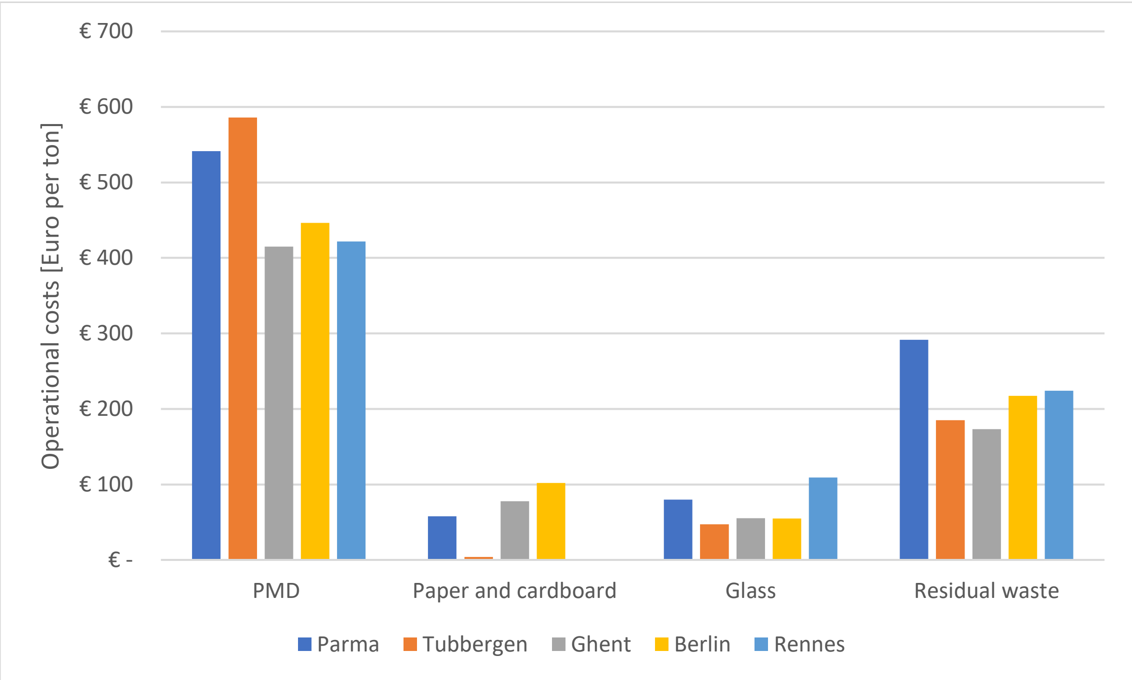


Figure 58 – Comparison of collection and processing costs per ton of collected material

The operational costs per unit of mass indicate to some extent the operational efficiency of the waste collection system, since e.g. less and more efficient pickup rounds could lead to lower costs per ton collected waste. The costs can also reflect the local context (e.g. the population density, the remoteness of equipment, traffic, remote/scattered housing, etc.).

Often however, the operational costs are expressed in Euro per inhabitant. Taking into account the mass flows of the waste streams, the absolute costs per capita can be expressed. Since the residual waste flow is in almost all cases still the largest in mass and e.g. PMD has a relatively low density, this translates into a different cost overview. NB: Here only the packaging part of the residual waste stream has been taken into account, excluding a significant part of the residual waste.

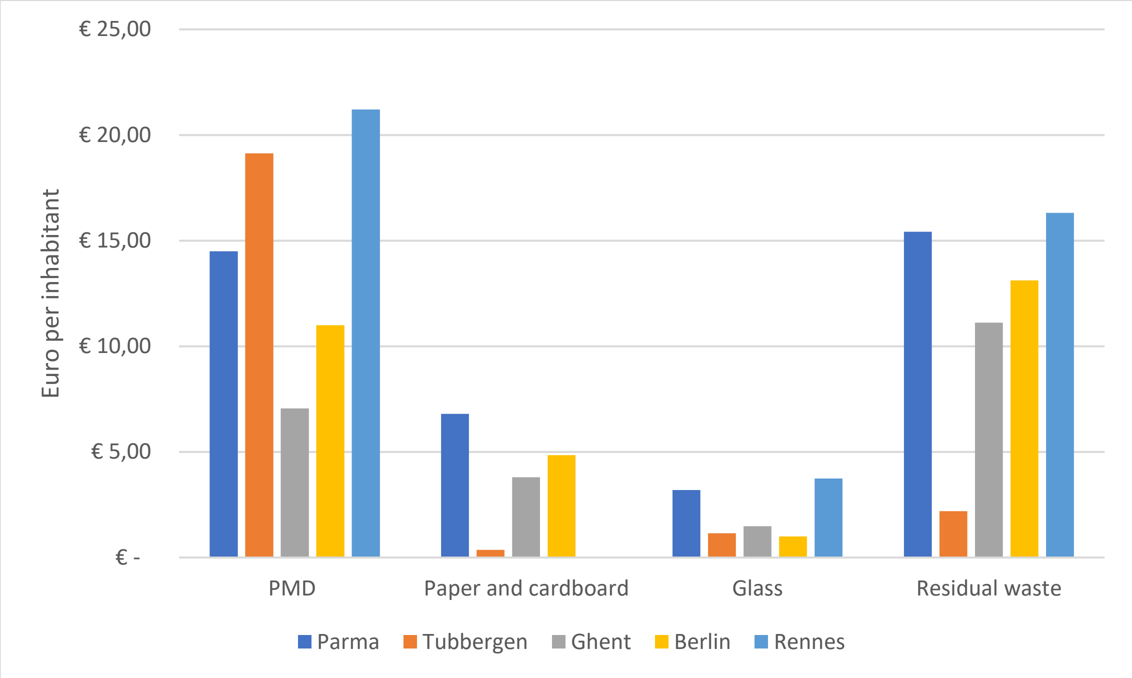


Figure 59 – Comparison of collection and processing costs per inhabitant

The figure presents similar trends, showing again that PMD and residual waste are the most expensive to collect. The difference between PMD and residual waste however, decreased significantly. For Parma, Ghent and Berlin collection of residual waste appears to be more expensive than collection of PMD (expressed in Euros per inhabitant). Between the five cases, overall different costs per inhabitant can be seen. This could relate to a number of elements, and perhaps the regional characteristics of the cases (large dense capital city, small rural village, etc.) could explain these differences. Also, the scale of economies available to a large city such as Berlin, but not to Tubbergen, could partly explain the difference in the operational costs for PMD. For other waste streams, this however does not show.

It is not possible to derive a summary of the costs per collection method from the case studies, as most cases use a combination of collection methods for different neighbourhoods and this data is not available or monitored. To provide some insight in this, the table below presents a detailed overview of four different collection methods in the Netherlands for 2014, reflecting the average collection costs in Euro per ton. These costs are largely in line with the operational costs presented for the five cases, but it must be noted that the numbers in Figure 58 also include the processing costs.

	Residual waste	**Paper and cardboard**	**PMD**	**Glass**
Dtd minicontainer	€ 65	€ 103	€ 316	€ 163
Combined duo bin	€ 62	€ 91	€ 468	€ -
Kurbside bags	€ 116	€ 85	€ 453	€ -
Bringbank	€ 144	€ 130	€ 383	€ 64
Average	*€ 79*	*€ 85*	*€ 370*	*€ 63*

Table 38 - Overview of collection costs in Euro per ton for different collection methods[115]

WASTE FEE

[115] NVRD, benchmark household waste in NL, 2014

As discussed in the paragraphs above, for all cases it can be seen that a significant part of the operational costs is covered by the waste fee paid by the citizens. The table below shows the average total waste fees over the last six years and the contribution of the waste fee to the total revenues.

Case	Average waste total fee [€/inhabitant]	Waste fee part of total revenues [%]
Parma	250	54%
Ghent	61	23%
Berlin	126	38%
Tubbergen	140	42%
Rennes	133	57%

Table 39 - Overview of average waste fees and contribution to the total revenues

From these numbers, Ghent has a remarkably low waste fee compared to the other cases. Rennes has the highest waste fee, with 57% of the revenues coming from the citizen waste fee. Rennes is followed by Parma, who however, is still below the national Italian average. The separate PAYT-based waste collection system in Ghent already has been operational for almost 20 years. Where the other four cases are still reducing their waste fees, Ghent has had a stable waste fee over the last years, and therefore serves as a good example of the positive financial viability of a separate PAYT-based waste collection system.

As discussed in the case evaluation paragraphs all cases follow more or less the same cost and revenue items, however, the waste fee varies due to the differences in EPR contributions, material revenues, tax incentives or potential cost optimisations (e.g. more efficient collection routes).

EPR FEES

Extended Producer Responsibility fees provide funding for the collection and recycling of packaging. Packaging producers pay a fee per kg or ton of packaging put on the market to a collective organisation, who then reimburses the costs incurred for collection and recycling. Various EPR models are currently operational in the studied countries; PRO's in the hands of obliged industry, Dual model, Shared model, vertically integrated systems, etc[116]. In Germany for instance, the Dual System scheme is responsible for the collection up until recycling. This broad scope of responsibility therefore comes with a higher EPR fee, as the PRO also needs to cover more costs. In most cases the responsibility is shared between industry and the local authorities based on common agreements regarding collection. Municipalities are responsible for collection, and often for sorting of packaging waste, arising on the municipal level, and receive financial compensation for this.

The table below shows the average contribution of the EPR fees as a percentage of the total revenues. In all cases the contribution from the packaging industry make up a significant portion of the total revenues, with Tubbergen and Berlin showing the highest contribution of 40% and 52% respectively.

Case	EPR fee/ of total revenues
Parma	10 %
Ghent	22 %
Berlin	52 %
Tubbergen	40 %
Rennes	23 %

Table 40 - Overview of producer fees as part of total revenues

[116] Extended Producer Responsibility at a glance, EXPRA, 2016
http://www.expra.eu/uploads/downloads/EXPRA%20EPR%20Paper_March_2016.pdf

The EPR fees prove a crucial incentive for local authorities to steer towards more separate waste collection. The newly implemented extended producer responsibility requirements, making extended producer responsibility scheme mandatory for all packaging by 2025, should result in better performance in waste collection and recycling[117]. The cases studied in this report endorse the crucial role of the EPR schemes. It is important to note here, that the cases have been able to introduce and maintain their separate waste collection system based upon the high (plastic) packaging producer fees. As shown for the Netherlands and Belgium the packaging fees for plastic and beverage cartons have increased significantly over the last years. A similar trend is seen in Italy.

Finally, it should be mentioned that some PRO's (e.g. CONAI in Italy and Afvalfonds in The Netherlands) have started to link their tariffs to the recyclability of the packaging put on the market, demanding higher prices for packaging that is not yet recyclable and lower prices for packaging that is easily sorted and recycled. This in turn could bring consequences for the financial overview, lowering the revenue from EPR fees and increasing the revenue from recovered materials.

OVERALL SHIFT IN REVENUES

Analysing the case specific revenue structure in more detail, various trends can be seen. In Table 41 below the change in revenue profile of all case has been presented. The table shows the contribution to the total revenue profile for the waste fee, the recovered materials, the EPR fees and incineration revenues. The first cell shows that for Parma, in the first year the waste fee made up 56% of all revenues, whereas in the final year this decreased to 49%.

In all cases the waste fee decreased, as well as the incineration revenues. In all cases this is compensated by a sharp increase in recovered material revenues and EPR fees.

Case	Waste fee [%]	Recovered materials [%]	EPR fees [%]	Incineration revenues [%]
Parma	56 → 49	18 → 26	8 → 12	16 → 6
Ghent	26 → 21	30 → 24	15 → 30	26 → 21
Berlin	-	-	47 → 52	14 → 10
Tubbergen	60 → 32	-	26 → 53	13 → 3
Rennes	58→ 55	19 → 18	19 → 25	-

Table 41 - Overview of revenue shifts shown as percentage of total revenue in first year and last year of project period[118]

FINANCIAL GOOD PRACTICES

Concluding, it is found that all good practices have similar financial schemes and levers in place to stimulate the separate collection of paper and packaging waste. The table below summarizes the most important external financial levers promoting separate waste collection systems; landfill bans, landfill and incineration taxes, and EPR schemes. Expect for Parma, all cases have a landfill ban on combustible or separately collected waste, and all cases expect Berlin have a landfill tax, ranging between 15 € per ton in Parma to 101.91 € per ton for landfilling combustible waste in Ghent. Expect for Berlin, all cases also have an incineration tax. Both in Belgium and in the Netherlands the incineration tax has been increasing over the last years, diverting more and more waste from incineration. Lastly, all countries have extended producer responsibility schemes, which is an important final incentive for high quality separate waste collection.

[117] New waste rules will make EU global front-runner in waste management and recycling, EC, 2018
[118] Only the (rounded) major revenue items are included in the table and do therefore not add up to 100%

	Parma	Ghent	Berlin	Tubbergen	Rennes
Landfill ban	✗	✓	✓	✓	✓
Landfill tax	✓	✓	✗	✓	✓
Incineration tax	✓	✓	✗	✓	✓
EPR scheme	✓	✓	✓	✓	✓

Table 42 - Overview of good practice financial incentives per case

That said, in addition to the available national tools, the ambition of the local government seems to play an equally important role in implementing better performing waste collection systems. As discussed in Parma, Ghent and Tubbergen the progressive local authorities have been taking additional measures to realise more and better waste collection. The financial incentives however, are a crucial foundation, without which the separate collection systems as identified in this report cannot exist.

5. WASTE ELECTRICAL & ELECTRONIC EQUIPMENT

5.1. PROJECT AND REFERENCE CASE

5.1.1. PROJECT RATIONALE

Waste electrical and electronic equipment (WEEE) poses a risk to the environment due to the presence of hazardous components, however, if recycled it has the potential to provide a source of important secondary raw materials, such as precious metals and other highly valuable materials. Due to the dependency of Europe on imports of materials, a high collection and recycling rate of electrical appliances has been given an increased focus. Since the introduction of the first WEEE Directive 2002/96/EC in 2003 in the European Union, legislation demanded a separate waste management system for that particular waste stream.

Based on the polluter-pays-principle and product stewardship, producers are obliged to finance waste collection, treatment, recovery and sound disposal[119] – the so-called WEEE costs. The WEEE-directive implemented the producer responsibility principle, which states that producers (importers, retailers, manufacturers, exporters) of electrical appliances (EEE) are financially responsible for at least the collection of disposed equipment to the recycling points. The “Producer Responsibility” principle obligates producers (importers, producers, retailers) to be financially responsible at least for the transport of WEEE from the communal collection points to the (pre-)treatment facilities.

Following the introduced principles, the new Directive 2012/19/EU brought forth in 2012 opened the scope of the Directive from the original 10 into 6 categories in which collected quantities are to be reported:

1. Temperature exchange equipment
2. Screens and Monitors
3. Lamps
4. Large equipment
5. Small equipment
6. Small IT and telecommunications equipment

Since 2006 countries have been obligated to fulfil a collection quota or otherwise risk being penalised for non-compliance. By 2016, this necessary quota was to be at least 45% of the average EEE put on the market in the three preceding years. The latest directive (art. 7) obliged countries to have a collection rate of 85% of the WEEE generated or 65 % of the average weight of EEE placed on the market in the three preceding years in the Member State. This target is to be reached by the year 2019. Despite countries not reaching those targets in 2017, it is unclear as to what extent the penalties are actually being imposed.

Currently, collection rates in the EU range from below 20% in Malta to over 90% in Croatia in 2016[120], however, the good practice elements are often very local successes. The figure below shows the collection data from 2016, and the 2019 target of 65%.

[119] Collection meaning: collection of WEEE from private households that has been deposited at collection facilities (art.12 of WEEE Directive)
[120] Eurostat, Waste statistics - electrical and electronic equipment, 2019

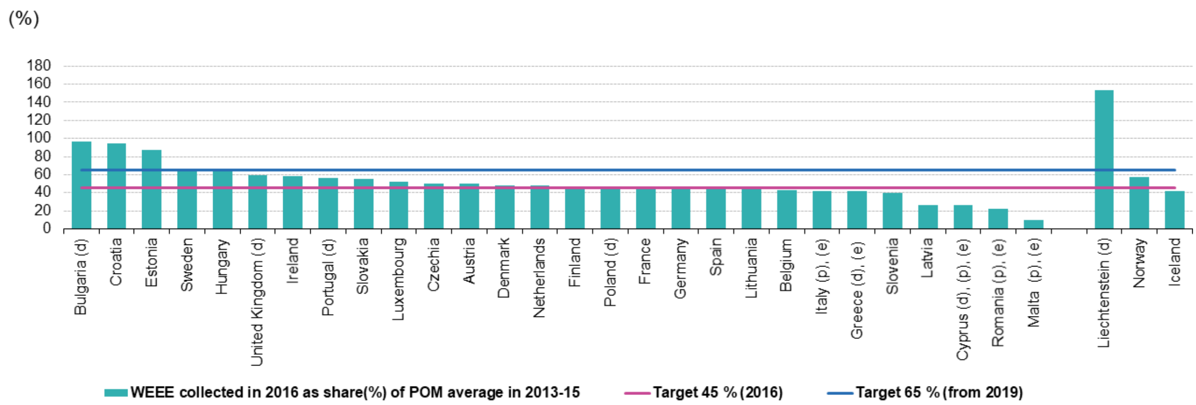


Figure 60 - Rate of total collection for WEEE in 2016 in relation to the average weight of EEE POM 2013-2015 percentage[120]

Different countries have had very disparate successes in implementing a functioning collection system. The Collectors project seeks to gather information from different regions with above average rates for the selected WEEE categories, and analyse them in order to serve as a reference case. The five case studies all face various (local) challenges and have come up with solutions to increase their WEEE collection. The most vital and shared challenges are;

Hoarding: Hoarding refers to the long-term storage of equipment. This challenge is especially the case for old small appliances including IT. Rising awareness for sensitive data on mobile phones, hard drives or cameras can decrease the threshold to bring appliances to the collection points.

Improper disposal: A certain amount of WEEE, due to lack of knowledge or other factors, is still conveniently disposed of through the mixed residual waste collection system and then landfilled or incinerated. This obviously affects smaller household appliances and IT products more than bigger equipment.

Illegal waste streams: Especially equipment which is financially interesting for scrap- and parts-dealers have a high risk of ending up illegally managed. Such include large household appliances containing a lot of metal, motors and cables. Small IT is becoming increasingly interesting due to PCB boards that can be sold separately for their precious metals. It is estimated that in 2016 a total of € 120 million euros of small household and IT appliances was lost due to scavenging (circa € 1,480 per ton) [121], based on material value. Illegal export to avoid high disposal and de-pollution costs of, for example displays, can also be a driver.

As can be seen in the breakdown overview below from the ProSUM project[122], for almost all EU countries there is a significant gap in the documented WEEE streams, ranging over 50% for some countries. Unreported flows listed above are assumed to be largely responsible for these gaps.

[121] United Nations University, WEEE Recycling Economics – the shortcomings of the current business model, 2018

[122] http://www.urbanmineplatform.eu/wasteflows/eee/percentage

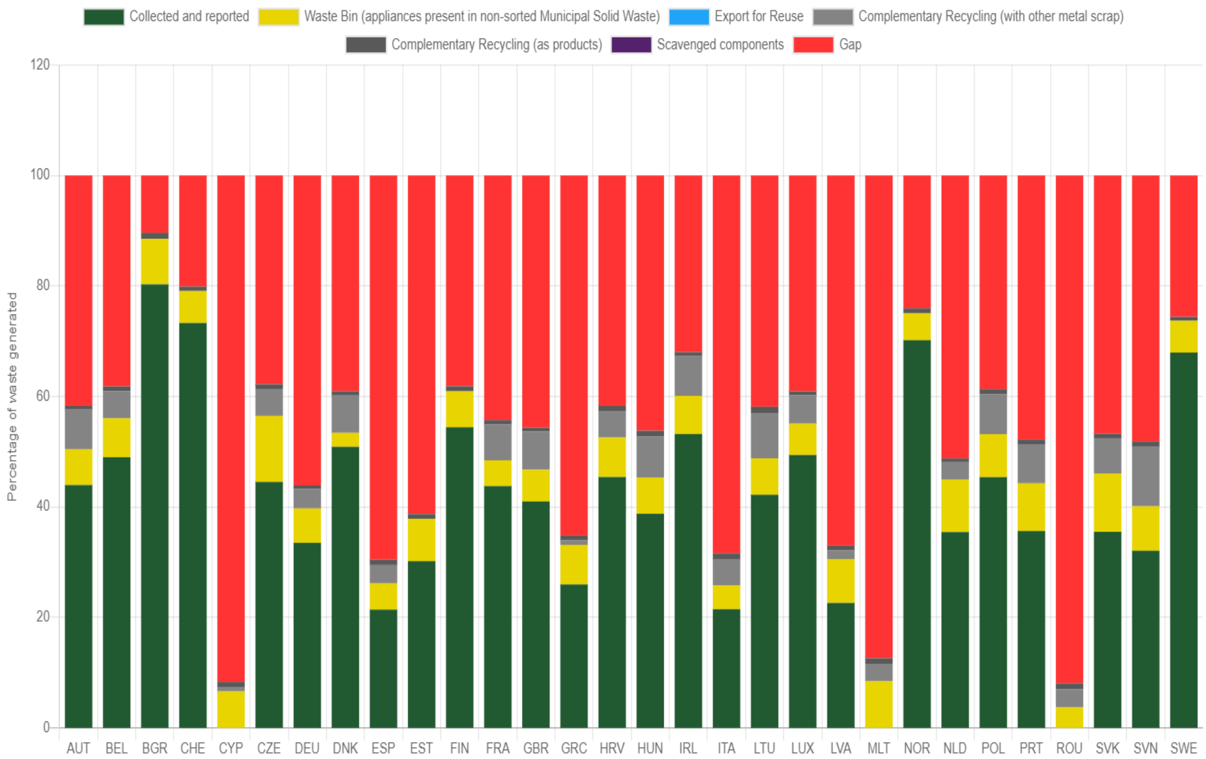


Figure 61 - Breakdown per country of collected EEE waste (Urban Mine platform, 2015)

SCOPE

Due to its increasing potential for recovery of valuable materials and their rapid increase in numbers, this report focusses on the following categories: Lamps, Small equipment and Small IT and telecommunications equipment (henceforth: small IT). As all WEEE-categories face their specific challenges, these categories were chosen due to their similar challenges. The three categories can be characterized by their small size, which makes it easy to dispose e.g. a lamp, cable, or an old mobile phone in the residual waste. In addition, it is known that many Small and IT appliances are kept at home or exit countries via illegal export routes.

As crucial player in financing proper WEEE collection and treatment, the PRO has been chosen as main focus in the CBA. Usually funded by EEE producers, who in turn add additional costs when selling appliances, the PRO collects, organises and divides financial compensation for logistic and treatment purposes. This means, that in the price of purchasing electronic equipment, the costs of collection, transport, recovery and proper disposal are already included. Figure 62 gives an overview of a price structure of products subject to EPR (the proportions do not necessarily represent the ratio of the costs).

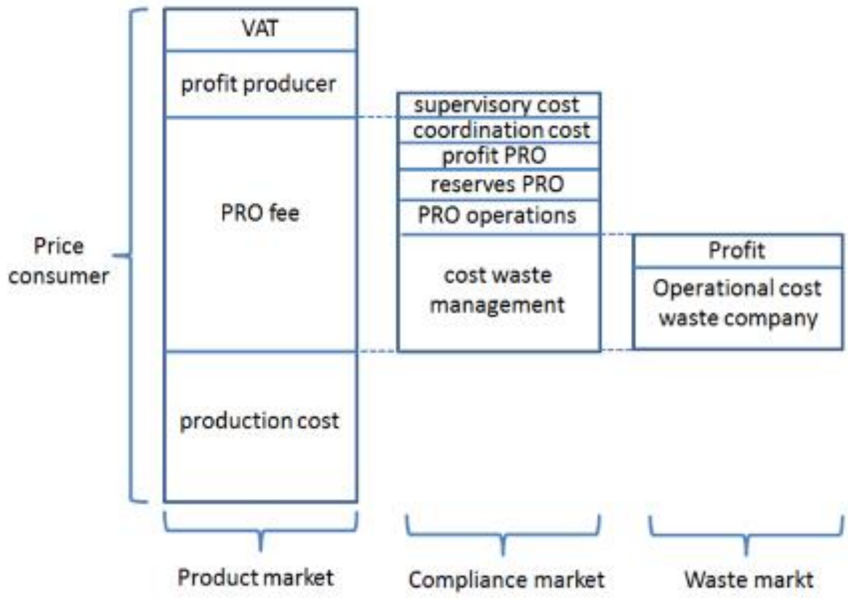


Figure 62 – Price structure of products subject to EPR[123]

Often, PRO's operate on a national level. In the five case studies however, the WEEE collection within a certain region has been assessed. In addition to the infrastructure and operational expenditures provided by the PRO, regional aspects, such as local collection points, repair cafes or other elements are included in the scope.

As discussed the PRO has several responsibilities beyond the collection of the WEEE. Since the PRO has been chosen as main focus, the scope for this assessment is also widened beyond collection, including the collection, transport and treatment of the electronic waste.

Material flow

In order to assess the financial flows of WEEE collection, it is first important to get an overview of all the relevant actors and material flows in the WEEE chain. From the NVMP benchmark report[124], CWIT project[125] and the NewInnonet project (D2.2) there is thorough insight in the WEEE value chain. An overview is presented below; starting at the top where electrical appliances are put on the market by producers or retailers. Next the appliances 'go through' society, and when at end-of-life they are collected in collection points, transported to treatment facilities and can come back as a secondary raw material in the production of new appliances. Central in this operation is the Producer Responsibility Organisation, the coordinating entity. Two additional flows are added where materials 'leave the circle', either via unreported waste streams or through residual waste routes, or as unrecyclable material to landfills or incineration.

[123] The role of Producer Responsibility Organizations for batteries and electrical and electronic equipment in the Flemish waste market, OVAM, 2016
[124] NVMP, Benchmark European WEEE systems, 2013 https://www.nvmp.nl/uploads/pdf/research/2013%2003%2004%20Benchmark%20European%20WEEE%20systems%20final.pdf
[125] CWIT final report, 2015https://www.cwitproject.eu/wp-content/uploads/2015/09/CWIT-Final-Report.pdf

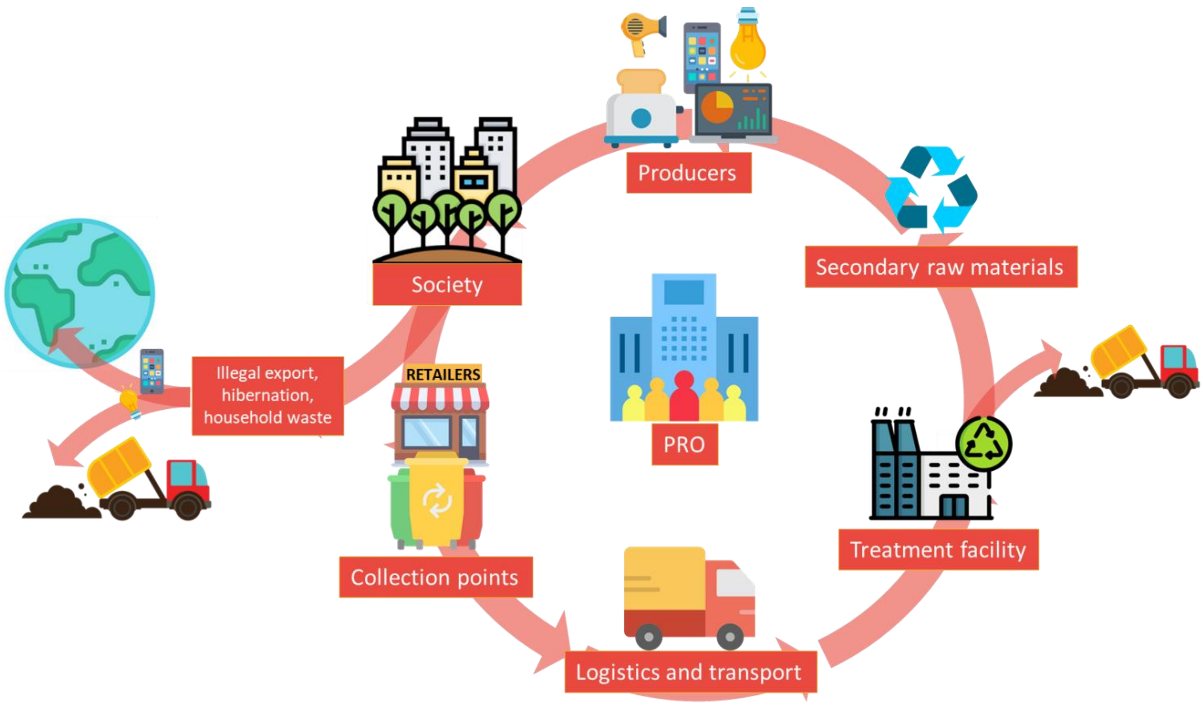


Figure 63 - Overview of the material flows in the WEEE value chain

Responsibilities in the WEEE chain

The WEEE directive determines that producers and importers are responsible for End-of-Life Electrical and Electronic Equipment. Producers are required to organize and finance the take-back, treatment, and recycling of WEEE, in addition to meeting mass-based recycling and recovery targets. Despite some producers are able to organise the necessary activities themselves, most producers and importers throughout the different countries in Europe are grouped into or hire compliance schemes which organise and coordinate the collection and treatment of WEEE on behalf of them. Looking at the PRO as central player in the WEEE chain, the following overview regarding the financial responsibility per phase is identified.

	Collection	Logistics	Pre-treatment	Treatment
United Kingdom[124]	Yes	Yes	No	Yes
Austria[126]	Yes	Yes	Yes	Yes
France[124]	Yes	Yes	Yes	Yes
Italy[127]	Yes	Yes	Yes	Yes
Finland[128]	Yes	Yes	Yes	Yes

Table 43 - Overview of financial responsibilities of PRO's per country

[126] The Management of Waste from Electrical and Electronic Products in Austria, Institute of Environmental Economics, 2016
[127] Interview Ecodom, July 2019 (In Italy the schemes do not directly cover the collection, but municipalities are financially rewarded for collected WEEE)
[128] Development of Guidance on Extended Producer Responsibility (EPR), 2014, European Commission – DG Environment

In addition to the producers, also the retailers bear a responsibility in the collection of equipment[129]. In most countries, retailers that sell electronic equipment are obliged to accept WEEE from customers. Retailers are grouped under the flag of 'collection points' in the figure below.

Financial flows

Based on the material flow overview and the financial responsibilities of the PRO (in the broadest sense), the following financial flows have been added to the overview, represented by the orange arrows (1-6).

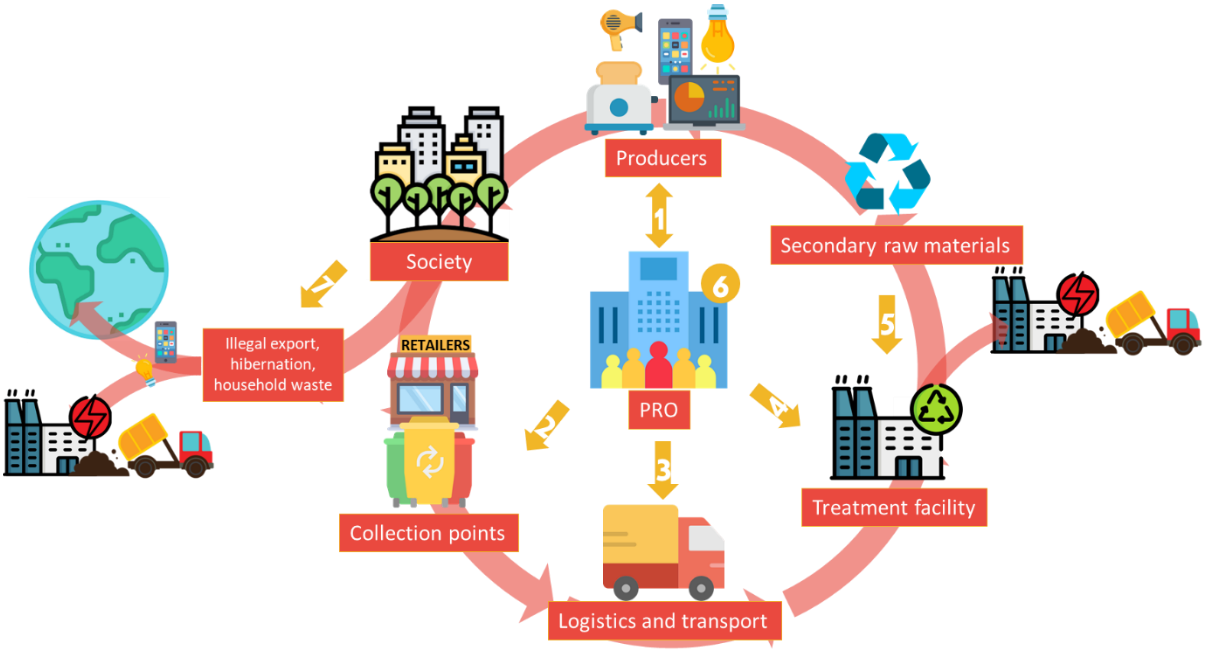


Figure 64 - Overview of material (red) and financial flows (orange) in the WEEE value chain

All financial flows are discussed in more detail below.

1. PRO fee

PRO's are a central part of the financial system of collection. Producers pay the PRO's according to their payment plan (indirectly, this fee is financed by consumers, as often the PRO fee is already included in the product price – see Figure 62). How the collection and treatment is financed varies per organization. The most common fee is paid according to amounts of appliances sold on the market, either paid per ton, per category or per appliance. The fees are contracted (often yearly) between the operating PRO and the producers, and can have a fixed or a dynamic nature. This price is already incorporated in the purchasing price for consumers, called eco-participation fee. The PRO fee varies per country and has been decreasing over the last couple of years due to more and more competition between PRO's.

One important notion on the PRO's operational strategy that may condition the investment in collection infrastructure is the short duration of the contracts and agreements set between the actors in the value chain. E.g. it can occur that a PRO has a one year permit, meaning that they will not be inclined to set long-term commitments with recyclers or collection facilities, and therefore neither PROs nor WEEE dedicated recyclers

[129] According to art.5 of the WEEE Directive, retailers must accept an old appliance when a similar one is bought, and distributors of a surface >400 square meters must also accept very small WEEE (no external dimension more than 25 cm) free of charge to end-users and with no obligation to buy EEE of an equivalent type.

will have the stability to invest in better-long term treatment or collection campaigns for improving their services.

2. Contribution to collection points

As can be seen in Table 43, in Austria, Finland and France PROs are financially responsible for the collection activities. This can be done through supplying collection containers, boxes or bags, either directly to the households or via local collection points. In addition, the PRO's pay collection points (e.g. civic amenity sites run by the municipal waste collector, or retailers) a certain amount per collected ton of WEEE. Depending on the manner of collection, this compensation can vary. Some PRO's work with flat fees, and some stimulate the collection of separate fractions by giving out higher compensations per ton when the WEEE is collected in more categories. Often communication and education campaigns are launched or financed by the PRO and are accounted for under contribution to collection points (as a local component) in this overview.

3. Logistic costs

Depending on the location and collected fraction, the WEEE will be transported either to a consolidation or bulking site, transhipment location, or directly to the treatment plant. In all five case studies, the PRO finances the logistics, which can be a significant part of the overall operation costs.

4. Treatment costs

After collection, the WEEE is transported to material recovery sites. At the treatment sites the dismantling, shredding, depollution and other processes, recycling and recovery take place. Not all materials can be recovered or recycled, therefore landfilling or incineration is also included. These pre-treatment facilities often collect a fee for their services. A part of the treatment cost is covered by the output recycled and sold materials (i.e. metals, secondary raw materials, etc.). The treatment costs, and revenues vary largely per WEEE category.

5. Costs or revenues from material recycling

See also 4. Treatment costs. The revenues from material recycling vary largely per WEEE category.

6. Compliance

In order to combat illegal export, scavenging and improper treatment, aspects such as monitoring, legal requirements in logistics, and depollution are becoming more and more important. These costs are included as compliance, and assumed to be covered by the PRO.

7. Costs for society for uncollected or wrongly collected WEEE

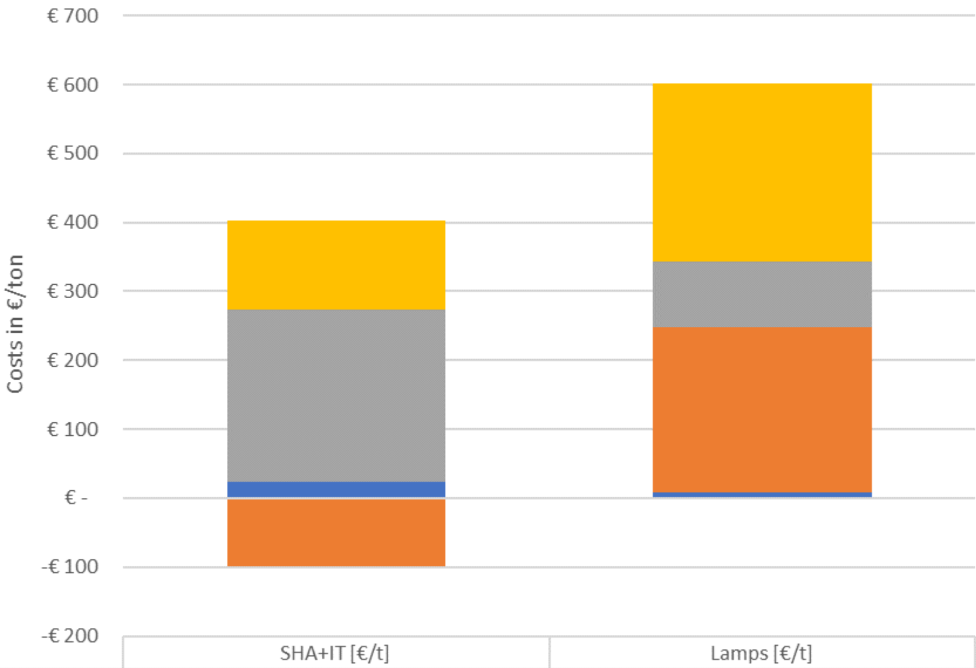
When electrical appliances are not collected via the proper routes and treated correctly, materials can get lost in incineration or landfilling, or exported. Another possibility is that EEE is recycled through informal actors who do recycle materials, but only extract the valuable ones (e.g. copper and irons). The costs associated with unreported WEEE recycling are often lower and generate a situation of unfair competition with the legal sector. Operators not working within the official system are likely not to be compliant with environmental protection regulations. Often, most of the costs that arise in these processes are not directly paid for (by the polluter), and therefore hard to address.

For the five cases the WEEE composition in residual household waste is limited, but can still add up to significant amounts for the three waste streams in the scope. In Wales for example, the percentage of WEEE found in the residual waste can be up to 2.2%[155]. This means significant amounts of appliances go straight to waste incinerators or landfill, after which materials are lost. In addition, this results in a direct financial cost for incineration or landfilling. The government of Wales estimates, that by compliant recycling, every year they save approximately € 110 per ton of WEEE by not having to send materials to landfill[130].

As mentioned above, the 'lost' value of scavenged and other unreported flows is significant.

Lastly, a final cost for society is in environmental savings and costs. Proper collection and recycling can yield an environmental benefit of not having to mine, process and transport the materials again. The LCA methodology and results in deliverable 3.1 and 3.3 reflect on these benefits in great detail. The potential CO_2 savings would be relevant to include in the financial analysis, as CO_2 emissions are becoming more and more a pollutant that organisations, companies and governments need to pay for. However, as this is not yet fully incorporated in the waste collection and management processes, it is excluded from the analysis.

As WEEE collection has become very competition sensitive, little case specific financial data has been obtained. For most analysis, average collection and treatment costs have been used. In the figure below, average operational costs per phase are presented (data from long running systems)[131]. It can be seen that collection costs for small appliances are quite low (129 €/t) but treatment costs are fairly high. Recovery and recycling of small appliances produces a revenue of about 98 €/t, which is not enough to cover the entire costs. Lamps generally don't have complex structure which results in lower dismantling and sorting costs, but can contain toxic elements, making treatment very expensive while producing no revenue.



	SHA+IT [€/t]	Lamps [€/t]
Transport and collection	€ 129	€ 259
Shredding, sorting, dismantling and pretreatment	€ 249	€ 95
Recycling and recovery	-€ 98	€ 240
Incineration and landfill	€ 24	€ 8

Figure 65 – Average EU technical costs for collection and treatment of WEEE, 2008

[130] https://myrecyclingwales.org.uk/materials/waste-electrical-and-electronic-equipment?finyear=2017
[131] 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE), United Nations University, 2008

From a more recent report in 2015, the minimum technical cost for WEEE recycling (treatment, depollution, disposal and compliance) are found. Based on an assessment of 13 EERA Members, encompassing 27 treatment locations in 13 countries for a total volume reported of 465,000 tons, recycling costs were estimated for four categories (SHA, LHA, screens and cooling appliances) [132]. For small household appliances, these are estimated to be € 266/ton. In addition, this reports endorses the importance of compliance, which is on average found to be around € 37 per ton, depending on the category.

As can be seen, the 2015 treatment costs are quite similar to the 2008 values. Based on these two reports, the following table with the average operational costs has been drafted. Where case-specific information is unavailable, these values are used. However, financial case-specific data was rarely available. The WEEE recycling sector links the overall lack of transparency to the high level of competition on the WEEE market, which makes it difficult to share economic information, even aggregated. As a result, for most cases, the average costs from the table below have been used.

Average operational costs	**SHA + IT [€/ton]**	**Lamps [€/ton]**
Transport and collection	129	259
Shredding, sorting, dismantling	203	95
Recycling, recovery	-98	240
Incineration and landfilling	50	50
Compliance	37	37

Table 44 - Average technical costs for collection and treatment for SHA, IT and Lamps

As mentioned these technical costs are averages, and are expected to change in the future due to various trends. First of all, over the years our electronic equipment has become smaller and smaller. In addition, (precious) metals are used in decreasing quantities, as they are used more efficiently or simply replaced by other materials. Despite the expected increasing EEE products put on the market, it is expected that per EEE product put on the market the potentially recoverable precious materials will decrease. One can imagine that this might lead to more difficult and therefore expensive recycling and recovery processes, as there is less valuable material to mine from the WEEE waste stream. On the bright side, new innovative technologies and recovery processes can arise and reduce the operational costs and/or recovery rates. These potential trends are not included in the current assessment.

Financial analysis

For every case, a relevant period of a minimum of 4 years has been identified, preferably a period in which an investment to boost WEEE collection has been made. Within this period the investment costs, operational costs for collection, processing and recycling as well as the benefits of the system are identified and graphed. The assessment will focus on the investments done by the PRO, municipality or collection entity in order to improve the amounts of officially registered WEEE in the local collection sites. The operational costs and the revenues from the PRO are mapped. All these financial flows are processed in a Cost Benefit Analysis, which ultimately aims to highlight the cost effectiveness of increasing the WEEE collection, the options of different stakeholders to invest in a better-performing collection system and the financial flows of the WEEE collection system.

5.1.2. REFERENCE CASE

In order to judge the financial impact and cost-effectiveness of investments since the beginning of the reference period it is necessary to compare the current and prospected future status of a system to a reference case.

[132] United Nations University, WEEE Recycling Economics – the shortcomings of the current business model, 2018

This reference case is defined as the collection system in the first year of the reference period. Along with its indicators such as collection rates, consumer awareness, infrastructure, landfilling and recycling rate it serves as the point of reference. From that point on we observe the changes that investments have caused in the following years.

For comparability purposes, it is assumed that the process of material recovery is equal to the one in 2019, when this report was written.

For all cases these flows have been mapped in detail in order to understand the financial scheme behind the cases WEEE collection system. For every case, a relevant period of six years has been identified, preferably a period in which an investment to boost WEEE collection has been made. Within this period the investment costs, operational costs for collection, processing and recycling as well as the benefits of the system are identified and graphed. Ultimately, this analysis aims to highlight the cost effectiveness of increasing the WEEE collection, the options of different stakeholders to invest in a better-performing collection system and the financial challenges of the WEEE collection system.

5.1.3. PROJECT DEFINITION

For all cases, the project is defined as the measure implemented to increase WEEE collection. In this assessment only small household and IT appliances and lamps are included, however often these waste streams will be collected, transported and treated along with other waste streams. Costs and benefits derived from other waste streams (such as large household appliances, screens, but also household waste) are discarded. The specifics of the collection system and financial responsibilities are discussed in detail below.

5.2. COST-BENEFIT ANALYSIS PEMBROKESHIRE

In Pembrokeshire, the PRO 'REPIC' is largely responsible for the collection, transport and recycling of EEE. Below the costs and benefits from REPIC's perspective are discussed.

5.2.1. PROJECT DEFINITION PEMBROKESHIRE

The collection system in Wales follows the "Municipal Sector plan collections blueprint" from 2011. It was a result of the "Towards zero waste"-initiative which aims at making Wales a waste-free country by 2050. The blueprint contains non-obligatory guidelines on how best to organize the collection system.

WEEE, in contrast to the rest of municipal waste, is not collected from households directly. Citizens are encouraged to bring their used electronics one of six household waste collection sites in the county[133]:

1. Winsel CA Site
2. St Davids CA Site
3. Pembrokeshire FRAME Pembroke Dock
4. Crane Cross Waste and Recycling Centre
5. Manorowen Civic Amenity & Recycling Centre
6. Hermon CA Site

Take back schemes with retailers are also available, however, in the UK retailers have the option to opt out[134].

The collection of WEEE arising at Designated Collection Facilities in Pembrokeshire is organized via the Producer Responsibility Organization REPIC. REPIC is contracted with the Local Authority and arranges for the collection

[133] https://www.pembrokeshire.gov.uk/waste-and-recycling-centres
[134] https://dts.valpak.co.uk/

and treatment of WEEE arising from Local Authority Designated Collection Facilities[135]. Producers pay for collection and treatment costs based on the amount of EEE they put on the market by category.

Residents are encouraged to bring their potential electronic waste to one of eight collection sites, some of which offer repair or second-hand shops where certain products can be fixed and resold, or donated to a charitable organization. The locations can be found via the local recycling tool on the recycleforwales.com website. They offer for-free disposal and some are repair and reuse centers.

Extra pick-up service can be requested online on the local government website. This is especially used for the white goods" such as for example, washing machines and refrigerators . Also, in case of incapability of the householder to bring the items to the collection point (due to age or disability), a direct in-house collection service can be requested directly from the community via an online account, or via a telephone call to the Pembrokeshire Remakery.

The collection points categorize the items according to their treatment method. REPIC hires a company that picks up the equipment and brings it to a dedicated treatment facility.

The flowchart of the Pembrokeshire WEEE collection system is presented below.

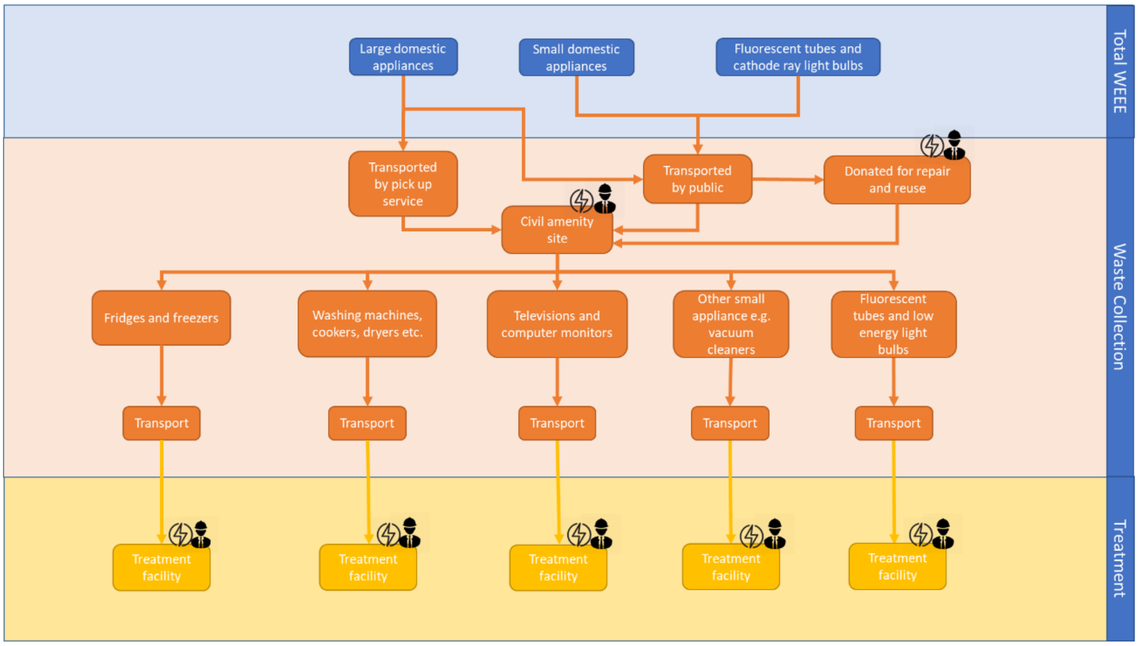


Figure 66 – Flowchart WEEE collection in Pembrokeshire

Increased focus has been given to the building of reuse centers such as "The green shed" or "Pembrokeshire Remakery", investments into school education programs and research and development funding as well as public awareness campaigns (recyclenow.com, Don't bin it, bring it"). First and foremost this is being established in cooperation with WRAP, a supporting charity organization dedicated to improving circular economy[136]. An important part of the strategy for the future was chosen to be an increased waste reduction by way of reducing appliances becoming waste in the first place. Currently the Pembrokeshire Remakery is run on a completely

[135] http://www.repic.co.uk/Weee/Our-WEEE-services
[136] https://resource.co/article/wales-invests-54m-new-reuse-and-recycling-projects-12970

voluntary basis, minimizing operational costs. Since 2018, 15 tonnes of household items are saved from entering the waste stream. Every ton of goods diverted from reuse can save 3.45 tonnes of carbon dioxide emissions[137].

5.2.2. IDENTIFICATION OF COSTS AND BENEFITS FOR WEEE COLLECTION IN PEMBROKESHIRE

THE INVESTMENT COSTS

To ensure the extended producer responsibility principle, the UK offers different pay mechanisms. Retailers generally offer free take-back service or opt to pay into the Distributor Takeback Scheme (DTS). Non-retailers often use collective compliance schemes to manage the collection (Producer responsibility organization - PROs). If the PRO fails to meet the collection target, they have the option to pay the "WEEE producer compliance fee" to compensate. This money plus what is collected through the DTS is intended to fund projects to improve levels of WEEE collection. This mechanism gathered over 1.4 million pounds for funding in 2015[138].

Any local authorities can apply for support of their projects. In 2019 the "Circular Economy fund" was launched. This 6.5 million £ fund is directed towards efforts to increase the re-use of products. Such projects include institutions like "The green shed", where second hand material, also clothes & furniture, can be donated. The centre also offers a repair and resell service for electrical appliances.

In order to tackle the main problems of unreported waste, efforts have been mainly directed at educational programs and awareness campaigns. Following a report from WRAP called "Preparation for re-use: a roadmap for a paradigm shift in Wales", increased attention was directed towards re-use and repair centres to capture value from reselling of used products.

Another point of focus was education. Together with associations such as "WRAP Cymru", public campaigns such as "Don't bin it, bring it" intended to stop people from throwing electrical appliances into the general waste bin. Their easy to use online website additionally educates the general public on what to do with WEEE.

REPIC indicated that they have been improving their collection pickup processes in order to reduce mileage and CO_2 emissions, which resulted in a decrease of pickup trips by 10 -15%. Exact numbers and investment over the last years are not available. All investments that have been found are of the national or regional government, who are very active in improving the waste infrastructure. As this is assumed to be a vital part of the good practice in Pembrokeshire, although not funded by the REPIC, these efforts are included.

Item	Assumption and Data source	Unit Cost
GPB to EURO	For all investments a conversion rate of 1 GBP = 1.09 € is used (Conversion rate 31/07/2019).	1.09€ /GPB
Improvement of collection system	In 2019, the Welsh government has committed GBP 15.5 million "to improve collections in the Vale of Glamorgan, Pembrokeshire and Denbighshire"[139]. It is assumed that these investments will be done in 2019. Of this 15.5 million, 500,000 GBP are given to the regions Vale of Glamorgan, Pembrokeshire and Denbighshire for improvements in the collection system. This investment is outside the reference period and therefore only mentioned as a reference and indication of the investments that are currently being done. The allocated amount of the investment for Pembrokeshire is calculated based on the number of citizens in Pembrokeshire (124,000) compared to the total in the three counties (350,900), which is approximately 35%[140]. These investments will focus on collection of household-waste, and are not further specified. The allocated part of investments for WEEE collection are therefore calculated by the total mass percentage of the WEEE stream in Pembrokeshire (1,340 t/63,022t = 1.93%)[141].	122,848 €

	It is assumed that a similar investment is done at least once before in the 2013-2018 reference period. Therefore a similar investment is included.	
Awareness and information campaigns	In 2018, The Welsh Government invested 500,000 GBP for the Zero Waste school's initiative[139] in Pembrokeshire, teaching primary and secondary school children in 24 schools about the importance of recycling. The allocated amount is calculated based on the amount of the total mass percentage of the WEEE stream in Pembrokeshire (1,340 t/63,022t = 1.93%)[141]; totalling to € 11,588 for awareness investments in 2018.	15,695 €
	For 2019, GBP 500,000 are given to the regions Vale of Glamorgan, Pembrokeshire and Denbighshire for improvements in the collection system(general). The allocated amount of investment for Pembrokeshire is calculated based on the citizens percentage (35%) and the mass percentage of WEEE/total household waste (1.93%); totalling to € 4,107 for awareness investments in 2019.	
	It is estimated that a similar investment is done yearly, in order to keep citizens informed.	
Construction of The Green Shed	The investment costs for the Green Shed in Pembrokeshire are assumed to be similar to the Green Shed investments in Conwy and Denbighshire; GBP 510,000. The investment is assumed to be done at the end of 2017[142].	€ 92,650
	The Green Shed houses a café (assumed to be 50% of costs) and repair place for bikes (assumed to be 16.67% of costs), furniture (assumed to be 16.67% of costs) and WEEE (assumed to be 16.67% of costs).	

Table 45 - Overview of investments

OPERATING COSTS

Material recycling carries certain costs. Apart from the process of recuperating the value of the materials, the products have to be transported, handled, treated, registered, etc. by personnel working in the civic amenity sites or repair shops.

In 2017, 56% of the separately collected WEEE in Wales, is treated and recycled in Wales, and 34% in England. Smaller flows go to Spain, Pakistan, Turkey and Italy[143]. A total of 21,581 tons has been recycled in 2017. By recycling this WEEE quantity, an estimated GBP 2,309,134 has been saved of landfill costs.

Again, as specific costs from REPIC are not available, some costs from the local county government have been included, such as public awareness raising.

[137] https://businesswales.gov.wales/walesruralnetwork/local-action-groups-and-projects/projects/pembrokeshire-remakery-green-shed-project
[138] Evaluation of Compliance Fee and Distributor Takeback Scheme funded WEEE projects
[139] https://resource.co/article/wales-invests-54m-new-reuse-and-recycling-projects-12970
[140] Statistics population UK, 2018 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland
[141] https://statswales.gov.wales/Catalogue/Environment-and-Countryside/Waste-Management/Local-Authority-Municipal-Waste/annualwastereusedrecycledcompostedby-material-source-year
[142] https://www.thegreenshedpembs.com/
[143] https://myrecyclingwales.org.uk/destinations

Item	Assumption & data source	Unit cost
Public awareness campaign	In 2008-2009, Welsh authorities spent GBP 2.26/household[144]; assumed investment every year	0.62 €/ household
	The municipal waste plan specifies four household waste streams that should be targeted for waste preventing; food waste, plastic, paper and WEEE. Therefore, it is assumed 25% of the awareness investments will focus on WEEE[144].	
Green Shed operational costs	The employees in the Green Shed mainly work on voluntary basis. Therefore, these costs are excluded from the operational costs.	€ -
Collection and transport costs SHA	No actual costs from REPIC are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of SHA are on average € 129 per ton[145]. However, in the UK, the PRO's are not available for costs of collection. Therefore only the transport costs have been included, which are estimated to be 50% of the 129€/t.	€ 65/ton
	Detailed WEEE collection data for Pembrokeshire is known for SHA between 2013 – 2018[141].	
Collection and transport costs Lamps	No actual costs from REPIC are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of lamps are on average € 259 per ton[145]. However, in the UK, the PRO's are not available for costs of collection. Therefore only the transport costs have been included, which are estimated to be 50% of the 259€/t.	€ 130/ton
	Detailed WEEE collection data for Pembrokeshire is known for SHA between 2013 – 2018[141].	
Recycling costs SHA	No actual costs from REPIC are publicly available or known, therefore average treatment costs have been used. The PRO's in Wales are not financially responsible for sorting (sorting costs are estimated to be 25% of treatment costs). The technical costs for shredding, dismantling and depollution of SHA are on estimated to be € 168 per ton[146]; the costs for recycling SHA are negative due to recovery of valuable materials at -€ 98/ton; and the average costs for incineration and landfilling of non-recyclable materials in 2008 are € 24 per ton[131]. The cost for landfilling and incineration seem to be outdated, as the landfill tax in the UK (and Wales) has been increasing sharply over the last couple of years (from GBP 72 in 2013 to GBP 88.95 in 2018)[147]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. For 2013, the total recycling costs for SHA come down to € 156/ton.	€ 321/ton
	It is assumed all collected appliances are shredded, sorted and dismantled. Based on the collection data mentioned above and the national WEEE recycling rates[148] the amount of WEEE sent to recycling and to landfill is calculated.	

[144] WRAP, Municipal Sector Plan (2009), http://www.wrapcymru.org.uk/sites/files/wrap/Municipal%20Sector%20Plan%20Wales.pdf
[145] 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE), United Nations University, 2008
[146] United Nations University, WEEE Recycling Economics – the shortcomings of the current business model, 2018
[147] Landfill taxes UK and Wales, 2018, https://gov.wales/landfill-disposals-tax-rates
[148] Around 75% of WEEE arising in 2010 was either re-used or treated to recover useful materials, either through the WEEE treatment system or through other routes, including local re-use http://www.wrap.org.uk/sites/files/wrap/WEEE%20recovery%20in%20the%20UK.pdf

Recycling costs Lamps	No actual costs from REPIC are publicly available or known, therefore average treatment costs have been used. The PRO's in Wales are not financially responsible for sorting (sorting costs are estimated to be 25% of treatment costs). The technical costs for shredding, sorting and dismantling lamps are estimated at € 71 per ton; the costs for recycling and recovery of lamps are € 240/ton; and the costs for incineration and landfilling of non-recyclable materials if € 8 per ton[131]. The cost for landfilling and incineration seem to be outdated, as the landfill tax in the UK (and Wales) has been increasing sharply over the last couple of years (from GBP 72 in 2013 to GBP 88.95 in 2018)[147]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. For 2013, the total recycling costs for lamps come down to € 398/ton.	€ 398/ton
	It is assumed all collected lamps are shredded, sorted and dismantled. Based on the collection data mentioned above and the national WEEE recycling rates[148] the amount of WEEE sent to recycling and to landfill is calculated.	
Compliance	In order to operate lawfully and abide the procedures set out by the national and European law, the PROs make certain costs for compliance; costs related to proof of legal compliance, quality and service level (e.g. waste classification, control by and reporting to authorities/compliance schemes), and implementation of standards. For both SHA these costs are on average € 37/ton[146]. For lamps, no compliance costs information is available, therefore these are assumed to be identical to compliance costs for SHA.	€ 37/ton

Table 46 - Overview of operational costs

REVENUES

For REPIC, the main revenues consist of the fee that producers pay to the compliance scheme. For improvement projects, REPIC can apply for subsidies from the circular economy fund. As this fund only has been operational since 2019, the potential grants from the fund are excluded.

Item	Assumption & data source	Unit cost
PRO Fee SHA	The PRO fee REPIC receives for her services is not known. It is also not known whether REPIC charges her members per category. It is therefore assumed REPIC receives the European average PRO fee for SHA[149]. For 2013 – 2016 averages are known. The average fee for 2013 is € 160 per ton, and € 155 per ton in 2016. As no data is available for the PRO fee in 2017 and 2018, three scenarios are foreseen; 1. The PRO fee stabilized at € 155/ton; 2. The PRO fee decreased with 10%. 3. The PRO fee increases by 10%.	160 €/ton
	The total PRO income is calculated using the above-mentioned PRO fee and the EEE Put on Market values from REPICS producers. REPIC is the only compliance scheme in Pembrokeshire[150].	
	The EEE put on market amounts are calculated from national average UK from the Urban Mine Platform[151] and amount of citizens in Pembrokeshire[152].	

[149] EEE fees and WEEE system – A model of efficiency and income in European countries, Sousa, R. Aganta, E. 2018
[150] https://www.gov.uk/government/publications/weee-list-of-local-authority-designated-collection-facilities/weee-list-of-local-authority-designated-collection-facilities
[151] ProSUM project, Urban Mine Platform, 2015-2018 http://www.urbanmineplatform.eu/wasteflows/eee/percentage
[152] https://statswales.gov.wales/Catalogue/Population-and-Migration

PRO Fee Lighting [149]	The PRO fee REPIC receives for her services is not known. It is also not known whether REPIC charges her members per category. It is therefore assumed REPIC receives the European average PRO fee for lamps[149]. For 2013 – 2016 averages are known. The average fee for 2013 is € 600 per ton, and € 640 per ton in 2016. As no data is available for the PRO fee in 2017 and 2018, three scenarios are foreseen; 1. The PRO fee stabilized at € 640/ton; 2. The PRO fee decreased with 10%. 3. The PRO fee increases by 10%.	555 €/Mt
	The total PRO income is calculated using the above-mentioned PRO fee and the EEE Put on Market values from REPICS producers. REPIC is the only compliance scheme in Pembrokeshire[150].	
	The EEE put on market amounts are calculated from national average UK from the Urban Mine Platform[151] and amount of citizens in Pembrokeshire[152].	

Table 47 - Overview of revenues

An additional potential benefit that is important to mention here is the non-compliance penalty[153]. The Welsh government will fine Pembrokeshire £ 140,000 for every one percent Pembrokeshire misses the target by (64% in 2020 and 70 in 2025[154]). Reducing the amount of WEEE from the residual waste stream could contribute to this target, as the mass percentage of WEEE in the Welsh MSW is 2.5% in 2009 and 2.2% in 2015[155]. Since this fine has not taken place before, it is unclear how this will work out. In principle, it is assumed that the local authority of Pembrokeshire will be fined, who then could pass this fine on to the households, recyclers or PRO's.

5.2.3. CBA RESULTS PEMBROKESHIRE

The graph below shows an overview of the investment costs, the operational costs, the total revenues and the financial net present value (FNPV). It can be seen that the operational costs and revenues follow a similar trend. The FNPV fluctuates between negative and positive values.

[153] https://www.milfordmercury.co.uk/news/pembrokeshire_news/17569340.changes-planned-at-pembrokeshire-waste-and-recycling-sites/
[154] Wales 'could become Europe's top recycling nation', BBC, 2016, https://www.bbc.com/news/uk-wales-37787961
[155] National municipal waste compositional analysis in Wales, WRAP, 2016, http://www.wrapcymru.org.uk/sites/files/wrap/Wales%20Municipal%20Waste%20Composition%202015-16%20FINAL.pdf

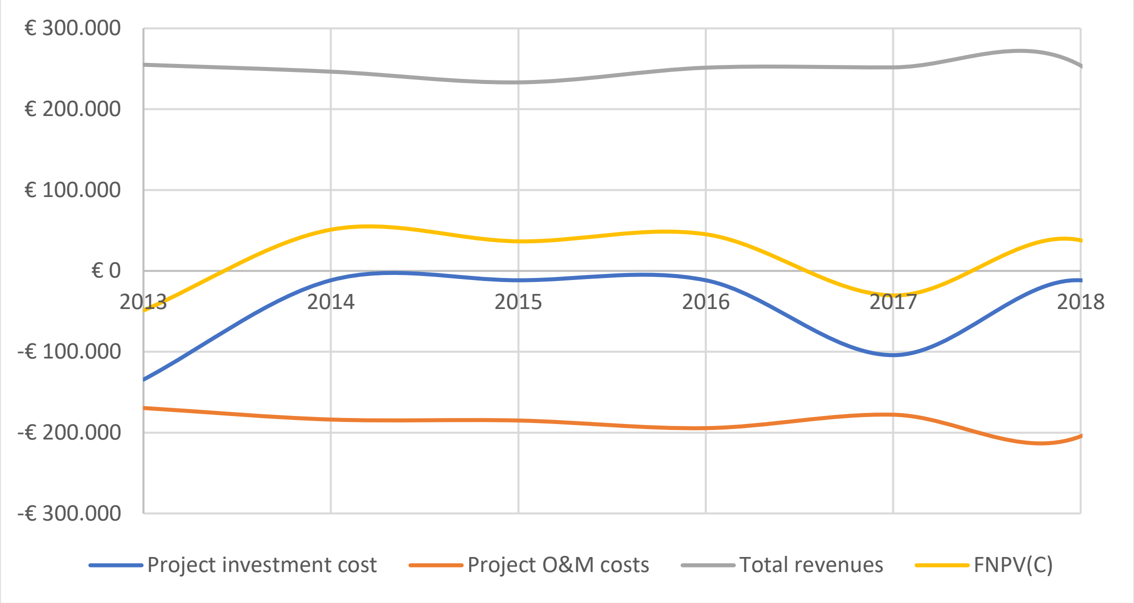


Figure 67 – Overview financial flows for WEEE collection in Pembrokeshire 2013 – 2018

5.2.4. SENSITIVITY ANALYSIS

In order to filter out the uncertainties in the data, a sensitivity analysis has been performed on three parameters; i) the PRO fee; ii) the collection costs and iii) the recycling costs.

The PRO fee

As discussed earlier in Table 47 above, the exact PRO fee charged by REPIC is not publicly available. It is also not known whether REPIC charges its members per category. Therefore, European average waste fees are used, as data for 2013 – 2016 is available. A fairly constant PRO fee can be noticed. As many countries have shown that competition between PRO's has played a significant role in reducing the PRO fees, it is reasonable to assess a scenario where the PRO fee further decreases. However, environmentally sound recycling is becoming more and more important, and comes with a price tag, inspiring higher PRO fees. Lastly, PRO fees may be affected by the level of market share (the more volumes a PRO treats, the better price they get for recycling) as well as the market prices of won materials (scrap, plastics, etc.). As no data is available for the PRO fee in 2015 and 2016, three scenarios are foreseen;

1. The PRO fee stabilizes for 2017 and 2018;
2. The PRO fee is 10% lower than the European average and decreases with a yearly 10% for 2017 and 2018;
3. The PRO fee is 10% higher than the European average and increases with a yearly 10% for 2017 and 2018;

Collection costs

The collection costs are largely based upon 2008 values[131], which might be outdated and have decreased due to efficiency gains. Therefore, a scenario is foreseen where the collection costs decrease by 50%.

Recycling costs

The recycling costs consist are largely based upon 2008[131] and 2016[132], which might be outdated and have decreased due to efficiency gains. The recycling costs consist of the cost for shredding, sorting, dismantling; recycling and recovery. It is quite possible that either one of these processes has become more efficient or cost effective in the last years, which would mean a decrease in cost. Similar to the collection costs, a scenario is foreseen where the recycling costs decrease by 50%.

These scenarios are confined in three potential scenarios, displayed in the table below. The first scenario is marked as the standard scenario, as this is based upon the currently available information. The second scenario is marked as the worst-case scenario, where the PRO fee further decreases due to competition between PRO's. The collection costs and recycling costs stay at the standard values. Lastly, the third scenario is marked as the best-case scenario, since in this scenario the PRO fees increase (more budget for compliance and recycling), and both the collection and recycling costs decrease (less expenditures on collection and recycling).

Scenario	PRO fee	Collection costs	Recycling costs
1 Standard	Stabilized	Std	Std
2 Worst-case	Decreasing	Std	Std
3 Best-case	Increasing	Decreased 50%	Decreased 50%

The result of this analysis is shown in the graph below. The graph below shows the net result (FNPV; all investment, operational costs and benefits combined).

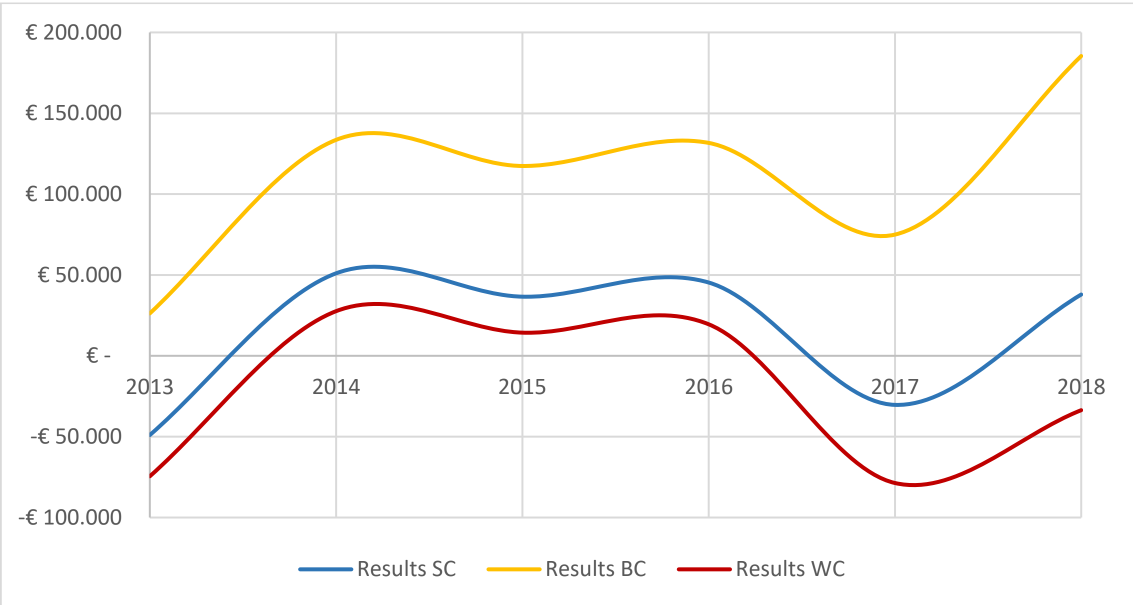


Figure 68 - Sensitivity analysis FNPV for Pembrokeshire

5.2.5. EVALUATION AND CONCLUSION

Assuming the operational costs haven't increased due to the implementation of the new WEEE collection system[156], we can assess the cost effectiveness of the investment. By investing € 104.238 between 2013-2018, the Welsh government was able to increase the collection rates of SHA and lamps significantly (see graph in introduction). Assuming 2013 as reference year, with 742 tons of SHA and 3.5 tons of lamps collected, the 2018 collection values show an increase in collection numbers of 122.96 tons of SHA and 0.30 tons of lamps. Taking the investments between 2013 and 2018, we find a price of € 845.68/ton of additional WEEE collected. It is important to note that collection, transport and processing costs are not even included in this cost-effectiveness calculation.

[156] It is known that REPIC recently implemented an improvement process to reduce the number of collection pick-ups and hence reduce the mileage and CO2 emissions. In 2018, the number of trips has been reduced by between 10 and 15%. Therefore it is assumed, if anything, the direct operational costs went down.

Total investment	€	104,238	Euro
Extra WEEE collected		123.26	Tons
Cost effectiveness	€	845.68	Euro/ton

Table 48 - Cost effectiveness of investment in Pembrokeshire

As discussed in the project rationale, an estimated € 1,480 per ton of WEEE is lost due to scavenging and improper recycling. The cost effectiveness calculated for the Pembrokeshire project is lower than the estimated material losses.

5.3. COST-BENEFIT ANALYSIS VIENNA

5.3.1. PROJECT DEFINITION VIENNA

The implementation of the EU-directive on the national scale in Austria was applied through the EAG-VO – the “Elektro Altgeräte Verordnung”. As a consequence of the regulation, the Austrian government founded the EAK, or “Elektroaltgeräte Koordinierungsstelle Austria GmbH (Austrian Coordination Body For Waste Electrical And Electronic Equipment)’, a central coordinating body in charge of a variety of tasks. Namely:

- Payment of the fixed infrastructure cost payback sum (Infrastrukturkostenpauschale)
- Pick-up coordination from public WEEE collection points
- Yearly planning of public awareness campaigns focused on WEEE
- Information gathering and writing of yearly report on current state of WEEE collection system
- Gathering of numbers and reporting to European central commission[157]

A separate working group (Arbeitsgruppe Oeffentlichkeitsarbeit) is in charge of providing a yearly plan on communication with end-users. They also provide education toolkits, posters, flyers and more.

Collection points can indicate a need for a PRO to pick up equipment via the EAK website when they have accumulated a certain amount.

Special focus is given the prevention of garbage in Austria. Recycling facilities in Vienna have “Tandler-Boxes” where equipment in functioning condition can be brought and offered for re-use. Also, there are numerous repair-shops, -activities, -organizations and events all over the city of Vienna. Via an online tool offered by the “Reperatur Netzwerk”, pick-up and return or home repair-service can be requested. The “Reparatur- und Service-Zentrum” has offered its services since 1998. Currently it offers a repair-café, a repair service at home, rent service for equipment and more. It was able to re-use more than 98 tons of equipment and repaired more than 9,000 broken items last year.[158]

[157] https://www.eak-austria.at/kompetenzen/
[158] https://rusz.mmf.at

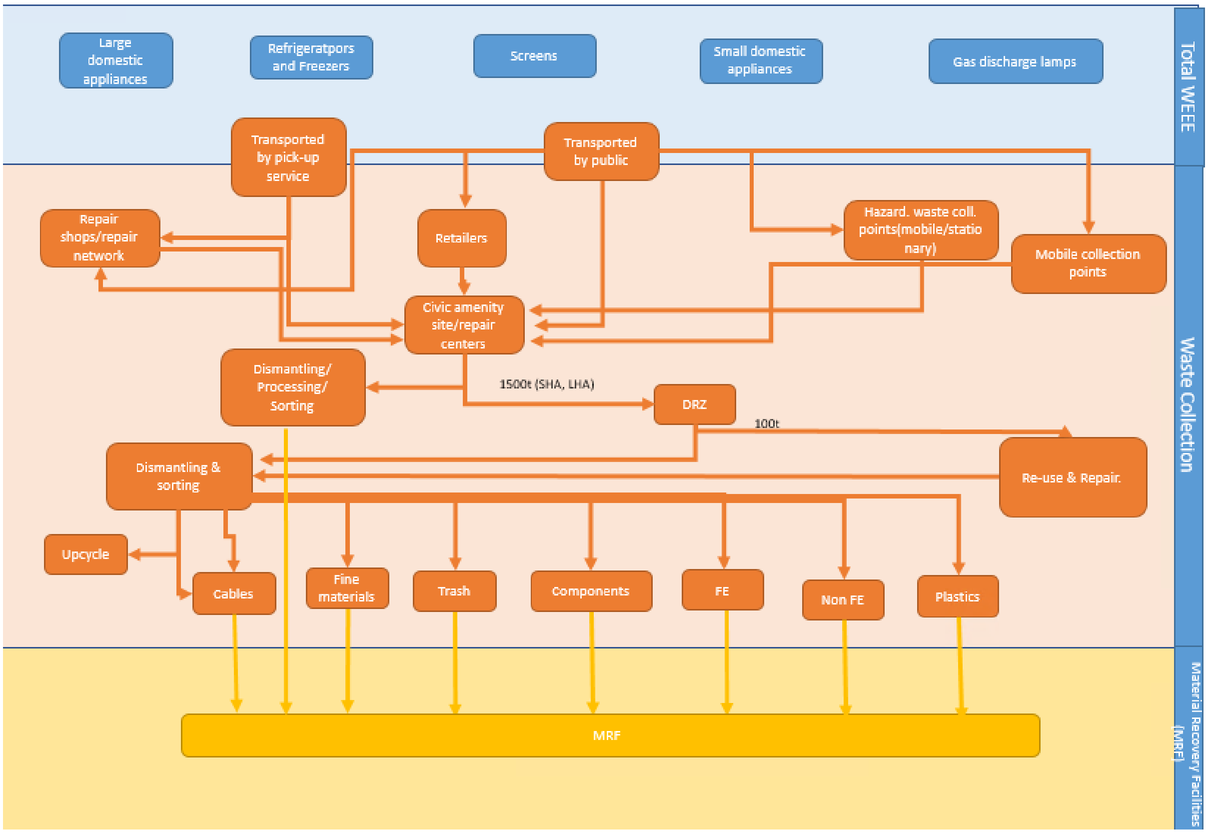


Figure 69 – Flowchart WEEE collection in Vienna

Collection in larger cities has proven especially difficult due to the anonymity they offer, but the "Demontage und Recycling Zentrum" (DRZ) deserves special mentioning. On top of offering pick-up, repair and recycling of WEEE, the center has its own upcycling unit and is able to cover up to 25-33% of its cost by selling used and redesigned appliances.[159] On top of that, a great part of the dismantling and repair is done by people previously long-term unemployed and, most recently, gives work to refugees. As such, it is also a project with a big positive social impact.

5.3.2. IDENTIFICATION OF COSTS AND BENEFITS FOR WEEE COLLECTION IN VIENNA

Austria, due to its short distance to borders, has a lot of problems with so called "Sammelbrigaden" from eastern Europe. It is assumed that up to 10% of WEEE is illegally exported abroad (on EU basis).[160] The rate in Austria is said to be above average at 16%. Increased efforts towards the prevention of this part of the waste stream is done in form of posters, flyers and campaigns and working groups such as "Stop illegal waste exports" [161].

Vienna's collection rate is among the lowest in Austria, with only 6 kg/inhabitant collected in 2017[162]. The great gap between more rural areas of Austria is believed to be caused by the anonymity of the city.[163]

Nonetheless, Vienna's specific reuse efforts have been chosen as a practice to assess. These efforts were chosen as a good practice example thanks to their unique combination of socially and ecologically beneficial reuse

[159] https://www.drz-wien.at/
[160] https://www.elektrojournal.at/elektrojournal/elektroaltgeraete-freude-mit-den-sammelquoten-aerger-mit-sammelbrigaden-und-versendern-62413
[161] https://www.mgg-recycling.com/the-fight-against-illegal-exports-of-electronic-waste-is-enhanced/
[162] Taetigkeitsbericht EAK, responsible partner for WEEE collection and recycling in Austria, 2017 https://www.eak-austria.at/presse/TB/Taetigkeitsbericht_2017.pdf
[163] https://www.vienna.at/elektroaltgeraete-entsorgen-wien-bleibt-das-sorgenkind/5939029

programs. Also, the centralized organization of WEEE collection as well as the planning into the future in Austria is worth serving as an example.

In Vienna, specific attention is given to reuse of EEE, before it becomes WEEE. In recent years there has been a significant increase in the reuse and recycling of electrical and electronic appliances in particular. Based on the Directive on waste electrical and electronic equipment (WEEE) 2012/19/EU, the reuse of WEEE is a high priority in legal terms.

To facilitate the reuse practice, Austria has a dedicated reuse network, RepaNet. Together with the City of Vienna (MA48) and the ReparaturNetzwerk Wien, RepaNet works on the establishment of a reliable Vienna wide network, in which reusable devices will be categorized separately, tested and get repaired in order to be sold as high quality secondhand products. RepaNet is the voluntary representation of socio-economic companies for reuse, repair networks and repair initiatives (e.g. Repair cafés), awareness guides for reuse in Austria and important players in the current debate on the circular economy. RepaNet focusses on creating fair jobs in the sector and aims to involve civil society in the debate on the circular economy.

A good example of a good reuse practice is the DRZ, one of the socio-economic companies focusing on reuse and recycling of WEEE is the Demontage- und Recycling-Zentrum (DRZ: Disassembly and Recycling Centre). The DRZ (Dismatling and Recycling Center) is a socio-economic enterprise run by „Die Wiener Volkshochschulen GmbH“. Through the refurbishment and recycling of used and waste electrical and electronic equipment (WEEE), job-seeking people get the opportunity to return to a regular working life. While employed at the DRZ under time bound contracts, the employees receive supervision from experienced professionals in order to improve individual strength, reduce social isolation, overcome possible personal handicaps and provide active support to seek a new job[164]. The Disassembly and Recycling Centre (D.R.Z) was formed in 2003 and was largely driven by the increased focus on WEEE, the demand for specialised repair-services and the increasing legal requirements concerning the treatment of waste appliances (removal of hazardous components, recovery and recycling). To date, the D.R.Z. has become a veritable player within the Viennese waste management system and the annual turnover of WEEE amounts to 1 200 tons. This corresponds to approximately 25 % of all waste appliances in the Vienna region (large appliances and small electrical appliances). The aims and objectives of the D.R.Z. tackle different indicators. In relation to employment aspects, the D.R.Z. as a socio-economic enterprise provides employment, VET opportunities, social pedagogical counselling and outplacement. From an economic perspective, the D.R.Z. generates 27-30 % of its financial needs by re-sale. Ecologically, the D.R.Z. aims to provide the optimal treatment to WEEE, as required or allowed by the specific item’s condition. This treatment entails the manual selection of re-usable devices in the first instance which are then prepared for reuse (e.g. cleaning, safety and functional testing) and then resold. The material is disassembled and reusable parts are extracted. Spare parts and creative parts are often used to create artistic objects in a dedicated department within the D.R.Z. called ’Trash Design Manufaktur’. From the material remaining, hazardous components are removed and other components are then channeled into appropriate disposal or recycling systems[165]. Thanks to the amount of manual processing in the “Demontage- und Recycling-Center”, materials and components can be separated to a higher degree than when only separated by categories. This leads to higher quality of recycling and yield from the available components.

The DRZ participates in various EU projects as frontrunner in the social workplaces and the reuse and recycling practices[166]. DRZ is partner in the CloseWEEE project[167], of which the main goal is to increase the range and yields of recovered materials from WEEE streams; the RUN project ("ReUse Notebook Collection, Refurbishment

[164] https://www.drz-wien.at/english-information/
[165] EEO Review: Promoting green jobs throughout the crisis, 2013
[166] https://europa.eu/investeu/projects/new-life-old-electrical-appliances_en
[167] http://closeweee.eu/

and Distribution System")[168] of which the aims is to is to set up a system for the collection, storage, remanufacturing and resale of used laptops.

This added focus on reuse is an additional aspect of the Vienna case. The scope is therefore slightly adapted, see the figure below. Annually, the DRZ processes 1,500 tons of used electronic equipment (UEEE), of which they manage to reuse and sell 150 tons[179]. The rest of the stream is manually dismantled and sent to treatment facilities. The amount of manual processing in the “Demontage- und Recycling-Center”, materials and components can be separated to a higher degree than when only separated by categories. This leads to higher quality of recycling and yield from the available components. The CBA is made for the combination of PRO’s in Vienna and the DRZ. Since there was no contact available at one of the PRO’s, nor where there direct investments made by the PRO which we assessed, it is decided to include all operational PRO’s in Vienna in the analysis (ERA, UFH, ERP and ISA). The market share of the four PRO’s is showed in the figure below, totaling to 100% of the POM in Vienna[169].

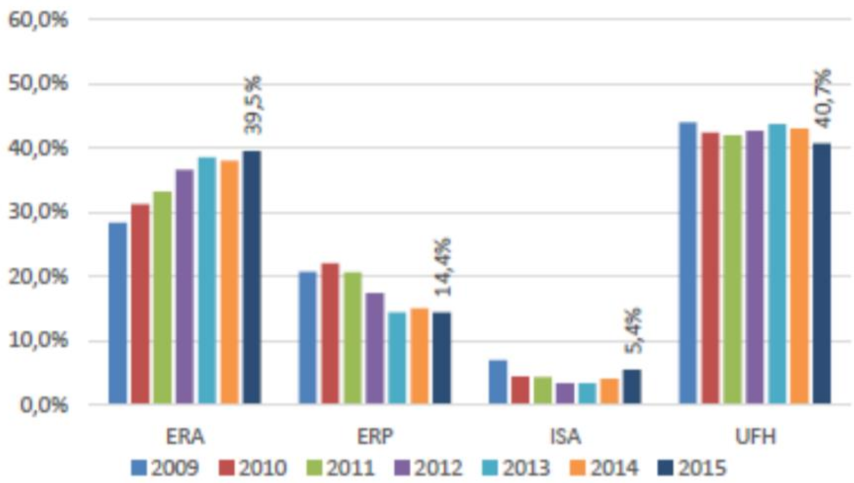


Figure 70 - Market share of ERA, ERP, ISA and UFH

168 http://reuse-notebook.com/de/startseite/
169 WEEE mgmt. in Austria, 2017, http://ewit.site/wp-content/uploads/2017/01/WEEE-Mgmt-in-Austria.pdf

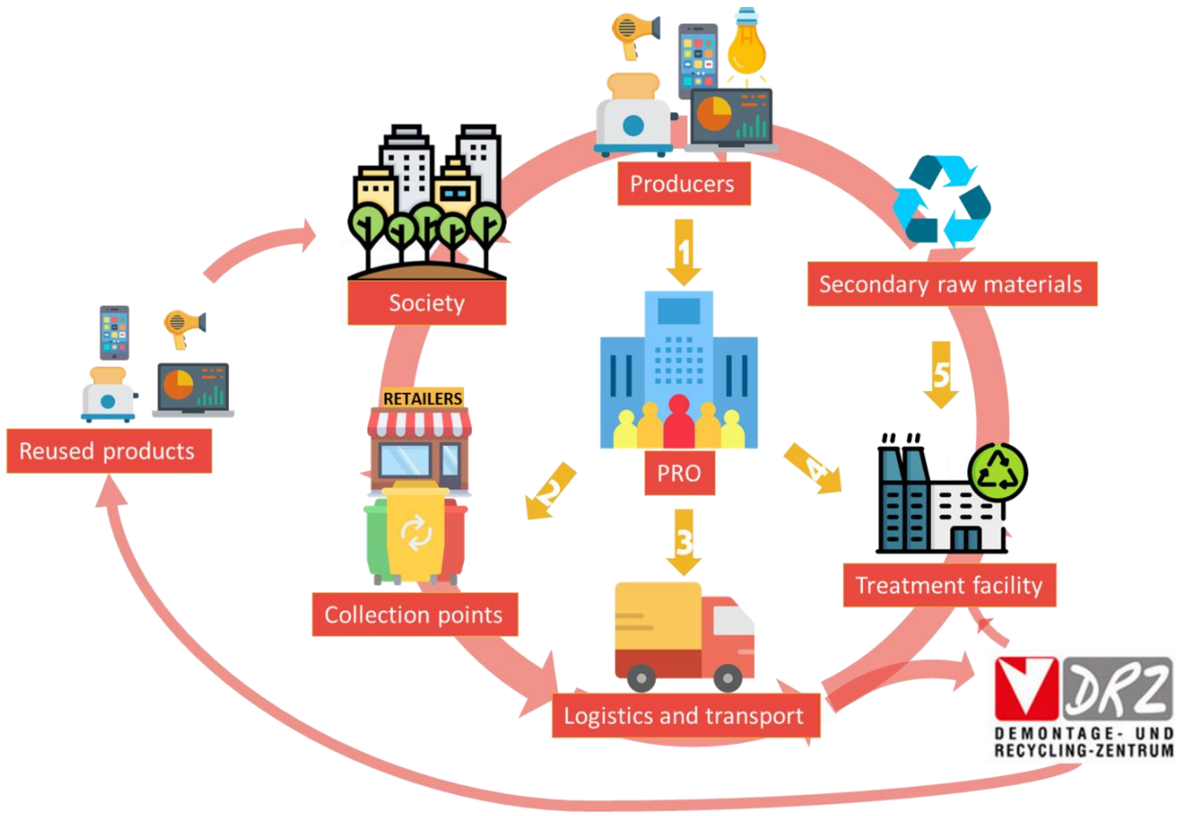


Figure 71 - Overview of WEEE material flows including reuse through DRZ

Additional good repair and reuse practices in Vienna such as the Reparatur und Service Zentrum[170] and the Reparaturnetzwerk[171] have been identified as well, however these have been excluded from the scope due to absence of data. In addition, it is found that these initiatives run on volunteers.

THE INVESTMENT COSTS

Item	Assumption & data source	Unit cost
Demontage- und Recyclingzentrum [172]	Founded in 2003 as a social support project	€ -
	Initial investment costs could not be found, but where also from 2003, a period out of the scope.	
Collection improvement projects Infrastrukturkostenpauschale	RepaNet run various projects in the last 10 years, of which Transwaste (targeting illegal export) and RepaMobil[173] (expanding repair and reuse services) are two examples of good WEEE practices. Unfortunately, no investment costs or project results have been found.	€ -
	In their plan for waste disposal “Abfallwirtschaftsplan 2024” the Vienna local government identified 98 measures and alternatives to improve waste management improvement in the city, some of which are directed towards electronic garbage. The measures	

170 https://blog.wir-leben-nachhaltig.at/2017/08/29/interview-mit-sepp-eisenriegler-vom-reparatur-und-servicezentrum-r-u-s-z/
171 https://www.reparaturnetzwerk.at/
172 https://www.drz-wien.at
173 https://www.repanet.at/themen/projekte-2/transwaste/

	mainly focus on increasing re-use and repair activities, support for repair networks and partnerships as well as facilitating legal changes towards re-use. One initiative focusses on a "Re-Use"-box, which can be filled at home with re-useable products. Direct past or future investments related to this plan are however not available.	

Table 49 - Overview of investment costs

OPERATING COSTS

As no case specific information for a PRO was available, the scope has been broadened to all operational PRO's in Vienna.

The PROs operating in Vienna cover their running costs through the eco participation fee of their customers, the producers of EEE. They serve as a central coordinating body for collection and treatment and do not operate a collection fleet themselves. Via an online tool, the collection points can request a pick-up, which is then collected by the recycling facilities. At the end of the year the facilities invoice the treated amounts and get reimbursed for their efforts.

The DRZ employs around 65 people of different backgrounds for waste management. Long term unemployed, refugees and artists are given the chance to work in dismantling, repair or upcycling of old electronic equipment.

Item	Assumption & data source	Unit cost
Collection & Transport SHA	No actual costs are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of SHA are on average € 129 per ton[145].	129 €/t
	The Austrian PRO's, e.g. UFH often have agreements with collection points owned by external collection operators, who they'll pay in euro's per ton for every amount of WEEE collected. The exact charges are not available, and therefore the average technical costs are used. In addition, collection points are partly supported by the EAK directly, not by the PROs, via the "Infrastrukturkostenpauschale". The amount depends on the types of equipment collected, and the type of collection facility. As the budget for the EAK, the coordinating body for Austrian WEEE management, is directly financed by all collective schemes operating in Austria according to their market share[174], this is an indirect investment in the collection infrastructure. Most WEEE is collected using collection points, and ca. 2% of the total WEEE is collected through pickup services. Based on monitoring checks at the collection points, the collection points get the payment for their collection efforts. The average fees are known, e.g. for 3 SHA boxes of 18m2 a collection point gets € 422.07[24], however, the exact amount of collection points is not known, and therefore the average technical costs are used.	
	Detailed numbers on collection amounts available in yearly "Tätigkeitsbericht" [162]	
Collection & Transport Lamps	No actual costs are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of lamps are on average € 259 per ton[145].	259 €/t

[174] Austrian Coordinating Body of WEEE (EAK), Presentation on the EAK, 2016, accessed in July 2019 via https://slideplayer.com/slide/12709751/

	For the collection costs, collection points are supported by the EAK directly, not by the PROs, via the “Infrastrukturkostenpauschale”. The amount depends on the types of equipment collected, and the type of collection facility. As the budget for the EAK, the coordinating body for Austrian WEEE management, is directly financed by all collective schemes operating in Austria according to their market share[175], this is an indirect investment in the collection infrastructure. Based on monitoring checks at the collection points, the collection points get the payment for their collection efforts. The average 2017 fees are known, e.g. for 5 lamp boxes of 30m2 a collection point gets € 433.51[24], however, the exact amount of collection points is not known, and therefore the average technical costs are used.	
	Detailed numbers on collection amounts available in yearly “Tätigkeitsbericht” [162]	
Information End consumer[176]	Communication campaigns on communal level are compensated. These amounts are paid by the coordinating body EAK to collection points, but indirectly financed by all operating PRO’s. • 0.055euro/inh in 2014 (assumed also 2011-2013) • 0.0575eur/in in 2015 (assumed also 2016)	0.0191 €/inh
	The investment costs are focused on all WEEE categories, and therefore an allocated percentage of 34.76% is used to assign the costs to the SHA and lamp categories. This percentage is the mass-based percentage of the combined SHA, IT and lamp streams to the full WEEE stream.	
Recycling Costs SHA/IT	No actual costs are publicly available or known, therefore average collection and transport costs have been used. The technical costs for shredding, sorting and dismantling SHA are on average € 203[146] per ton; the costs for recycling SHA are negative due to recovery of valuable materials at -€ 98/ton; and the costs for incineration and landfilling of non-recyclable materials if € 24 per ton[145]. The landfill tax in Austria however is higher than the stated 24€/ton. The tax has been increasing over the last couple of years from circa € 52/ton to € 62 per ton for landfills[177]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. This totals to € 157 per ton.	€ 157/ton
	Detailed numbers on collection amounts available in yearly “Tätigkeitsbericht”[162]	
Recycling Costs Lamps	No actual costs are publicly available or known, therefore average collection and transport costs have been used. The technical costs for shredding, sorting and dismantling SHA are on average € 95[146] per ton; the costs for recycling SHA are negative due to recovery of valuable materials at € 240/ton; and the costs for incineration and landfilling of non-recyclable materials if € 8 per ton[145]. The landfill tax in Austria however is higher than the stated 8€/ton. The tax has been increasing over the last couple of years from circa € 52/ton to € 62 per ton for landfills[177]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. This totals to € 387 per ton.	387 €/t

[175] Austrian Coordinating Body of WEEE (EAK), Presentation on the EAK, 2016, accessed in July 2019 via https://slideplayer.com/slide/12709751/

[176] https://newsletter.eak-austria.at/verguetung-der-kommunalen-massnahmen-zur-information-der-letztverbraucher-auszahlungsvoraussetzungen/

[177] https://www.altlasten.gv.at/finanzierung/altlastenbeitrag.html

	Detailed numbers on collection amounts available in yearly "Tätigkeitsbericht"[162]	
Compliance	In order to operate lawfully and abide the procedures set out by the national and European law, the PROs make certain costs for compliance; costs related to proof of legal compliance, quality and service level (e.g. waste classification, control by and reporting to authorities/compliance schemes), and implementation of standards. For both SHA these costs are on average € 37/ton[146]. For lamps, no compliance costs information is available, therefore these are assumed to be identical to compliance costs for SHA.	€ 37/ton
Demontage- und Recyclingzentrum [178]	Yearly, the DRZ processes more than 1,500t of collected WEEE and upcycles more than 150 t[179]. DRZ processes mainly large and small household equipment, which are manually disassembled in the dismantling department. Cooling appliances, various screens and lamps are sent to partner companies for recovery of recyclable materials[180]. It is assumed that 50% of the processed and reused WEEE is SHA.	€ 266.67 ton
	According to an employee, the running costs are somewhere between 1.5 and 2 million €/year[179].	
	The DRZ does reuse, repair, dismantling and upcycling unit of WEEE. WEEE that can't be repaired or reused, is dismantled and sent to treatment facilities.	
	The DRZ covers a major part of her running cost from subsidies for reintegration and educational efforts of the DRZ from the AMS (circa 1.35€mio/y)[179]. This leaves on average € 400,000 per year to be invested in the WEEE reuse, repair and dismantling.	
	The DRZ processes 1,500 ton of WEEE per year at a cost of € 400,000; which comes down to € 266.67 per ton of processed WEEE. It is assumed after dismantling, the 1,350 tons of WEEE that haven't been reused or repaired will be sent to treatment facilities.	

Table 50 - Overview of operational costs

REVENUES

The DRZ treats around 1,500t of material a year. Through the online and their brick-and-mortar shop as well as the pic-up and treatment activities, they are able to finance up to one third of their running costs. The rest is covered by AMS, the national unemployment office, for their efforts for reintegration and education. [181]

The collection points are paid partly by the EAK by means of the "Infrastrukturkostenpauschale". These cover investments in the collection infrastructure (metal cages, collection bins, etc.). The amount depends on the equipment set down in the collection facilities and is paid on a yearly basis.

Additional funds can be requested when a collection point is host to at least 2 collection and re-use campaigns in a year. The following amounts are based on the 2016 compensation.

[178] https://m.gewinn.com/management-karriere/unternehmen-maerkte/artikel/vom-abfall-zum-designerstueck/
[179] Interview with DRZ, July 2019
[180] https://www.drz-wien.at/english-information/
[181] https://m.gewinn.com/management-karriere/unternehmen-maerkte/artikel/vom-abfall-zum-designerstueck/

Item	Assumption & data source	Unit cost
Upcycled/Repaired products from shop, waste treatment[181]	Since the start of the DRZ, between 1-2 tons has been reused, resulting in ca. € 150,000 per year.	€75,000/a
	It is assumed that 50% of this amount is sold by SHA items.	
PRO fee SHA	Pro fee calculated from the PRO tariff from ERA GmbH[182], verified with the tariffs from Interseroh[183]. Tariffs available from UFH are only available per piece of appliance, which therefore cannot be used[184]. Tariffs for the other PRO's are not available. The fee for SHA (assumed to be Elektrokleingeräte < 8 kg) dropped from € 56 per ton in 2011 to € 38 per ton in 2016. IT appliances also fall under this category[185].	€ 56/ton
	Put on market amounts in Vienna calculated based on national average POM[186] and citizens of Vienna[187] (between 2011 and 2016)	
PRO fee lamps	Pro fee calculated from the PRO tariff from ERA GmbH[182], verified with the tariffs from Interseroh[183]. Tariffs available from UFH[184] are only available per piece of appliance, which therefore cannot be used. Tariffs for the other PRO's are not available. For lamps, the fee was € 860 per ton in 2011 and dropped to € 800 per ton in 2016.	€ 860 /ton
	Put on market amounts in Vienna calculated based on national average POM[186] and citizens of Vienna[187] (between 2011 and 2016)	

Table 51 - Overview of revenues

5.3.3. CBA RESULTS VIENNA

The graph below shows an overview of the investment costs, the operational costs, the total revenues and the financial net present value (FNPV). It can be seen that the operational costs and revenues follow a similar trend. The FNPV therefore is fairly constant and negative. This means that for these assumptions, the operations of the PRO are not financially viable.

[182] https://www.ara.at/fileadmin/user_upload/ARA_Transparenzbericht_2018.pdf
[183] https://www.interseroh.at/leistungen/recycling/elektroaltgeraete/
[184] https://ufh.at/download/pricelist-weee-private-and-commercial/
[185] Geraeteliste 2018, http://www.era-gmbh.at/fileadmin/user_upload/Geraeteliste/Stand_Jaenner_2018/EAG_Geraeteliste_2018_WEEE_Bezug.pdf
[186] Eurostat https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en
[187] https://www.wien.gv.at/statistik/bevoelkerung/

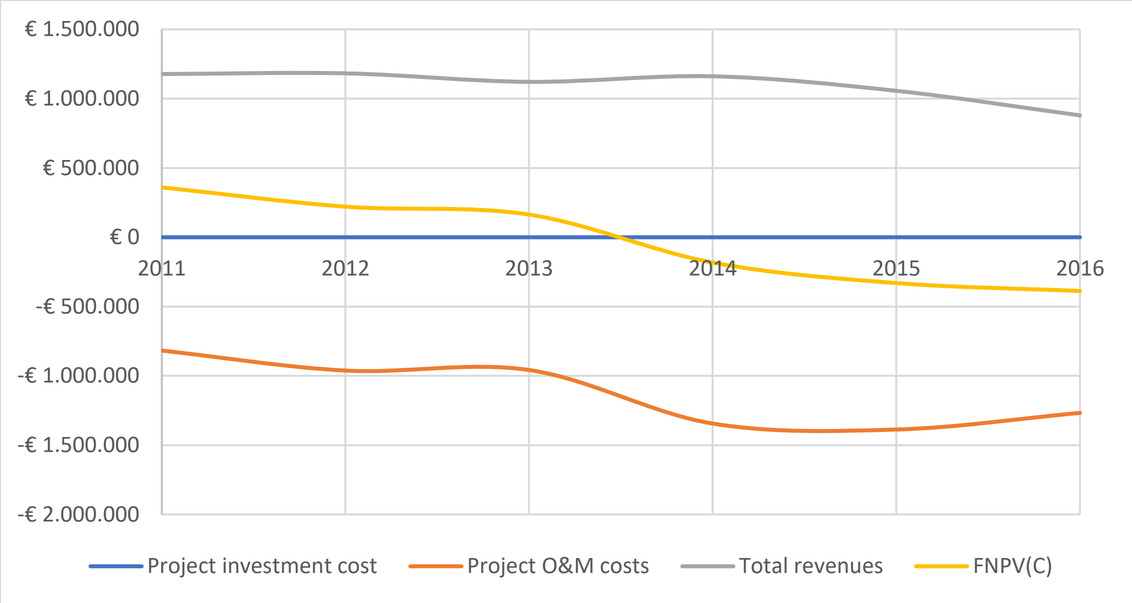


Figure 72 – Overview financial flows for WEEE collection in Vienna 2011 - 2016

5.3.4. SENSITIVITY ANALYSIS

In order to filter out the uncertainties in the data, a sensitivity analysis has been performed on three parameters; i) the PRO fee; ii) the collection costs and iii) the recycling costs.

The PRO fee

The PRO fee as discussed in Table 51 is assumed to represent the average fee for the four PRO's. A slightly decreasing PRO fee can be noticed. As many countries have shown that competition between PRO's has played a significant role in reducing the PRO fees, it is reasonable to assess a scenario where the PRO fee further decreases. To ensure a complete picture of the PRO fees, three scenarios are drafted;

1. ERA reflects the average PRO fee in Austria;
2. The PRO fee in Austria is 10% lower than the ERA fee;
3. The PRO fee in Austria is 10% higher than the ERA fee;

Collection costs

The collection costs are largely based upon 2008 values[131], which might be outdated and have decreased due to efficiency gains. Therefore, a scenario is foreseen where the collection costs decrease by 50%.

Recycling costs

The recycling costs consist are largely based upon 2008[131] and 2016[132], which might be outdated and have decreased due to efficiency gains. The recycling costs consist of the cost for shredding, sorting, dismantling; recycling and recovery. It is quite possible that either one of these processes has become more efficient or cost effective in the last years, which would mean a decrease in cost. Similar to the collection costs, a scenario is foreseen where the recycling costs decrease by 50%.

These scenarios are confined in three potential scenarios, displayed in the table below. The first scenario is marked as the standard scenario, as this is based upon the currently available information. The second scenario is marked as the worst-case scenario, where the PRO fee further increases due to competition between PRO's. The collection costs and recycling costs stay at the standard values. Lastly, the third scenario is marked as the best-case scenario, since in this scenario the PRO fees increase, and both the collection and recycling costs decrease.

Scenario	PRO fee	Collection costs	Recycling costs
1 Standard	Stabilized	Std	Std
2 Worst-case	10% lower	Std	Std
3 Best-case	10% higher	Decreased 50%	Decreased 50%

The result of this analysis is shown in the graph below. The graph below shows the net result (all cost and benefits combined). It can be seen that only in the best-case scenario (increasing PRO fee and decreasing operating cost) the net result is positive. For scenario 1 and 2 the result starts positive, but shortly becomes negative. This is explained by the decreasing PRO fees, and increasing collection numbers.

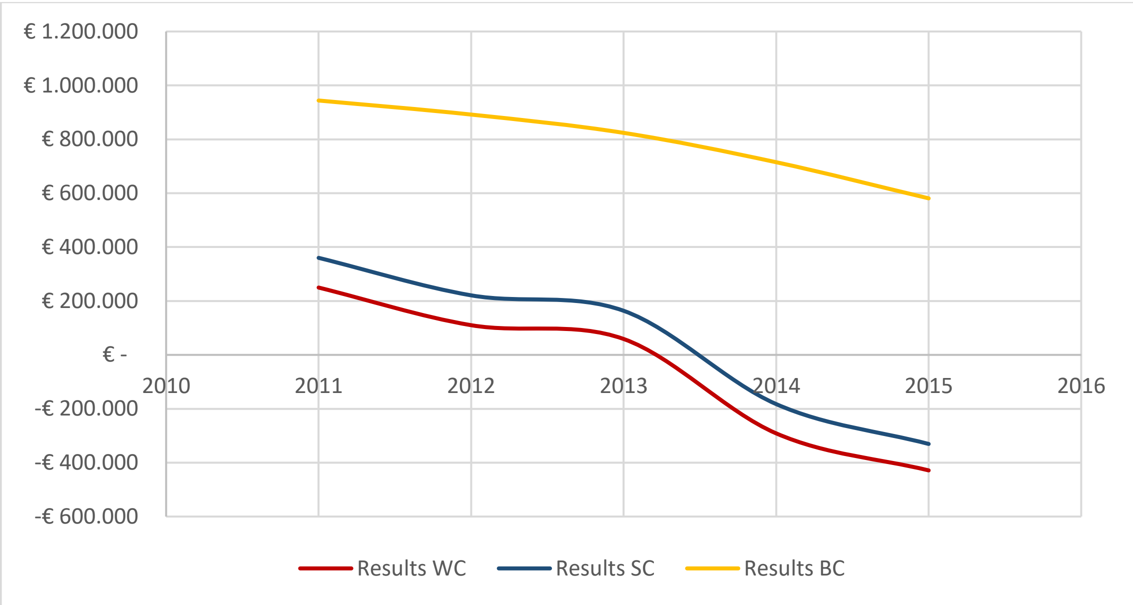


Figure 73 - Sensitivity analysis Vienna

5.3.5. EVALUATION AND CONCLUSION

As for the Vienna case identified no direct investments in the reference period, no cost effectiveness number is calculated.

Total investment	€ -	Euro
Extra WEEE collected	1350	Tons
Cost effectiveness	€ -	Euro/ton

Table 52 - Cost effectiveness of investment in Vienna

5.4. COST-BENEFIT ANALYSIS GENOVA

5.4.1. PROJECT DEFINITION GENOVA

With the launch of the WEEENMODELS project, the WEEEE collection system in Genoa has been significantly expanded. 47 new mobile collection points were created for small WEEE, as well as four ecological islands, i.e. collection and recycling areas, distributed all over the territory, where citizens can bring their WEEE.

The mobile collection system operates daily in different parts of the city. In practice the mobile collection system operates through a system of two equipped vans (ECOVAN +, and ECOCAR) which stop at different stations at scheduled times and locations and where citizens can confer their small WEEE, including lamps. Small household equipment can be brought to the ecological islands and to the ECOVAN+. IT equipment can be brought to the ecological islands or to the ECOVAN+.

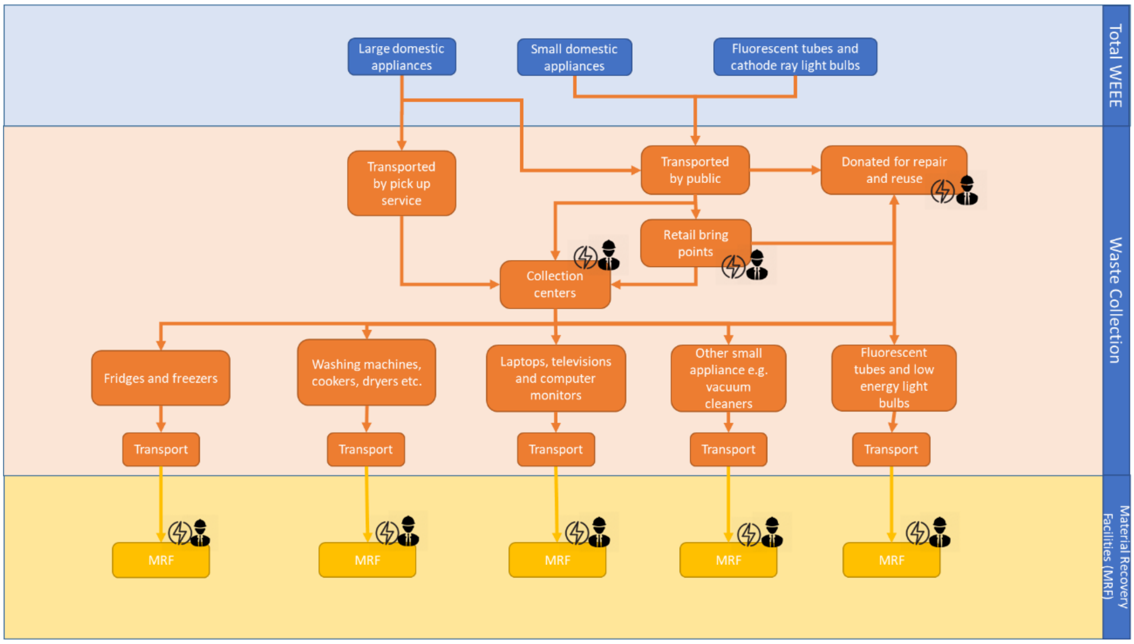


Figure 74 - Flowchart WEEE collection in Genova

5.4.2. IDENTIFICATION OF COSTS AND BENEFITS FOR WEEE COLLECTION IN GENOVA

The costs and benefits of the practice within the WEEENmodel project has been assessed by identifying the various cost and benefits for the period of 2013 to 2016.

THE INVESTMENT COSTS

Item	Assumption & data source	Unit cost
Collection points and recycling areas	Starting in 2014, AMIU created 47 new mobile collection points for small WEEE and 4 ecological islands, i.e. collection and recycling areas, distributed all over the territory, where citizens can bring their WEEE[188]. The investment costs are assumed to be the costs for creation of the new WEEE Collection centre (€ 172,876) and implementation, coordination and tuning of collection services (€	€ 27,780

[188] WEEENmodels project, http://www.weeenmodels.eu/EN/collection_web_system.html

	129,728) from the WEEENmodels Technical report[189], totalling at € 302,604. As part of LIFE project, 50% of these cost have been financed by the European Commission[190].	
	The investment costs are focused on all WEEE categories, and therefore an allocated percentage of 18.36% is used to assign the costs to the SHA and lamp categories. This percentage is the mass based percentage of the combined SHA and lamp stream to the full WEEE stream.	
Public awareness	Information and public awareness raising costs are € 89,715 and costs for the promotion of the new collection services are € 49,393[189]. As part of LIFE project, 50% of these cost have been financed by the European Commission[190].	€ 12,771
	The investment costs are focused on all WEEE categories, and therefore an allocated percentage of 18.36% is used to assign the costs to the SHA and lamp categories. This percentage is the mass based percentage of the combined SHA and lamp stream to the full WEEE stream.	
Mobile collection points	AMIU has invested in two equipped vans (ECOVAN +, and ECOCAR) for collection of WEEE[188]. No investment costs are known, but these are estimated at € 5,000 per van. The vans are purchased in XXX.	€ 1,836
	The investment costs are focused on all WEEE categories, and therefore an allocated percentage of 18.36% is used to assign the costs to the SHA and lamp categories.	

Table 53 - Overview of investment costs

OPERATING COSTS

Item	Assumption & data source	Unit cost
Collection and transport costs SHA	No actual costs from AMIU are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of SHA are on average € 129 per ton[191]. As Italian PRO's are not financially responsible for collection (assumed to be 50%), only transport costs have been taken into account.	€ 65/ton
	Detailed collection data from AMIU is known from the WEEENmodels project[192], for 2013 – 2016.	
Collection and transport costs Lamps	No actual costs from AMIU are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of lamps are on average € 259 per ton[191]. As Italian PRO's are not financially responsible for collection (assumed to be 50%), only transport costs have been taken into account.	€ 130/ton
	Detailed collection data from AMIU is known from the WEEENmodels project[192], for 2013 – 2016.	

189 WEEENmodels project, technical report; http://www.weeenmodels.eu/allegati/Weeenmodels%20life%20Final%20Technical%20report.pdf
190 http://www.weeenmodels.eu/allegati/E1%20MIDTERM_REPORT%2030_June%202015.pdf
191 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE), United Nations University, 2008
192 http://www.weeenmodels.eu/allegati/C1%20WEEE%20Data%20Overview%202013-2016%20.pdf - 2009-2011 data unkown and extrapolated

Recycling costs SHA	No actual costs from AMIU are publicly available or known, therefore average collection and transport costs have been used. The technical costs for shredding, sorting and dismantling SHA are on average € 203 per ton; the costs for recycling SHA are negative due to recovery of valuable materials at -€ 98/ton; and the costs for incineration and landfilling of non-recyclable materials of € 24 per ton. This fits with Italy's landfill tax, which varies between regions, from 5.2€ to 25.82€ per ton[206]. It is assumed all collected WEEE is shredded, sorted and dismantled. Based on the collection data mentioned above and the national WEEE recycling rates[193] the amount of WEEE sent to recycling and to landfill is calculated.	€ 129/ton
Recycling costs Lamps	No actual costs from AMIU are publicly available or known, therefore average collection and transport costs have been used. The technical costs for shredding, sorting and dismantling lamps are on average € 95 per ton; the costs for recycling and recovery of lamps are € 240/ton; and the costs for incineration and landfilling of non-recyclable materials if € 8 per ton[191]. It is assumed all collected WEEE is shredded, sorted and dismantled. Based on the collection data mentioned above and the national WEEE recycling rates[193] the amount of WEEE sent to recycling and to landfill is calculated.	€ 343/ton
Compliance	In order to operate lawfully and abide the procedures set out by the national and European law, the PROs make certain costs for compliance; costs related to proof of legal compliance, quality and service level (e.g. waste classification, control by and reporting to authorities/compliance schemes), and implementation of standards. For both SHA these costs are on average € 37/ton[146]. For lamps, no compliance costs information is available, therefore these are assumed to be identical to compliance costs for SHA.	€ 37/ton

Table 54 - Overview of operational costs

REVENUES

Item	Assumption & data source	Unit cost
PRO fee from producers	As mentioned earlier AMIU is the collection service owned by the Genova Municipality and largely financed by the City of Genova through the citizen waste tax. The scope of the CBA is from the PRO's perspective, therefore, average national CDCR numbers of members charges per ton of WEEE collected are used[194]. AMIU is not directly charging a PRO fee, as they are largely paid by the City of Genova through the Waste Tax. This amount is unknown, as it covers multiple waste streams and a breakdown is not available/measured. AMIU does receiving a contribution from the Italian PRO's in the form efficiency prices; AMIU receives € 113/ton for good quality collected WEEE.	€ 63.55/ton

[193] National WEEE recycling rates https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_rt130&plugin=1

[194] The evolution of the Italian EPR system for the management of household Waste Electrical and Electronic Equipment (WEEE). Technical and economic performance in the spotlight: http://www.weeenmodels.eu/upload/030716100520.pdf

	It is assumed AMIU operational costs are covered by the PRO's operational costs. Data for 2009 – 2014 is known. A sharp decrease in PRO fee can be noticed, from € 653/ton is 2009 to € 374/ton in 2014. It is stated that competition has played a significant role in reducing the fees. As no data is available for the PRO fee in 2015 and 2016, three scenarios are foreseen; 1. The PRO fee stabilized at € 374/ton; 2. The PRO fee decreased further with a similar trend to € 287.45 and € 231.30 per ton in 2015 and 2016 respectively. 3. The PRO fee increases and gets back to 2009 and 2010 values of € 653/ton and € 539.83/ton.	
	This PRO fee is covering all WEEE categories. Based on a weight percentage, the allocated part for SHA and lamps is calculated. Using the total collected amounts of WEEE per year by AMIU, the percentage of SHA and lamps is calculated for 2013 – 2016. On average, SHA and lamps make up 18% of the total weight of the collected WEEE. Including this percentage, the PRO fee for 2014 is calculated at € 63.55/ton.	
	The total PRO income is calculated using the above-mentioned PRO fee and the Put on Market values (WEEENMODELS report). Using inhabitant numbers from Weeenmodels.	
Rewards or government contributions	The Centro di Coordinamento RAEE (CDCRAEE) mentions Efficiency Rewards[195]; monetary amounts paid by the producers through the Collective Systems to local authority designated collection facilities, distributors' collection sites and individual collection sites according to the quantities of WEEE they collect. Efficiency Rewards promote efficient collection processes and increase the numbers of WEEE collected and sent for suitable treatment. Only 2018 data is available, and AMIU is not mentioned as a recipient of this reward in 2018.	-
	WEEE Coordination Centre, EEE Producers, ANCI (National Association of Italian Borough Councils) and recycling companies have set up a fund of € 13 per ton. The amounts collected are used to upgrade and build infrastructures of designated collection facilities. There is no mention whether AMIU was sponsored with this fund.	

Table 55 - Overview of revenues

5.4.3. CBA RESULTS GENOVA

The graph below shows an overview of the investment costs, the operational costs, the total revenues and the financial net present value (FNPV). It can be seen that the estimated operational costs are lower than the revenues and therefore the FNPV is positive throughout the project period.

[195] CDCR, annual report 2018

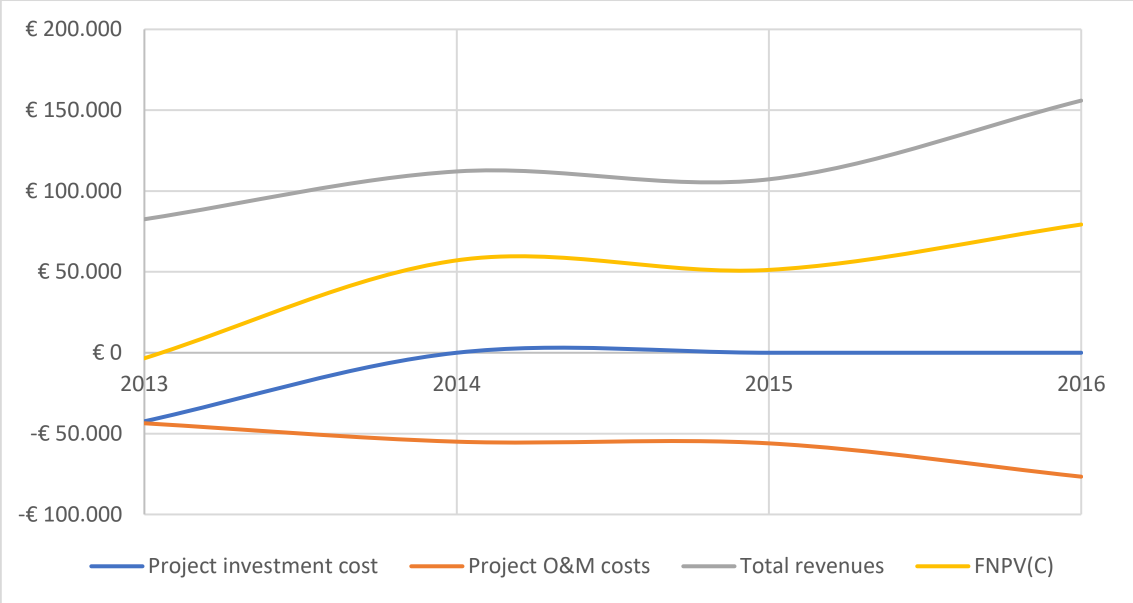


Figure 75 – Overview of financial flows for WEEE collection in Genova 2013 -2016

5.4.4. SENSITIVITY ANALYSIS

In order to filter out the uncertainties in the data, a sensitivity analysis has been performed on three parameters; i) the PRO fee; ii) the collection costs and iii) the recycling costs.

The PRO fee

As discussed earlier in the table above, the exact PRO fee charged is not available. Therefore, average national CDCR numbers of members charges per ton of WEEE collected are used[196]. Data for 2009 – 2014 is known. A sharp decrease in PRO fee can be noticed, from € 653/ton is 2009 to € 374/ton in 2014. It is stated that competition has played a significant role in reducing the fees. As no data is available for the PRO fee in 2015 and 2016, two scenarios are foreseen;

1. The PRO fee stabilized at € 374/ton;
2. The PRO fee decreased further with a similar trend to € 287.45 and € 231.30 per ton in 2015 and 2016 respectively.
3. The PRO fee increases and gets back to 2009 and 2010 values of € 653/ton and € 539.83/ton.

Collection costs

The collection costs are largely based upon 2008 values[131], which might be outdated and have decreased due to efficiency gains. Therefore, a scenario is foreseen where the collection costs decrease by 50%.

Recycling costs

The recycling costs consist are largely based upon 2008[131] and 2016[132], which might be outdated and have decreased due to efficiency gains. The recycling costs consist of the cost for shredding, sorting, dismantling; recycling and recovery. It is quite possible that either one of these processes has become more efficient or cost

[196] The evolution of the Italian EPR system for the management of household Waste Electrical and Electronic Equipment (WEEE). Technical and economic performance in the spotlight: http://www.weeenmodels.eu/upload/030716100520.pdf

effective in the last years, which would mean a decrease in cost. Similar to the collection costs, a scenario is foreseen where the recycling costs decrease by 50%.

These scenarios are confined in three potential scenarios, displayed in the table below. The first scenario is marked as the standard scenario, as this is based upon the currently available information. The second scenario is marked as the worst-case scenario, where the PRO fee further increases due to competition between PRO's. The collection costs and recycling costs stay at the standard values. Lastly, the third scenario is marked as the best-case scenario, since in this scenario the PRO fees increase, and both the collection and recycling costs decrease.

Scenario	PRO fee	Collection costs	Recycling costs
1 Standard	Stabilized	Std	Std
2 Worst-case	Decreasing	Std	Std
3 Best-case	Increasing	Decreased 50%	Decreased 50%

The result of this analysis is shown in the graph below. The graph below shows the net result (all cost and benefits combined). It can be seen that only in the best-case scenario (increasing PRO fee and decreasing operating cost) the net result becomes positive right away. For scenario 1 the results is realistic, and for scenario 2 the result is negative.

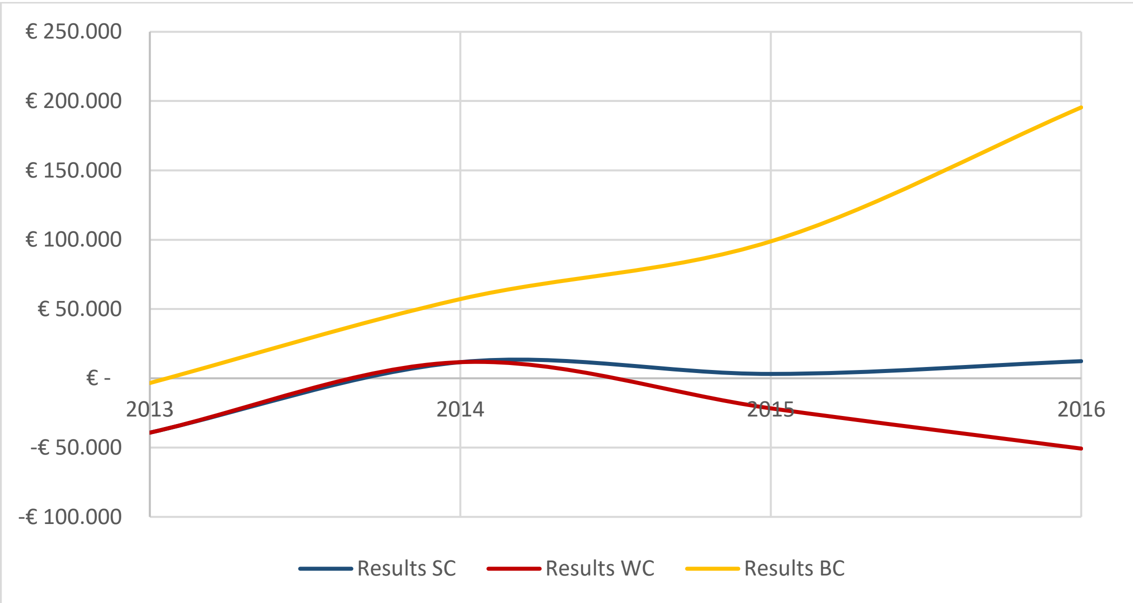


Figure 76 – Sensitivity analysis Genova

5.4.5. EVALUATION AND CONCLUSION

Assuming the operational costs haven't increased due to the implementation of the new WEEE collection system, we can assess the cost effectiveness of the investment. By investing € 42,387, AMIU was able to increase the collection rates of SHA and lamps significantly (see graph in introduction). Assuming 2013 as reference year, with 263 tons of SHA and 4.43 tons of lamps collected, the 2016 collection values show an increase in collection numbers of 229.72 tons of SHA and 2.51 tons of lamps. Taking the full investment, we find a price of € 182.52/ton of additional WEEE collected. It is important to note that collection, transport and processing costs are not even included in this calculation. Including these operational costs, combined with the potential recycling benefits (mention 2008 weee costs source), would results in a higher number.

Total investment	€	42,387	Euro
Extra WEEE collected		232.23	Ton
Cost effectiveness	€	182.52	€/ton

Table 56 - Cost effectiveness of investment in Genova

As discussed in the project rationale, an estimated € 1.480 per ton of WEEE is lost due to scavenging and improper recycling. The cost effectiveness calculated for the Genova project is lower than the estimated material losses.

5.5. COST-BENEFIT ANALYSIS CYCLAD

5.5.1. PROJECT DEFINITION CYCLAD

Cyclad has 25 civic amenity sites (CAS), where citizens can drop of WEEE. At each collection site, there are normally two containers for small WEEE & IT, and two for large WEEE. These containers are shared with Eco-systèmes and once they are full, Cyclad contacts Eco-systèmes or Recylum (for lamps) to hire the pick up and transport to the recycling facilities.

The EPR compliance organizations responsible for the collection, depollution and sorting of household WEEE and lamps are Eco-systemes and Recylum respectively. Since January 2018, both companies merged by the name, ESR, with the interest of developing a more circular economy and promoting eco-design initiatives of member producers (Cyclad, 2019).

Cyclad cooperates also with a number of retailers. When the retailers' storage space is full, they call Eco-systèmes to pick up the WEEE. In addition, supermarkets provide drop off points for lamps, batteries and mobile phones. There are 5 social economy shops on Cyclad territory, where people can drop off WEEE and buy second hand upcycled/recycled WEEE objects, i.e. the Emmaüs and Envie networks.

The collection consists of recovering WEEE from consumer-dwellers, sorting them into 3 separate streams and making them available to its service providers at collection points, these consist of waste disposal centers, shops and Emmaus centers. This work is carried out by the partners/stakeholders of the territory (communities, distributors, social and solidarity economy shops). 25 civic amenity sites spread over the territory are provided per zip codal area. In addition, Cyclad cooperates with a number of retailers for the collection of the WEEE. Citizens are also able to dispose WEEE via the CAS. Citizens do need to provide ID; either a utility bill, ID, or a registration documents for car. Also, supermarkets provide drop off points for lamps and mobile phones. In total, there are 11 social economy shops and 1 Emmaüs centre on Cyclad's territory, where people can drop off WEEE and buy second hand upcycled/recycled WEEE objects.

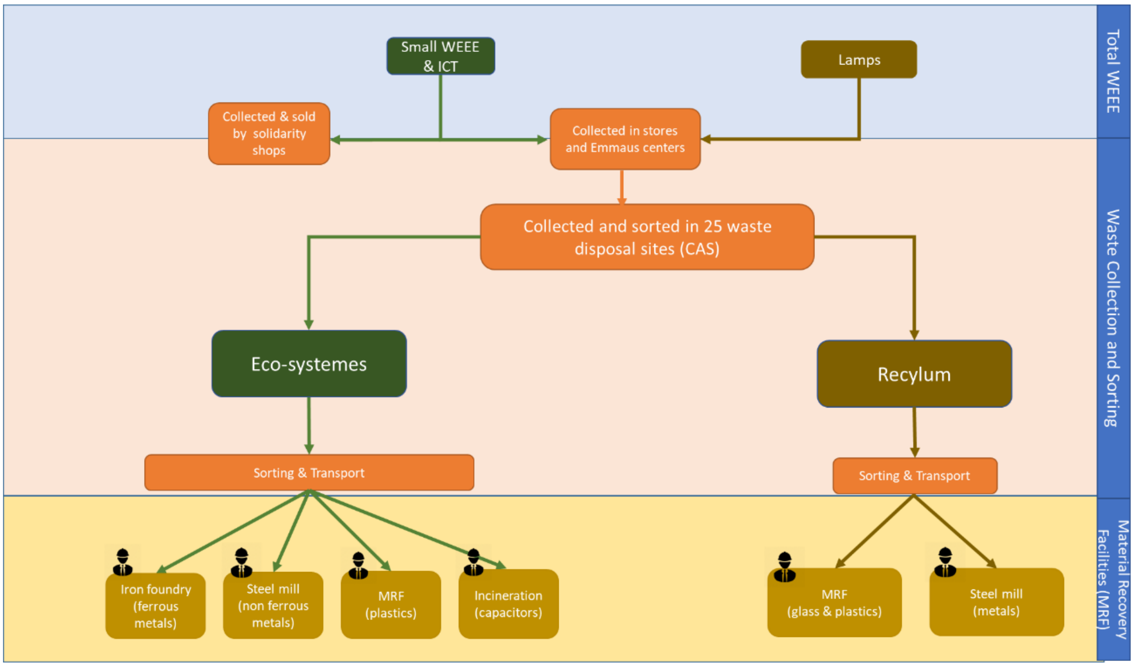


Figure 77 - Flowchart WEEE collection in Cyclad

5.5.2. IDENTIFICATION OF COSTS AND BENEFITS FOR WEEE COLLECTION IN CYCLAD

The biggest problem related to WEEE collection in the past was theft. In 2011 France introduced a legal ban on cash transaction for metals, to avoid WEEE leakage at borders and to include scrap dealers in the system and avoid WEEE non-compliant treatment. In order to protect metals, WEEE and batteries Cyclad bought containers (20ft) with special locks. In addition, they introduced video surveillance at all sites. Cyclad marks LHA with orange paint making them easier to recognize as collected WEEE. In addition all treatment operators nearby are informed that if someone brings a marked appliance to their facilities, it means the appliance was stolen from a collection point. Furthermore, a special contract with the police who regularly checks the site to make sure that the employees are safe. Thanks to these measures the stealing decreased significantly and the WEEE flow is better under control. Further measures that increased the collected WEEE quantities include awareness raising campaigns to mobilize small WEEE that people keep at home in their drawers. Since there was a hoax in France that all WEEE is going to India, some campaigns have been launched to inform the general public on where the WEEE goes.

At the big civic amenity sites (CAS), there are normally two containers for small WEEE & IT, and two for large WEEE. These containers are shared with Eco-systèmes and once they are full, Cyclad contacts Eco-systèmes hire the pick up and transport to their sorting facilities.

THE INVESTMENT COSTS

In the table below the investment costs are discussed.

Item	Assumption & data source	Unit cost
Containers for WEEE storage	In 2014, Cyclad invested in 20ft containers to prevent theft of valuable WEEE appliances. One container cost approximately € 2,500. Cyclad has 25 disposal sites for WEEE[197], and 2-4 containers per site[198].	€ 64,748

[197] Information on WEEE disposal in Cyclad, 2018, http://www.cyclad.org/page.php?P=55
[198] Telephonic interview Cyclad, March 2019

	Assumed allocated costs for awareness for these waste streams are calculated based on a mass percentage (SHA, IT, and lamps compared to the total WEEE stream = ~ 35%).	
Video surveillance and protection[199]	In 2014, Cyclad invested in video surveillance for protection of the WEEE. The costs for video protection are € 5,000 per disposal site[198]. Cyclad has 25 disposal sites for WEEE[197]. Assumed allocated costs for awareness for these waste streams are calculated based on a mass percentage (SHA, IT, and lamps compared to the total WEEE stream = ~ 35%).	€ 43,166

Table 57 - Overview of investments

OPERATING COSTS

Eco-Systemès supports logistics costs and treatment of WEEE from collection points. Logistics operations include the collection, but also the consolidation and provision of pallets crates and bins. Recycling, pollution control and sorting of materials are the most important treatment processes.

Item	Assumption & data source	Unit cost
Communication and awareness campaigns	ESR supports collection points by providing financial support for awareness and communication campaigns. The costs are specified per regional area type (rural, semi-urban, urban) and per number of inhabitants. Collection points can request financial support up to: - Posters € 800 - Sorting guides € 1,000 - Signs € 1,800 - Communication events € 5,000 This totals to € 8,600 per year per collection point. It is assumed Cyclad requests 50% of the financial support every year. Assumed allocated costs for awareness for these waste streams are calculated based on a mass percentage (SHA, IT, and lamps compared to the total WEEE stream = ~ 35%).	1,485 €/ year
Collection and transport costs SHA	Collection points, such as Cyclad, receive a contribution for their WEEE collection. For Cyclad, the financial contribution for the collection activities are known for the period of 2010-2017[198]. The contribution fluctuates between € 44 – 88 per ton of collected WEEE, depending on the quality. On average, the contribution for collection is € 69.13/ton. No information is available for transport costs from ESR. The logistical costs for the transport of SHA are estimated to be € 120/ton[200]. Detailed WEEE collection data for Cyclad is known for SHA between 2014 – 2018[201,202]. The numbers are reported in four categories; LHA (GEM HF), Cooling appliances (GEM F), Screens (Ecrans) and SHA and IT (PAM).	€ 189.13 /ton
Collection and transport costs Lamps	Collection points, such as Cyclad, receive a contribution for their WEEE collection. For Cyclad, the financial contribution for the collection activities are known for the period of 2010-2017[198]. The contribution fluctuates between € 44 – 88 per ton of collected WEEE, depending on the quality. On average, the contribution for collection is € 69.13/ton.	€ 189.13 /ton

[199] www.eco-systemes.fr/soutiens-protection
[200] Skype call with WEEEForum members, July 2019
[201] Annual report DEEE, Cyclad 2017 http://www.cyclad.org/UserFiles/medias/doc/2017%20-%20Rapport%20DEEE.pdf
[202] Annual report DEEE Cyclad 2018, http://www.cyclad.org/UserFiles/medias/doc/ESR%202018-compresse.pdf

	No information is available for transport costs from Recylum or ESR. The logistical costs for the transport of WEEE are on average € 120 per ton[200].	
	Since 2018, ESR is collaborating with the French collection scheme for lamps; Recylum. Recylum reports the amounts of collected lamps in France. For 2018, the amount of collected lamps in Cyclad is available[198]. Unfortunately, for the other years, no specific data is known for Cyclad, and only national data is available[203]. For 2014-2017 national data has been extrapolated based on the total Cyclad inhabitants and the total inhabitants in France[204]. As Collectors focuses on household waste, only collected lamps from household sources are included (Recycleurs DEEE, Collecteurs, Utilsateurs finaux).	
Recycling costs SHA	No actual costs from ESR are publicly available or known, therefore average recycling costs have been used. The technical costs for shredding, sorting and dismantling and depollution of SHA are on average € 203 per ton[205]; the costs for recycling SHA are negative due to recovery of valuable materials at -€ 98/ton; and the average costs for incineration and landfilling of non-recyclable materials in 2008 are € 24 per ton[131]. Especially the cost for landfilling and incineration might be outdated, as this is easily influenced by policy. The landfill tax in France has been increasing over the last couple of years to € 40 per ton for authorized landfills[206]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. For 2017, the net total recycling costs for SHA come down to € 145/ton.	€ 145/ton
	It is assumed all collected appliances are shredded, sorted and dismantled. Based on the collection data mentioned above and the ESR WEEE recycling rates[207] the amount of WEEE sent to recycling and to landfill is calculated. Only recycling data for 2017 is known, for other years a similar percentage is assumed.	
Recycling costs Lamps	No actual costs from ESR are publicly available or known, therefore average recycling costs have been used. The technical costs for shredding, sorting and dismantling lamps are on average € 95 per ton; the costs for recycling and recovery of lamps are € 240/ton; and the costs for incineration and landfilling of non-recyclable materials if € 8 per ton[131]. Especially the cost for landfilling and incineration might be outdated, as this is easily influenced by policy. The landfill tax in France has been increasing over the last couple of years to € 40 per ton for authorized landfills[206]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. For 2013, the total recycling costs for lamps come down to € 375/ton.	€ 375/ton
	It is assumed all collected lamps are shredded, sorted and dismantled. Based on the collection data mentioned above and the national ESR WEEE recycling rates the amount of WEEE sent to recycling and to landfill is calculated[203].	
Compliance	In order to operate lawfully and abide the procedures set out by the national and European law, the PROs make certain costs for compliance; costs related to proof of legal compliance, quality and service level (e.g. waste classification, control by and reporting to authorities/compliance schemes), and implementation of standards. For both SHA these costs are on average € 37/ton[146]. For lamps, no compliance costs information is	€ 37/ton

[203] Recylum, annual report 2017, https://www.recylum.com/presse/rapports/rapport-dactivite-deee-2017/
[204] Google Public Data, Inhabitants France 2014-2017
[205] United Nations University, WEEE Recycling Economics – the shortcomings of the current business model, 2018
[206] CEWEP, 2017, http://www.cewep.eu/wp-content/uploads/2017/12/Landfill-taxes-and-bans-overview.pdf
[207] ESR recycling rates for SHA, 2017, https://www.eco-systemes.fr/en/all-about-eco-systemes

	available, therefore these are assumed to be identical to compliance costs for SHA.	

Table 58 - Overview of operational costs

REVENUES

The recycling of WEEE is financed by the Eco-participation fee paid with each purchase of new equipment. The use of eco-modulated fees in France directly incentives producers to put more environmental friendly products on the market; e.g. when a product meets certain environmental criteria, the producer receives a discount on the PRO fee. This is nationally agreed with ADEME and the other PROs in France.

Under the EU WEEE directive vendors have an obligation to recover end-of-life devices. More and more communities are offering this line to their waste treatment centers to facilitate sorting and promote recycling. Eco-systemes distributes the ecoparticipation as follows:

- 4%: Ecosystemes wages / offices / cars
- 3%: External Communication
- 73%: Operational cost (to collect / transport / recycle / research and development).
- 20%: Financial compensation for the structures who are collecting WEEE.

Item	Assumption & data source	Unit cost
PRO fee for SHA	The exact PRO fee ESR receives for her services is not known. It is known that ESR charges her members per category[208]. In addition, the French system uses eco-modulated fees: EEE that is more environmentally friendly gets a discount on the fees. Since the fees are available per product category, no prices per ton of collected WEEE are available. It is therefore assumed ESR receives the French average PRO fee for SHA[149]. For 2013 – 2015 average EEE fees for France are known. The average fee for 2013 is € 145 per ton, and € 234 per ton in 2015. As no data is available for the fees in 2016, 2017 and 2018, three scenarios are foreseen; 1. The PRO fee stabilizes at € 234/ton for future years; 2. The PRO fee is 10% lower than the average French fee and decreases with a yearly 10% for future years; 3. The PRO fee is 10% higher than the average French fee and increases with a yearly 10% for future years;	€ 234/ton
	The total PRO income is calculated using the above-mentioned PRO fee and the EEE Put on Market values from ESR producers. REPIC is the only compliance scheme active in Cyclad[201].	
	The EEE put on market amounts are calculated from national average French from the Urban Mine Platform[151] and the amount of citizens in Cyclad[201].	
PRO fee for Lamps	The PRO fee Récylum receives for her services is available, per product[209]. Since the fees are available per product category, no prices per ton of collected lamps are available. It is therefore assumed Récylum receives the average European PRO fee for lamps[149]. For 2014 – 2016 average European EEE fees for are known. The average fee for 2014 is € 500 per ton, and € 625 per ton in 2016. As no data is available for the fees in 2017 and 2018, three scenarios are foreseen; 1. The PRO fee stabilizes at € 625/ton for future years;	€ 625 /ton

[208] https://www.eco-systemes.fr/partenaires-et-professionnels/producteurs/bareme-eco-systemes
[209] https://www.recylum.com/assets/recylumuploads/2017/10/Bareme_DEEE_Pro_ESR_Recylum_2018.pdf

	2. The PRO fee is 10% lower than the European average fees and decreases with a yearly 10% for future years; 3. The PRO fee is 10% higher than the European average fees and increases with a yearly 10% for future years;	
	The total PRO income is calculated using the above-mentioned PRO fee and the EEE Put on Market values from Récylum producers. Recylum is the only compliance scheme active in Cyclad[201].	
	The EEE put on market amounts are calculated from national average French from the Urban Mine Platform[151] and the amount of citizens in Cyclad[201].	

Table 59 - Overview of revenues

5.5.3. CBA RESULTS CYCLAD

The graph below shows an overview of the investment costs, the operational costs, the total revenues and the financial net present value (FNPV). It can be seen that the operational costs and revenues follow a similar trend. The FNPV therefore is fairly constant and positive.

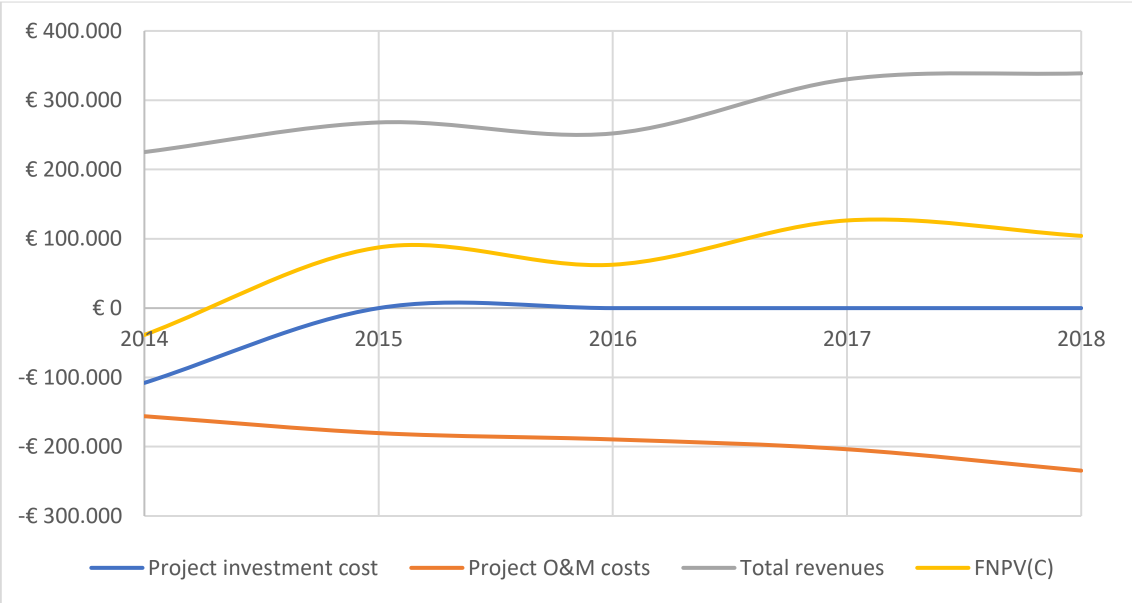


Figure 78 – Overview of the financial flows of WEEE collection in Cyclad, 2014 - 2018

5.5.4. SENSITIVITY ANALYSIS

In order to filter out the uncertainties in the data, a sensitivity analysis has been performed on three parameters; i) the PRO fee; ii) the collection costs and iii) the recycling costs.

The PRO fee

As discussed earlier in Table 59 above, the PRO fee charged by ESR only available per product type. It is therefore assumed ESR receives the French average PRO fee for SHA and the European average PRO fee for lamps[149]. For 2013 – 2016 average EEE fees are known. Due to various uncertainties, the following scenario's are assumed;

1. The PRO fees stabilize for future years;
2. The PRO fees are 10% lower than the average fees and decreases with a yearly 10% for future years;
3. The PRO fees are 10% higher than the average fees and increases with a yearly 10% for future years;

Collection costs

The collection costs are largely based upon 2008 values[131], which might be outdated and have decreased due to efficiency gains. Therefore, a scenario is foreseen where the collection costs decrease by 50%.

Recycling costs

The recycling costs consist are largely based upon 2008[131] and 2016[132], which might be outdated and have decreased due to efficiency gains. The recycling costs consist of the cost for shredding, sorting, dismantling; recycling and recovery. It is quite possible that either one of these processes has become more efficient or cost effective in the last years, which would mean a decrease in cost. Similar to the collection costs, a scenario is foreseen where the recycling costs decrease by 50%.

This results in three possible scenarios, displayed in the table below. The first scenario is marked as the standard scenario, as this is based upon the currently available information. The second scenario is marked as the worst-case scenario, where the PRO fee further increases due to competition between PRO's. The collection costs and recycling costs stay at the standard values. Lastly, scenario three is marked as the best-case scenario, as in this scenario the PRO fees increase, and both the collection and recycling costs decrease.

Scenario	PRO fee	Collection costs	Recycling costs
1	Stabilized	Std	Std
2	Decreasing	Std	Std
3	Increasing	Decreased 50%	Decreased 50%

The result of this analysis is shown in the graph below. It can be seen that all scenarios are positive.

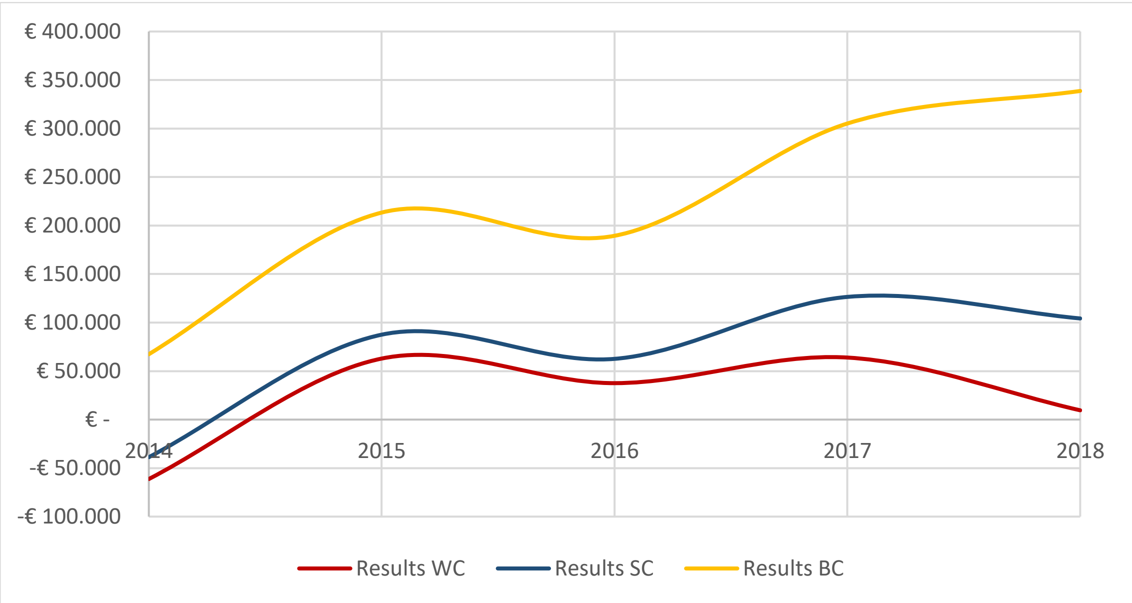


Figure 79 - Sensitivity analysis Cyclad

5.5.5. EVALUATION AND CONCLUSION

Assuming the operational costs haven't increased due to the implementation of the new WEEE collection system, we can assess the cost effectiveness of the investment. Considering the investment of € 107,914 made by Cyclad in 2014, and financially supported by ESR, we can assess the cost effectiveness of the collection practice. By investing this amount, Cyclad was able to increase both the collection of SHA, IT and lamps by keeping the valuable WEEE appliances within their collection grounds. Assuming 2014 as reference year, with 433 tons of SHA and IT and 1.82 tons of lamps collected, the 2018 collection values show an increase in collection numbers of 201.9 tons of SHA/IT and 3.52 tons of lamps. Taking the full investment, we find a price of €

525.33/ton of additional WEEE collected. Although € 523 per ton of WEEE is substantial, it is significantly smaller than the earlier mentioned € 1,480 per ton of SHA lost due to scavenging.

Total investment	€ 107,914	Euro
Extra WEEE collected	205	Ton
Cost effectiveness	€ 525.33	Euro/ton

Table 60 - Cost effectiveness of investment in Cyclad

As discussed in the project rationale, an estimated € 1,480 per ton of WEEE is lost due to scavenging and improper recycling. The cost effectiveness calculated for the Pembrokeshire project is lower than the estimated material losses.

5.6. COST-BENEFIT ANALYSIS HELSINKI

5.6.1. HELSINKI, FINLAND

In Finland approximately 450 collection points existed in 2011 around the country. Most of these are located in the populated southern area of Helsinki. Permanent collection points are, in most cases collectively financed by the producer associations, provided by the municipality and, in some cases, by private companies or social enterprises. Private users and households can bring their end-of-life products to the collection points free of charge. However, permanent collection systems are not always efficient, due to e.g. long distances and low quantities of returned devices, therefore also pickup services are available.

The logistics services are typically sourced from private regional operators. At the collection points, the WEEE is divided into four different fractions with lamps and batteries being collected separately: cooling appliances, large household appliances, small household appliances and IT. All kind of lamps are collected separately of other SDA by FLIP Association, a producer organization responsible for the producer responsibility of lamps falling within the scope of the WEEE directive[2].

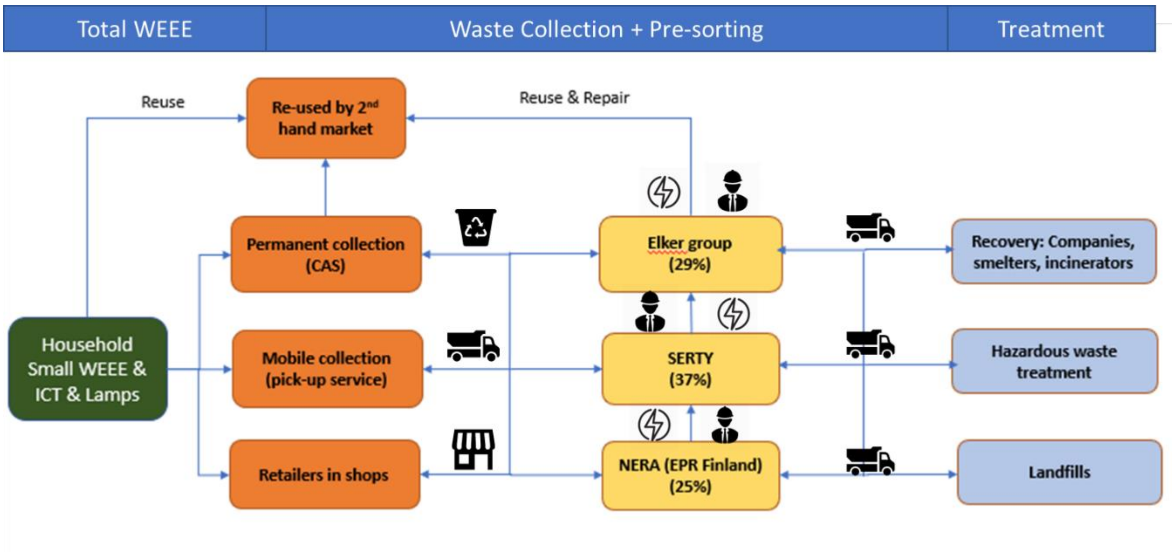


Figure 80 - Flowchart WEEE collection in Helsinki

5.6.2. IDENTIFICATION OF COSTS AND BENEFITS FOR WEEE COLLECTION IN HELSINKI

THE INVESTMENT COSTS

In the table below the investment costs are discussed.

Item	Assumption & data source	Unit cost
Expanding collection network	Since May 2013 small WEEE including lighting equipment (all dimensions no more than 25 cm) can be returned with no purchase obligation to electronics shops with area larger than 200 m2 or to grocery shops of 1000 m2 minimum. There was invested in 500 bring containers in the Helsinki capital region[210]. It is assumed only Serty invested in containers.	€125,000
	Containers are estimated to be of various sizes and cost approximately 250eu per piece (including, design, installation, transport and replacement).	

Table 61 - Overview of investments

OPERATING COSTS

As no case specific information for a PRO was available, the scope has been broadened to all operational PRO's in Helsinki.

Item	Assumption & data source	Unit cost
Communication and awareness campaigns	On average, Serty invested € 50 000 in communication and awareness (e.g. taping of containers).	€ 250,000/ year
	As there are 5 PRO's (i) FLIP ry, (ii) ICT-tuottajaosuuskunta, (iii) SELT ry, (iv) SERTY ry, (v) ERP Finland ry (Elker Ltd. is founded by Flip, ICT and SELT), it is assumed all five spent money on communication efforts.	
Collection and transport costs SHA	No actual costs from Helsinki PRO's are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of SHA are on average € 129 per ton[131].	€ 129 /ton
	Collection data from Finland is known from the Urbanmine platform, for 2011 – 2015[211].	
Collection and transport costs Lamps	No actual costs from Helsinki PRO's are publicly available or known, therefore average collection and transport costs have been used. The technical costs for collection and transport of SHA are on average € 259 per ton[131].	€ 259 /ton
	Collection data from Finland is known from the Urbanmine platform, for 2011 – 2015[211].	
Transport	Due to large distances, transportation is the most expensive part of WEEE collection and recycling in Finland. Due to more efficient transport, load weights increased (> 40%) and smarter route planning, the transportation costs were decreased by 30 %. It is assumed this measure is implemented in 2013.	30% decrease
Recycling costs SHA	No actual costs from Finnish PROs is publicly available or known, therefore average recycling costs have been used. The technical costs for shredding, sorting and dismantling and depollution of SHA are on average € 203 per ton[146]; the costs for recycling SHA are negative due to recovery of valuable materials at -€ 98/ton[131].; and the average costs for incineration and landfilling of non-recyclable materials in 2008 are € 24 per ton[131]. Especially the cost for landfilling and incineration might be outdated, as this is easily influenced by policy. The landfill tax in Finland has been increasing over the last couple of years from € 40 per ton in	€ 155/ton

[210] Interview Serty, June 2019
[211] Urban mine, accessed on 8aug2019

	2011 to € 78 per ton in 2018[212]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. For 2015, the net total recycling costs for SHA come down to € 155/ton.	
	It is assumed all collected appliances are shredded, sorted and dismantled. Based on the collection data mentioned above and the WEEE recycling rates[213] the amount of WEEE sent to recycling and to landfill is calculated.	
Recycling costs Lamps	No actual costs from Finnish PROs is publicly available or known, therefore average recycling costs have been used. The technical costs for shredding, sorting and dismantling lamps are on average € 95 per ton; the costs for recycling and recovery of lamps are € 240/ton; and the costs for incineration and landfilling of non-recyclable materials if € 8 per ton[131]. Especially the cost for landfilling and incineration might be outdated, as this is easily influenced by policy. The landfill tax in France has been increasing over the last couple of years to € 40 per ton for authorized landfills[212]. Therefore, the landfill tax is assumed to be the cost for landfilling and incineration. For 2015, the total recycling costs for lamps come down to € 375/ton.	€ 385/ton
	It is assumed all collected lamps are shredded, sorted and dismantled. Based on the collection data mentioned above and the national ESR WEEE recycling rates the amount of WEEE sent to recycling and to landfill is calculated[213].	
Compliance	In order to operate lawfully and abide the procedures set out by the national and European law, the PROs make certain costs for compliance; costs related to proof of legal compliance, quality and service level (e.g. waste classification, control by and reporting to authorities/compliance schemes), and implementation of standards. For both SHA these costs are on average € 37/ton[146]. For lamps, no compliance costs information is available, therefore these are assumed to be identical to compliance costs for SHA.	€ 37/ton

Table 62 - Overview of operational costs

REVENUES

Item	Assumption & data source	Unit cost
PRO fee for SHA	The PRO fee the Finnish PROs receive for their services is not known. As the WEEE flows in Finland are fairly similar to the ones in Norway[214], the Finnish PRO fee is approximated by taking the average of the average EU PRO fee and the PRO fee in Norway[149]. For 2013 – 2015 average EEE fees are known. The average Norwegian fee for 2013-2015 is € 60 per ton. The average EU fee is presented below. For 2011 and 2012 no data is available, these values are extrapolated based on the 2013-2015 values.	€ 103/ton

[212] Landfill tax in Finland; http://www.materiaalitkiertoon.fi/download/noname/%7BF212F529-17B9-45BF-B3DF-5D87FBF3714E%7D/138102, http://ec.europa.eu/taxation_customs/tedb/legacy/taxDetail.html?id=252/1388754737&taxType=Other%20indirect%20tax

[213] https://www.ymparisto.fi/fi-FI/Kartat_ja_tilastot/Jatetilastot/Tuottajavastuun_tilastot/Sahko_ja_elektroniikkalaitetilastot

[214] https://www.researchgate.net/publication/262603927_WEEE_Management_System_-_Cases_in_Norway_and_Finland

<table>
<tr>
<td></td>
<td>
<table>
<tr><th>In €/ton</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td>Norway avg</td><td>60</td><td>60</td><td>60</td><td>60</td><td>60</td></tr>
<tr><td>EU avg</td><td>174</td><td>166</td><td>160</td><td>149</td><td>145</td></tr>
<tr><td>Combined avg</td><td>117</td><td>113</td><td>110</td><td>105</td><td>103</td></tr>
</table>

1. The PRO fee is equal to the Norwegian average;
2. The PRO fee is equal to the combination of both averages;
3. The PRO fee is equal to the EU average.

As a base case scenario 2 is chosen. The other two scenarios are assessed in the sensitivity analysis.
</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The total PRO income is calculated using the above-mentioned PRO fee and the total EEE Put on Market in the Helsinki region.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The EEE put on market amounts are calculated from national average Finnish from the Urban Mine Platform[151] and the amount of citizens in the Helsinki region[215,216].</td>
<td></td>
</tr>
<tr>
<td>PRO fee for Lamps</td>
<td>
The PRO fee the Finnish PROs receive for their services is not known. As the WEEE flows in Finland are fairly similar to the ones in Norway[214], the Finnish PRO fee is approximated by taking the average of the average EU PRO fee and the PRO fee in Norway[149]. For 2013 – 2015 average EEE fees are known.
The average Norwegian fee for 2013-2015 is € 60 per ton. The average EU fee is presented in below. For 2011 and 2012 no data is available, these values are extrapolated based on the 2013-2015 values.

<table>
<tr><th>In €/ton</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td>Norway avg</td><td>60</td><td>60</td><td>60</td><td>60</td><td>60</td></tr>
<tr><td>EU avg</td><td>695</td><td>640</td><td>600</td><td>500</td><td>490</td></tr>
<tr><td>Combined avg</td><td>377.5</td><td>350</td><td>330</td><td>280</td><td>275</td></tr>
</table>

1. The PRO fee is equal to the Norwegian average;
2. The PRO fee is equal to the combination of both averages;
3. The PRO fee is equal to the EU average.

As a base case scenario 2 is chosen. The other two scenarios are assessed in the sensitivity analysis.
</td>
<td>€ 275 /ton</td>
</tr>
<tr>
<td></td>
<td>The total PRO income is calculated using the above-mentioned PRO fee and the total EEE Put on Market in the Helsinki region.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The EEE put on market amounts are calculated from national average Finnish from the Urban Mine Platform[151] and the amount of citizens in the Helsinki region[215,216]</td>
<td></td>
</tr>
</table>

Table 63 - Overview of revenues

5.6.3. CBA RESULTS HELSINKI

The graph below shows an overview of the investment costs, the operational costs, the total revenues and the financial net present value (FNPV). It can be seen that the operational costs and revenues follow a similar trend.

[215] UN population data, 2018
[216] Collectors data base Helsinki, https://www.collectors2020.eu/wcs-weee/helsinki-capital-region-fi/

The FNPV therefore is fairly constant and positive. This means that for these assumptions, the operations of the PRO are financially viable.

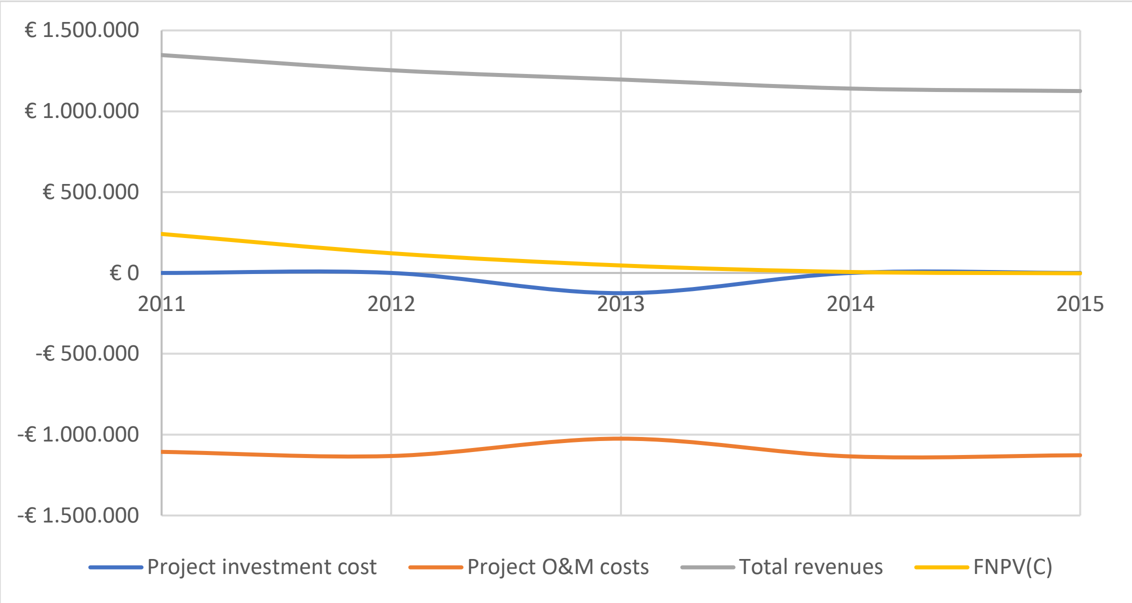


Figure 81 - Overview of financial flows of WEEE collection in Helsinki capital region 2011 -2015

5.6.4. SENISTIVITY ANALYSIS

In order to filter out the uncertainties in the data, a sensitivity analysis has been performed on three parameters; i) the PRO fee; ii) the collection costs and iii) the recycling costs.

The PRO fee

As discussed earlier in the table above, the exact PRO fee charged by the Finnish PRO's is not publicly available. It is therefore assumed the PRO's operating in Helsinki receive either the Norwegian or the European average PRO fee[149]. Due to these uncertainties, the following scenarios are assumed;

1. The PRO fee is equal to the Norwegian average;
2. The PRO fee is equal to the combination of both averages;
3. The PRO fee is equal to the EU average.

Collection costs

The collection costs are largely based upon 2008 values[131], which might be outdated and have decreased due to efficiency gains. Therefore, a scenario is foreseen where the collection costs decrease by 50%.

Recycling costs

The recycling costs consist are largely based upon 2008[131] and 2016[132], which might be outdated and have decreased due to efficiency gains. The recycling costs consist of the cost for shredding, sorting, dismantling; recycling and recovery. It is quite possible that either one of these processes has become more efficient or cost effective in the last years, which would mean a decrease in cost. Similar to the collection costs, a scenario is foreseen where the recycling costs decrease by 50%.

This results in three possible scenarios, displayed in the table below. The first scenario is marked as the standard scenario, as this is based upon the currently available information. The second scenario is marked as the worst-case scenario, where the PRO fee further increases due to competition between PRO's. The collection costs and recycling costs stay at the standard values. Lastly, scenario three is marked as the best-case scenario, as in this scenario the PRO fees increase, and both the collection and recycling costs decrease.

Scenario	PRO fee	Collection costs	Recycling costs
1	EU+NW average	Std	Std
2	NW average	Decreased 50%	Decreased 50%
3	EU average	Std	Std

The result of this analysis is shown in the graph below. It can be seen that all scenarios are positive.

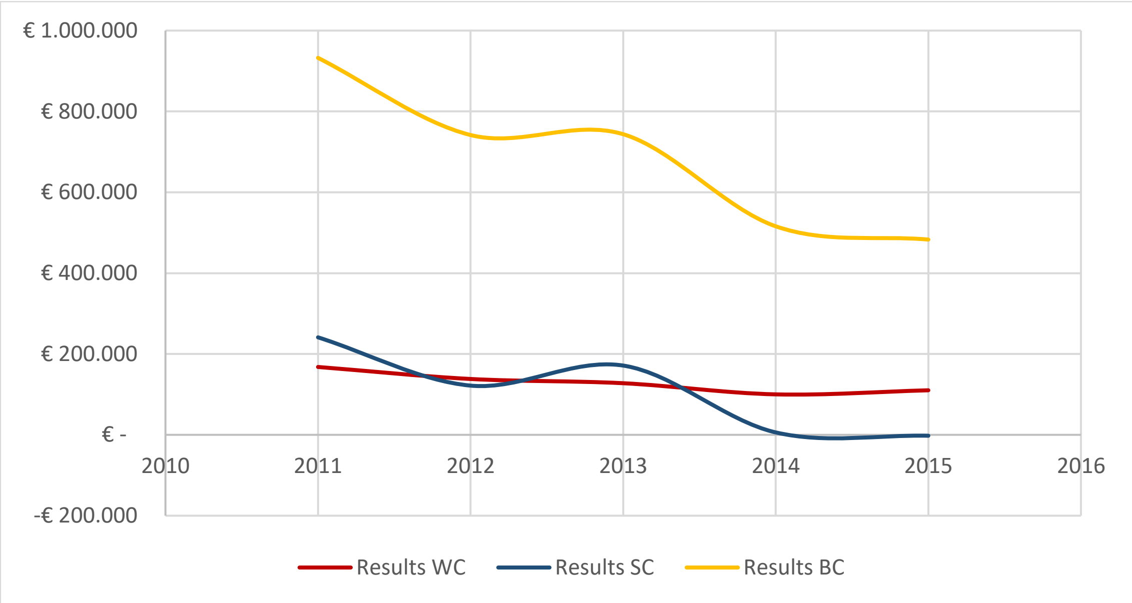


Figure 82 -Sensitivity analysis Helsinki

5.6.5. EVALUATION AND CONCLUSION

Assuming the operational costs haven't increased due to the implementation of the new WEEE collection system, we can assess the cost effectiveness of the investment. Considering the investment of € 125,000 made by Serty, we can assess the cost effectiveness of the collection practice. Assuming 2011 as reference year, with 2888 tons of SHA and IT and 47 tons of lamps collected, the 2015 collection values show an increase in collection numbers to 3944 tons of SHA/IT and 63 tons of lamps. Taking the full investment, we find a price of € 116.67/ton of additional WEEE collected.

Total investment	€ 125,000	Euro
Extra WEEE collected	1,071	Ton
Cost effectiveness	€ 116.67	Euro/ton

Table 64 - Cost effectiveness of investment in Helsinki

As discussed in the project rationale, an estimated € 1,480 per ton of WEEE is lost due to scavenging and improper recycling. The cost effectiveness calculated for the Pembrokeshire project is lower than the estimated material losses.

5.7. CONCLUSIONS ON THE WEEE STUDY

In this final paragraph the conclusions of the WEEE study will be discussed. As indicated earlier in the report, the comparability of the cases is limited which means no concrete quantitative conclusions can be drawn.

Below an evaluation of the case scope; cost effectiveness; the PRO fees vs. the collection rate; and the FNPV is given.

CASE SCOPE AND COST EFFECTIVENESS

The table below shows a quick summary of the case characteristics, the scope, the additional WEEE collected over the project lifetime due to the implemented practice and lastly extra WEEE collected per inhabitant.

Case	Inhabitants	Density [inh/km²]	Scope	Extra WEEE collected [ton]	Extra WEEE collected [kg/inh]
Pembrokeshire	125,000	79	Awareness campaigns	123	0,98
Vienna	1,870,000	4,502	Reuse	1,350	0,73
Genova	580,097	2,417	Mobile pickup	232	0,40
Cyclad	148,659	55	Scavenging	205	1,38
Helsinki	1,200,000	1,037	Low population density	1,071	0,89

Table 65 - Evaluation of all cases

The table shows that in absolute numbers Vienna has collected the most additional WEEE, however, when translating these numbers to amount of extra WEEE collected per inhabitant we see that Cyclad has been most 'successful'. The comparability here is limited, as factors such as e.g. the regions geography, local challenges, WEEE in stock and the functionality of the broader waste collection system will vary per case and are not possible to correct for within this study. The numbers are not meant to reflect the effectiveness of the implemented measure, as more data and research would be required to draw conclusions on this.

Case	Extra WEEE collected [ton]	Extra WEEE collected [kg/inh]	Cost effectiveness [€/ton]
Pembrokeshire	123	0,98	€ 846
Vienna	1,350	0,73	-
Genova	232	0,40	€ 183
Cyclad	205	1,38	€ 525
Helsinki	1,071	0,89	€ 117

Table 66 - Evaluation of cost effectiveness

What can be said based on these numbers is that all cases managed to increase their WEEE collection with a higher cost effectiveness than the estimated € 1,480 per ton of WEEE that is lost due to scavenging and improper recycling. This means all cases managed to increase their WEEE collection more cost effectively compared to the WEEE that would otherwise be exported or treated improperly.

PRO FEE AND COLLECTION RATE

As discussed through the assessment the PRO fees vary per country and per waste stream. In the figure below the average PRO fee over the project lifetime for the two waste streams is plotted. It is interesting to see that for all cases (except Genova for which no specific data was available) the PRO fee for lamps is significantly higher; which is explained by the limited amount of valuable and recoverable materials in the lamps waste stream and the specific transport and handling needs (due to the lamps being fragile and lightweight).

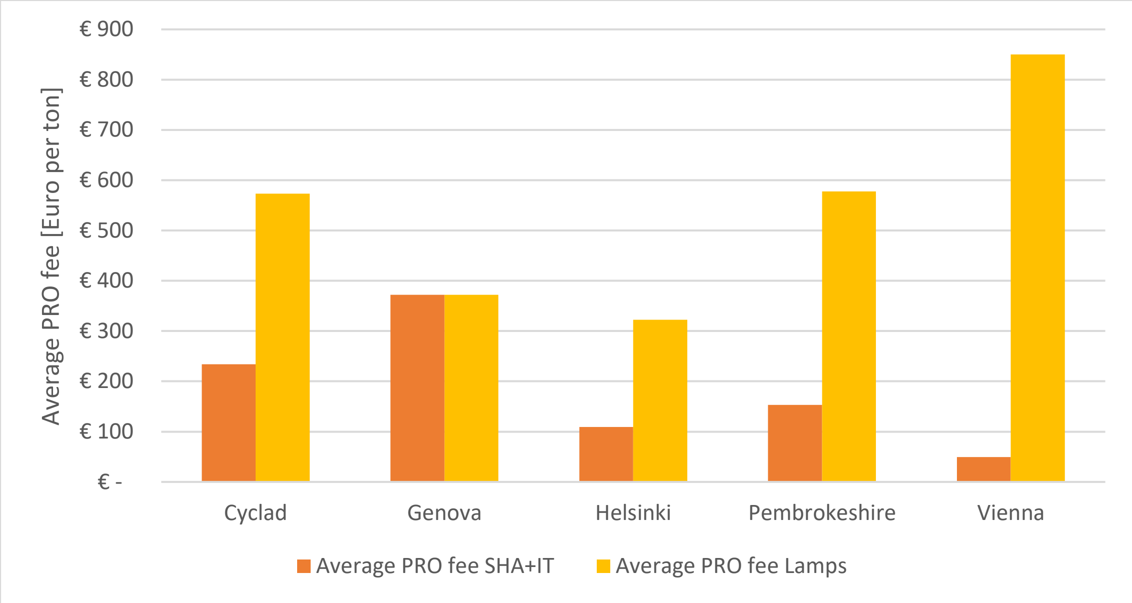


Figure 83 – Average PRO fee per case in Euro per ton

Based on this we can assess whether a higher PRO fee stimulates higher collection rates. In Figure 84 the average PRO fees is plotted against the average collection rates over the project lifetime.

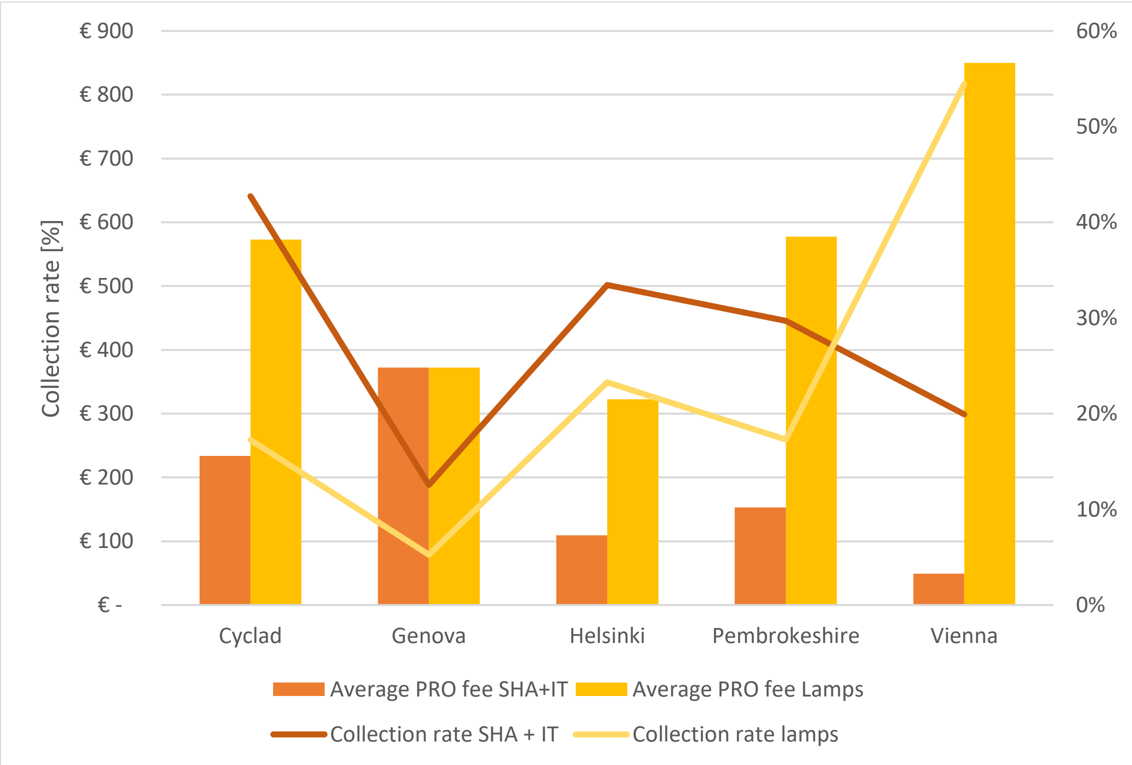


Figure 84 - Average PRO fee per case vs. Average collection rate

This seems to shows that there is no direct relation between the collection rate and the height of the PRO fee. However, this could be due to the fact that the nuances got lost in the average numbers taken. Also, the fact that the responsibility of collection is assigned to municipalities and thus sustained by the municipal public taxes, might explain the lack of relation between the PRO fee and the collection rate.

Therefore, the table below shows the difference in collection rate and PRO fee between the first project year and last project year. The table reveals that all cases managed to increase their collection rate significantly, despite sometimes even dropping PRO fees. For instance, Vienna increased the collection rate for lamps with 45%, despite a decrease in the PRO fee of € 60 per ton. So despite less financial resources to collect the waste, cases still manage to increase their collection numbers. This could be explained by the fact that recyclers offer better tariffs for receiving higher volumes.

	SHA + IT		Lamps	
	Δ Collection rate [%]	**Δ PRO fee [Euro/ton]**	**Δ Collection rate [%]**	**Δ PRO fee [Euro/ton]**
Pembrokeshire	7%	€ -5	21%	€ 25
Vienna	6%	€ -18	45%	€ -60
Genova	8%	€ 7	3%	€ 7
Cyclad	9%	€ -	21%	€ 125
Helsinki	11%	€ -14	16%	€ -103

Table 67 - Difference in collection rate and PRO fee between start and end project lifetime

FNPV

In evaluating the FNPVs of the five cases, it can be seen that there are a few cases that show a decreasing or negative FNPV; meaning that the operational costs outweigh the generated revenues from the collection. For all cases we unfortunately have to conclude that data is not readily available and the CBA scenarios are developed under large data uncertainty. For three of the five cases it seems that the measures studied to increase WEEE collection do not directly result in a positive or maintainable business case. As shown in Figure 65 the costs for transport and collection alone outweigh the potential cost gained from recycling and recovery. The limited recycling and recovery revenues therefore rightly warrants the crucial role of the PRO fee in the WEEE landscape. It is therefore alarming to see that in three of the five cases we see the PRO fees decreasing. Further consultation of the WEEEForum network explained that a decrease in the PRO fee is often sparked by an increase in efficiency (e.g. more efficient processes, logistics, market dynamics such as higher volumes resulting in better recycling tariffs). Still, in some of the COLLECTORS cases this decrease in PRO fee means that collecting more WEEE leads to higher operational costs that might not covered by the revenues.

In addition, electronic equipment keeps getting smaller and valuable materials such as metals are used in decreasing quantities. This is expected to lead to less valuable material to mine from the WEEE waste stream, which in turn is expected to make recovery and recycling processes even less economically viable. Innovation in new innovative recycling and recovery technologies would be required to reduce the operational costs and/or increase the recovery rates.

The short duration of the contracts and agreements set between the actors in the value chain may influence the decision to invest in collection infrastructure, as it can occur that a PRO has a one-year permit for collection, meaning that they will not be inclined to set long-term commitments. In this case the PRO relies heavily on the local waste collection infrastructure, which is not always organised optimally for collection of WEEE.

As shown the FNPV for the studied cases is negative in some cases, and some of the trends described above seem worrying. It is therefore positive to see that in this challenging and complex landscape all five cases managed to increase their WEEE collection. The assessment reconfirms the importance of monitoring of data, as due to a lack of specific financial and WEEE-quality data the assessment was forced to rely on benchmark reports and various assumptions. In addition, it is important to state the crucial role of the quality of collected WEEE, which is largely excluded from the assessment due to limited data. Good quality WEEE has more value for recyclers, and therefore a positive effect on the business case.

Also, the assessment reconfirms the importance enforcement of unfair competition and unregistered treatment. Improper treatment is tempting for actors in the value chain, as this is less expensive, at least in the short term. However, if we were to include the environmental costs, we expect to see a different scenario as proper treatment of WEEE is environmentally sound and aims to remove all valuable and toxic materials. Including the environmental costs would require to have detailed data on the costs of materials lost due to improper recycling or treatment, which unfortunately is not available. In general, it seems that the ENPV would be positive, as the increase in proper WEEE collection and subsequently recycling would result in various environmental benefits. Some cases show that financial means to implement these measures need to come from outside the value chain; e.g. Genova received LIFE-funding, but also other measures seem largely dependent on public money.

6. CONSTRUCTION AND DEMOLITION WASTE

6.1. PROJECT AND REFERENCE CASE

6.1.1. PROJECT RATIONALE

Construction and demolition waste (CDW) is one of the heaviest and most voluminous waste streams generated in the EU and as such it has been identified as a priority waste stream by the European Union. It accounts for approximately 25% - 30% of all waste generated in the EU and consists of numerous materials, including concrete, bricks, gypsum, wood, glass, ceramics, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled.

CDW arises from activities such as the construction of buildings and civil infrastructure, total or partial demolition of buildings and civil infrastructure, road planning and maintenance[217]. Technology for the separation and recovery of construction and demolition waste is well established, readily accessible and in general inexpensive. Despite this, and despite its potential, the level of recycling and material recovery of CDW varies greatly (between less than 10% and over 90%) across the European Union. If not separated at source, CDW can contain hazardous waste, the mixture of which can pose particular risks to the environment and can hamper recycling. A minimum of 70% (by weight) of non-hazardous construction and demolition waste (excluding uncontaminated soils and naturally occurring material) shall be prepared for reuse, recycled or undergo other material recovery, such as backfilling[218] operations using waste to substitute other materials[219].

As can be seen in Figure 85 construction and demolition waste was used almost exclusively for backfilling in 2011. Over the years the recycling practice of CDW has improved, as shown in Figure 86 where recycling has increased significantly in many countries. Recycling here means any recovery operation by which waste materials are reprocessed into products materials or substances, as defined in the Waste Framework Directive (2008/98/EC).

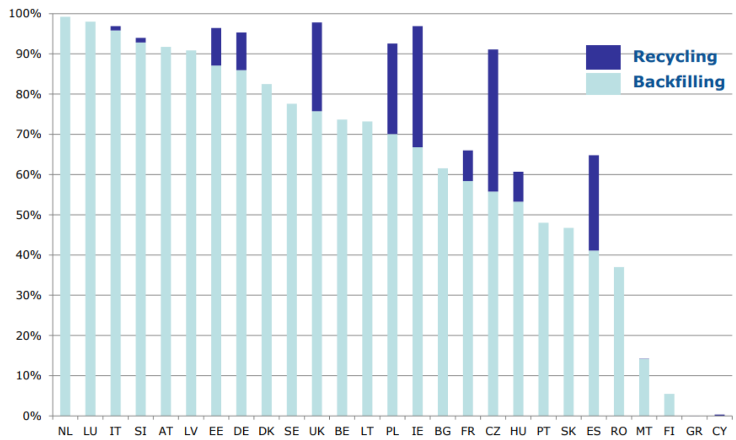


Figure 85 - CDW material recovery & backfilling in Europe, 2011[220]

[217] European Commission, 2019, https://ec.europa.eu/environment/waste/construction_demolition.htm

[218] *Backfilling is interpreted as using suitable waste materials for reclamation purposes in excavated areas or for engineering purposes in landscaping and where the waste is a substitute for non-waste materials, whereas landfilling is burying waste under layers of earth*. EC, Guidance on the interpretation of the term backfilling, 2010

[219] European Commission, 2008. DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives.

[220] European Commission, CDW, https://ec.europa.eu/environment/waste/construction_demolition.htm

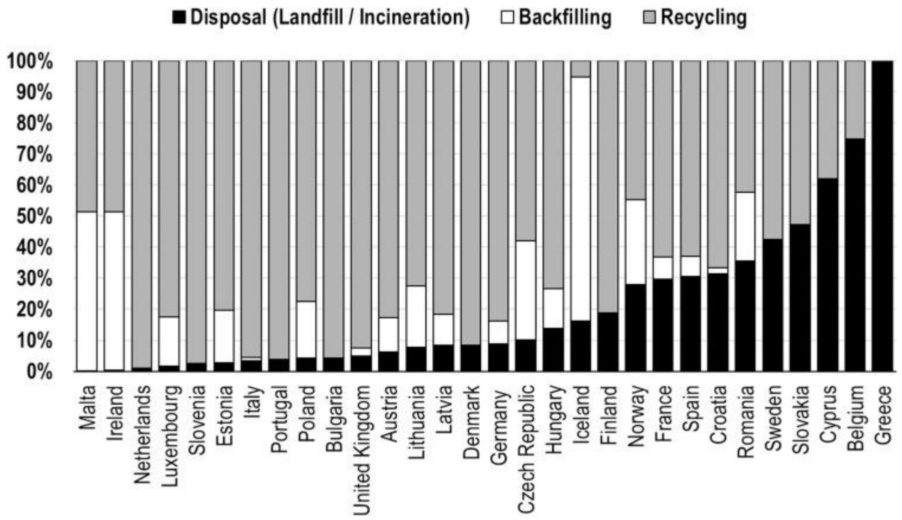


Figure 86 - CDW material recovery and backfilling in 2018[221]

Various municipalities have succeeded in boosting the recycling rate of their collected CDW, by collecting the various CDW streams separately at the CAS and working together with local recyclers. The goal of this CBA is to assess the financial feasibility of this separately collecting specific waste streams from the CDW.

In contrast to PPW and WEEE, the collection of CDW is mainly in hands of private companies, being the building companies and contractors. The relevance of publicly organised waste collection systems is very different for CDW compared to PPW and WEEE, and mostly limited to providing a service to citizens for the collection of specific fractions of CDW that citizens want to get rid of. The scope of the assessment therefore will focus merely at the operation within the influence of the municipality; the operation at the civic amenity site, the subsequent transport and ultimately the disposal of the waste stream.

The focus is on two systems which manage well the waste bricks, insulation, sanitary ceramics and gypsum produced by the municipalities.

6.1.2. REFERENCE CASE

The reference case for both CDW case studies is defined as the collection, often comingled with other alike CDW waste streams, transport and subsequent landfilling or backfilling of the materials.

For Odense it is assumed that in the reference case the bricks, insulation and sanitary waste is all sent to the local landfill.

For Reimerswaal the reference case is somewhat more complex. The previous (2011) high tariff for landfilling combustible waste was € 108 per ton, however this tariff was abolished in 2012. Mid-2014 a new (lower) tax was introduced, combined with the landfill ban and minimum standard for gypsum waste. This high landfilling tariff was one of the reasons that in the past gypsum waste often has been disposed comingled with other construction and demolition waste streams or even with residual waste streams. Moreover, large quantities of gypsum waste have been transported to Germany for landfilling and backfilling of old mines[222,223] mainly due to low gate fees. Trying to regulate and optimise the recycling of valuable materials, the Netherlands has a national landfill ban in place for waste streams that have a recovery potential, which is the case for gypsum waste. The

[221] Construction and demolition waste best management practice in Europe, Gálvez-Martos, J., 2018
[222] Gipsrecycling Nederland, 2017, http://gipsrecycling.nl/13447-1/
[223] EC Parliamentary questions regarding gypsum landfilling in Germany, 2011, https://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+WQ+E-2011-002256+0+DOC+XML+V0//NL

Dutch national waste plan (LAP2)[224] states that the minimum standard for processing gypsum waste is recycling. However, an exception on this landfill ban applies to gypsum that is not recyclable (due to composition or contamination) or for which the recycling route is so expensive that the costs for disposal would be higher than € 175 per ton. As law dictates there is no practical reference case possible (other than recycling), it is chosen to sketch a hypothetical reference case, where the gypsum waste is backfilled in German mines between the years 2011 – 2014, and is being landfilled between 2015 – 2021 at the local landfill in Sluiskill. The most recent tariff of € 108 per ton in 2011[225] for landfilling gypsum waste is used for this reference case.

6.1.3. PROJECT DEFINITION

For both cases, the project is defined as the separate collection of the specific waste streams at the CAS and the subsequent transport to a dedicated recycling facility. The cost, benefits and savings from other waste streams collected at the CAS are not included in the assessment. The specifics of the collection system are discussed in detail below.

6.2. COST-BENEFIT ANALYSIS ODENSE

6.2.1. ODENSE, DENMARK

The construction and demolition waste is collected through civic amenity sites by Odense Waste Management Ltd., who operates 8 recycling stations for private households and smaller enterprises. The citizens sort their waste into more than 40 categories which all have their own container (see Figure 87 below). Both CDW and WEEE are collected in various categories such as gypsum, bricks, windows with frames, mineral wool, asphalt, asbestos, SHA, LHA, cooling equipment, lamps and many more.

Figure 87 - Overview of a typical CAS in Odense[226]

With this elaborate approach, the inhabitants of Odense have reached one of the country's highest levels of recycling: 87 % of the bulky waste is recycled. The rest is incinerated for energy production and only a small percentage is landfilled.

This scope of this assessment is done from the financial perspective of Odense Waste Management Ltd. The flow chart for CDW collection in Odense is presented below. The CDW fractions are directly transported from the CAS to the recyclers as soon as the container is about full. Bricks are transported to Gamle Mursten, insulation waste to Noreco and sanitary waste to KI Hansen. Not all collected bricks, insulation and sanitary waste is suitable for recycling. Bricks are cleaned and reused in new buildings and constructions, but the brick

[224] LAP2, gypsum, https://lap3.nl/publish/pages/129294/31_gips.pdf
[225] PBL, Opties voor een afvalstoffenbelasting 2014, https://www.pbl.nl/sites/default/files/downloads/PBL_2014_Opties-voor-een-afvalstoffenbelasting_1406_0.pdf
[226] Types of Waste, Odense, DK, 2020, https://www.odensewaste.com/recycling-stations/recycling-stations/types-of-waste/

material that is not suitable for reuse as bricks is crushed for use in road filling. In contrast to bricks, sanitary ceramic ware (toilets, sink basins etc.) are not recycled into new sanitary ceramic ware. Instead, waste sanitary ceramic ware is used in the production of concrete as a replacement for aggregates (i.e. sand and gravel)[230]. The recovered mineral wool is assumed to replace the mineral wool in the production of new insulation.

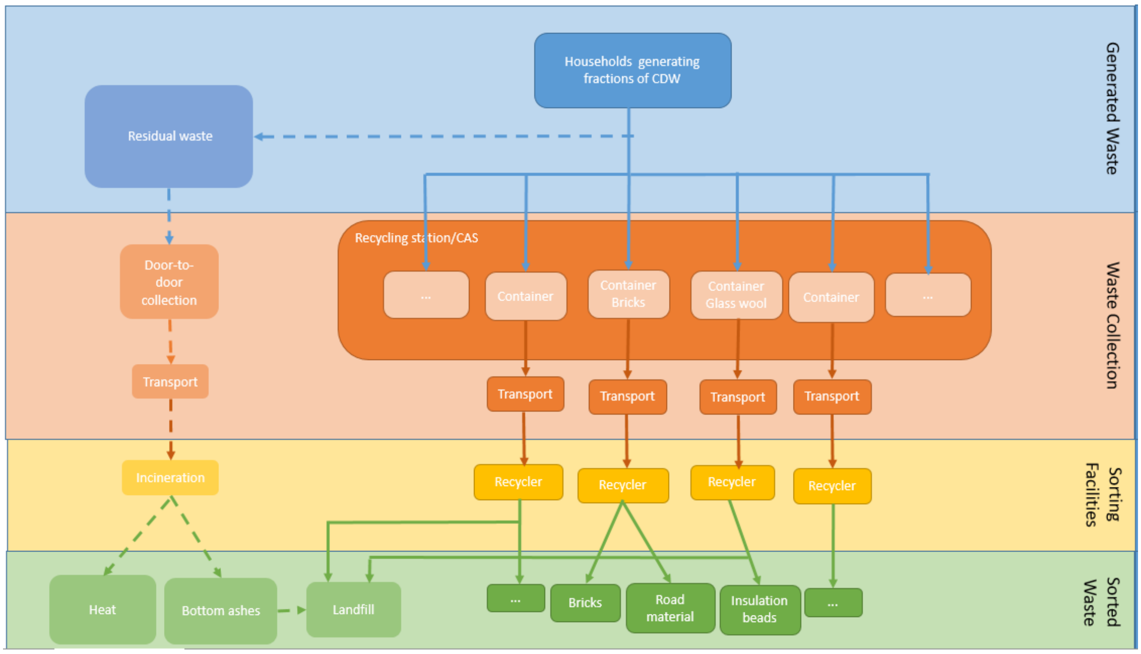


Figure 88 - Flow scheme of CDW collection at CAS and corresponding recycling in Odense

6.2.2. IDENTIFICATION OF COSTS AND BENEFITS FOR CDW COLLECTION IN ODENSE

THE INVESTMENT COSTS

In the table below the investment costs are discussed.

<table>
<tr><th>Item</th><th>Assumption & data source</th><th>Unit cost</th></tr>
<tr><td rowspan="5">Investment in additional containers for separate collection</td><td>Odense invested in five additional containers for separate collection of bricks. One container costs € 3,000. Five of the eight civic amenity sites in Odense have a separate container for bricks. This investment was done in 2011.</td><td rowspan="5">€ 33,000</td></tr>
<tr><td>Odense invested in one additional container for separate collection of insulation. One container costs € 3,000. One of the eight civic amenity sites in Odense have a separate container for insulation material. This investment was done in 2016.</td></tr>
<tr><td>Odense invested in five additional containers for separate collection of sanitary waste. One container costs € 3,000. Five of the eight civic amenity sites in Odense have a separate container for sanitary waste. This investment is done was 2016.</td></tr>
<tr><td>It is assumed the lifetime of a container is 10 years[227]. Therefore, no replacement costs are included.</td></tr>
<tr><td>No additional investments in monitoring and or trucks has been done.</td></tr>
</table>

Table 68 - Overview of investments

[227] Transport geography, Container Usage during its Life-Span, 2000, https://transportgeography.org/?page_id=2719

OPERATING COSTS

Item	Assumption & data source	Unit cost
Additional operational costs of CAS	The operational costs for all eight civic amenity sites is € 5.5 million per year. The additional operational costs coming from the separate collection of bricks, insulation material and sanitary waste are negligible. Staff is present on site anyways, and does not have more work due to the separate collection system.	€ -
Additional transport costs bricks	Odense estimated the transport costs for construction and demolition waste at € 1 per km of transported waste by truck. This includes labour, fuel and depreciation costs. It is assumed 33-ton trucks are used, which are fully stocked with material. In the reference case all brick material is sent to landfill for road material. The bricks are transported over a distance of 50 km in 33 ton trucks. It is assumed the truck drives back and forth, i.e. the return journey is empty . The capture rate was 62% in 2018, meaning of the 1,300 tonnes of brick waste 806 tonnes was in good enough quality to be reused. Of that amount, 65% were in good enough condition to be reused in new buildings and 35% were in somewhat damaged condition and thus collected for recycling into road material (replacing sand or gravel). For all years this capture rate is assumed. The reused bricks are transported over a distance of 225 km in 33 ton trucks[228]. This means an additional 175 km is driven. The yearly collected quantities of bricks and concrete is known for 2010 – 2016[229]. For future years a similar trend is extrapolated. The additional transport cost based on the additional distance driven is calculated to be € 5,377 in 2018.	€ 5,377 per year
Additional transport costs insulation and sanitary	In the reference case all waste is sent to landfill. The average distance from the CAS to the landfill site is 15 km. In the project case the insulation material and sanitary waste is sent to the recycling facility, which is on average only 6 km from the CAS. This means on average 9 less kilometres have to be made for insulation and sanitary transport. Therefore, no additional transport costs are made. The savings are included under the revenues.	€ -

Table 69 - Overview of operational costs

REVENUES

Item	Assumption & data source	Unit cost
Savings diverting brick from landfilling	There is no direct revenue, but the gate fee for recycling is cheaper than landfilling. In the reference case brick and concrete material is used for road filling. Odense pays € 10 per ton of material for landfilling bricks as road material.	€ 5 per ton

[228] Møller, J., Damgaard, A., Astrup, T. & DTU Miljø, 2013. LCA af genbrug af mursten, s.l.: s.n.
[229] Odense waste management statistics, Affald private husstande 2010 - 2016

	In the project case bricks are sent to recycling. Odense pays a gate fee of € 5 per ton of brick material sent to recycling. In 2018, Odense separately collected 1,300 tons of bricks, of which ca. 40% (62% times 62%) had sufficient quality for reuse. For earlier years, no direct data is available. For 2010 – 2016 aggregated data is available for separately collected concrete and bricks[229].	
Savings diverting insulation waste from landfilling	There is no direct revenue, but bringing the waste to recycling is cheaper than landfilling. Odense started collecting insulation and sanitary waste separately in 2016, it is assumed before 2016 all waste was landfilled. It is assumed 98% of the insulation waste can be recycled. In the reference case insulation material and sanitary waste are sent to landfill. Odense pays € 100 for landfilling one ton of material. In the project case insulation waste is sent to recycling. Odense pays a gate fee of € 90 per ton of insulation material sent to recycling.	€ 10 per ton
Savings diverting sanitary waste from landfilling	There is no direct revenue, but bringing the waste to recycling is cheaper than landfilling. Odense started collecting insulation and sanitary waste separately in 2016, it is assumed before 2016 the waste was all landfilled. Sanitary ceramic waste can potentially replace up to 50% of the fine aggregate and 25% of the coarse aggregate in concrete. Thus, based on the composition of concrete, it is assumed that 53% of the sanitary ceramic waste that is collected is crushed into fine grains and substitutes sand, the remainder of the ceramic material is crushed into finer grains and substitutes gravel in concrete production[230]. It is assumed all sanitary waste can be recycled into new materials. In the reference case insulation material and sanitary waste are sent to landfill. Odense pays € 100 for landfilling one ton of material. In the project case sanitary waste is sent to recycling. Odense pays a gate fee of € 55 per ton of sanitary material sent to recycling.	€ 45 per ton
Transport savings	Odense estimated the transport costs for construction and demolition waste at € 1 per km of transported waste by truck. This includes labour, fuel and depreciation costs. It is assumed 33-ton trucks are used, which are fully stocked with material. In the reference case all waste is sent to landfill. The average distance from the CAS to the landfill site is 15 km. In the project case the insulation material and sanitary waste is sent to the recycling facility, which is on average only 6 km from the CAS. This means on average 9 less kilometres have to be made for insulation and sanitary transport. Odense started collecting insulation and sanitary waste separately in 2016, it is assumed before 2016 the waste was all landfilled. 200 tonnes of insulation were collected in Odense in 2018, of which 98% was ultimately recycled. This is transported over a distance of 6 km from the CAS in Odense to the company NORECO. 140 tonnes of sanitary ceramics were collected at the CAS in Odense in 2018 and transported over a distance of 6 km to the company HJ Hanson. Sanitary ceramics are assumed to be fully recycled in new materials[230]. This results in a total transport saving of € 180 in 2018.	€ 180 per year
Gate fee	It is assumed the gate fee paid by citizens for disposing brick, insulation and sanitary waste in Odense did not increase due to the separate collection approach.	€ -

[230] Guerra, I., Eco-efficient concretes: The effects of using recycled ceramic material from sanitary installations on the mechanical properties of concrete. Waste Management, 1 2, 29(2), pp. 643-646.

Residual value	It is assumed the lifetime of a container is 10 years. The investment in 2011 therefore yields no residual value at the end of the project, but the investment done in 2016 does. The residual value is found to be € 10,800 occurring at the end of the project in 2020; calculated by multiplying one tenth of the original investment with the remaining lifetime years.	€ 10,800

Table 70 - Overview of revenues

6.2.3. CBA RESULTS ODENSE

The figure below shows both the total costs (negative) and the benefits (positive) in one overview (not discounted). The dotted line shows the benefits minus the costs. It can be seen that for the brick collection practice (2011 – 2015) the incremental costs seem to outweigh the benefits. This is caused by the high costs of transporting the bricks to the recycling/reuse facility, which is further away than the landfill site. After 2016, including insulation and sanitary waste the practice starts to shift, and the benefits start outweighing the costs, making the operation more financially viable than the alternative.

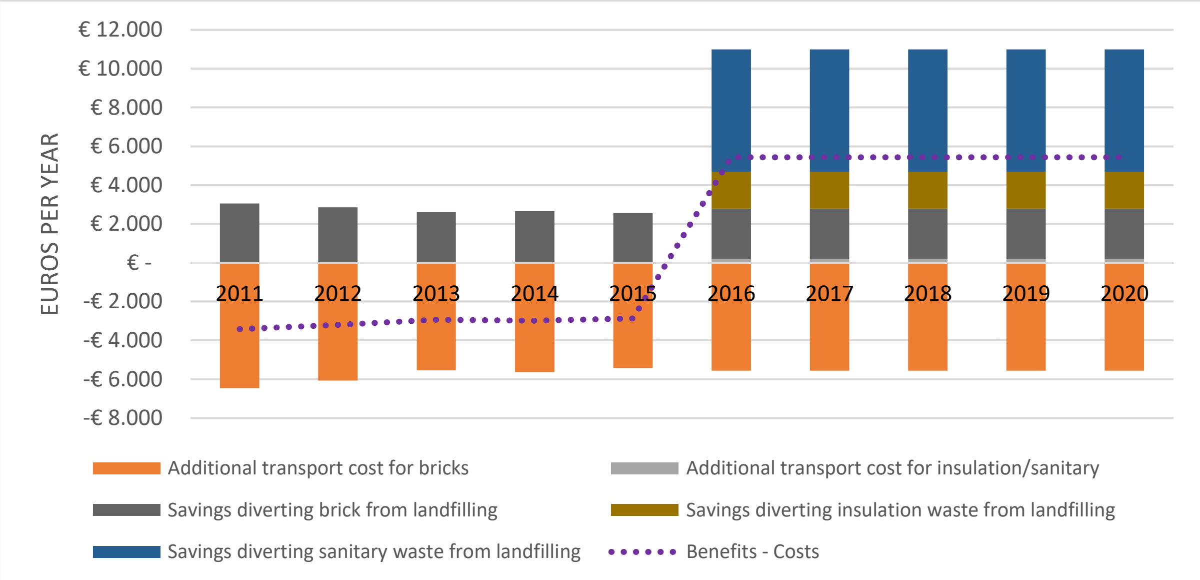


Figure 89 - Overview of total cost (-) and benefits (+) per year for Odense 2011 – 2020

The graph below shows an overview of the investment costs, the operational costs, the total revenues and the financial net present value (FNPV), in which the costs are discounted and calculated to 2011 values. The FNPV is negative for the first six project years, ultimately resulting in a negative overall FNPV at the end of the project. For the assumptions made the separate collection of the CDW waste streams the separate collection approach for bricks alone is not a financially viable operation for Odense, however, by including separate collection and processing of insulation and sanitary waste the operation does become financially attractive.

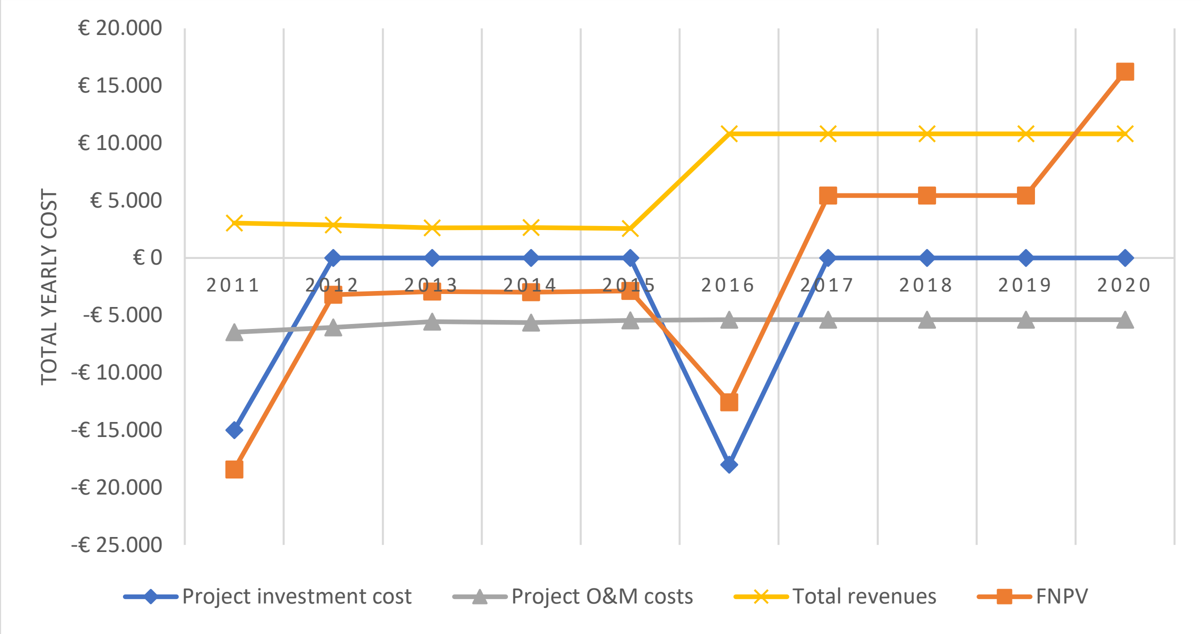


Figure 90 - Overview of financial flows of CDW collection in Odense 2011 -2020

6.2.4. SENSITIVITY ANALYSIS

In order to highlight the sensitivity of the CBA results and reflect on potential uncertainties in the data, a sensitivity analysis will be performed on the following parameters: i) the transport costs in euro per kilometre; ii) the gate fee for recycling; and iii) the gate fee and/or tax for landfilling. In Table 71 below the results of the sensitivity analysis are presented. The delta values presented are the differences compared to the standard scenario.

Scenario	FNPV	Delta FNPV	B/C ratio	Delta B/C
Standard scenario	€ -15,845	-	1.210	-
Decrease in transport costs of 10%	€ -11,090	30%	1.344	11%
Decrease in gate fee recycling of 10%	€ -4,163	74%	1.478	22%
Increase in landfill gate fee or tax of 10%	€ 1,228	108%	1.599	32%

Table 71 - Sensitivity analysis of Odense results[231]

Increasing the landfill gate fee (or tax) affects the FNPV and the benefit cost ratio the strongest. For every 1% of increase in this category, the FNPV goes up with 10.8%, and the benefit/cost ratio with 3.2%. The decrease in the gate fee for recycling has a significant effect as well, whereas the decrease in transport cost appears to have the least effect on the FNPV and B/C ratio.

6.2.5. EVALUATION AND CONCLUSION

Looking at the Odense case, it can be concluded that with a limited investment Odense managed to implement a financially viable practice for separate collection and recycling of insulation and sanitary waste. Brick waste, as shown in Table 72 below, is a more expensive mainly due to the increase in transport costs and therefore not more expensive than the reference landfilling scenario. The values in the table are calculated based on 2018 figures.

Evaluation	
Total investment	€ 33,000
Investment per inhabitant	€ 0.16 per inhabitant
Total disposal cost recycling bricks	€ 11,70 per ton
Total disposal cost landfill bricks	€ 11,52 per ton
Total disposal cost recycling insulation	€ 90,39 per ton
Total disposal cost landfill insulation	€ 100,45 per ton
Total disposal cost recycling sanitary	€ 100,45 per ton
Total disposal cost landfill sanitary	€ 55,18 per ton

Table 72 - Evaluation of Odense results

6.3. COST-BENEFIT ANALYSIS REIMERSWAAL

6.3.1. REIMERSWAAL, THE NETHERLANDS

The municipality of Reimerswaal is responsible for the collection and management of household waste and has outsourced the operation to private scheme the Zeeuwse Reinigingsdienst (ZRD). ZRD does the collection of all household waste (residual, organic, plastics and beverage cartons) as well as the management of all the CAS in

[231] Despite the positive B/C ratio, the FNPV is still negative. This is caused by the investments (not included in the B/C ratio) and the fact that future costs and revenues are discounted.

Zeeland, where all CDW fractions are collected. ZRD operates the CAS in Reimerswaal and 12 other CAS in the province. The scope of this CBA is the operation of ZRD in the municipality Reimerswaal.

ZRD collects about 25 separate waste streams at the CAS[232], amongst which are gypsum, wood, bricks and concrete, glass, plate glass, hard plastics, metals, and many more. Gypsum waste is collected on every CAS in Zeeland (except for Kapelle). ZRD focusses on collecting clean gypsum waste, free from contamination, such as tiles and wood. The flow scheme for gypsum waste collection in Reimerswaal is shown in Figure 91 below. Gypsum that is not collected is assumed to be disposed of in road filling and or sanitary landfills.

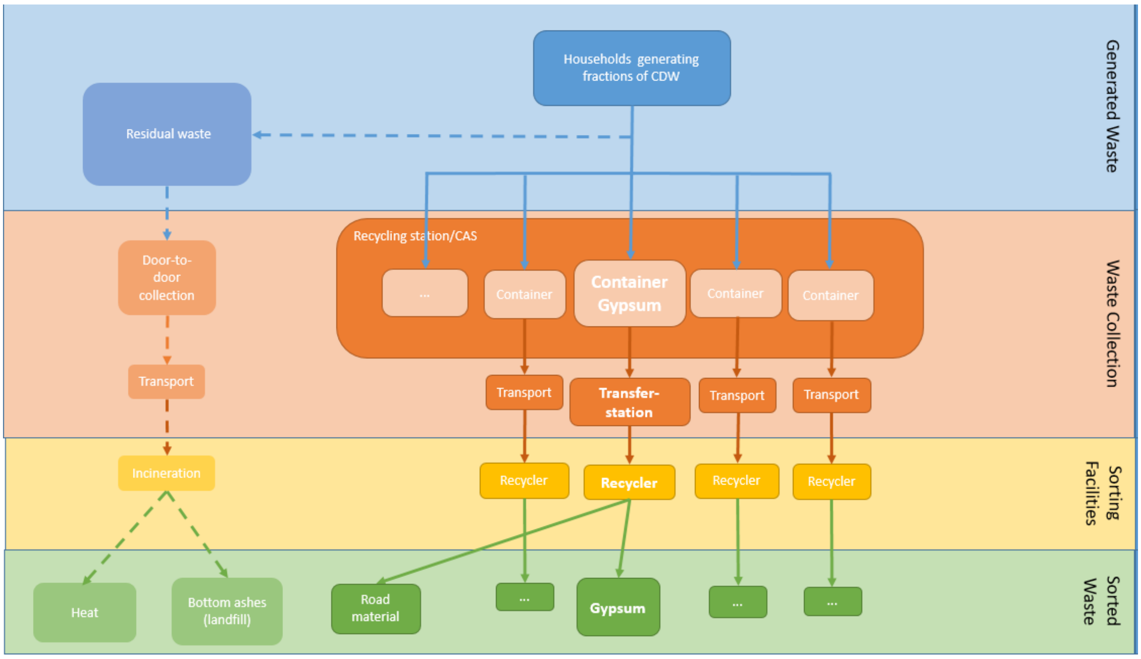


Figure 91 - Flow scheme of CDW collection at CAS and corresponding recycling in Reimerswaal

After collection in a separate container, all gypsum waste from ZRD is transported to their CAS in Middelburg from where it is transported to New West Gypsum Recycling in Kallo near Antwerp. It is essential that the recycled gypsum achieves a pre-determined quality suitable for the manufacturing of new gypsum products. Presently there is no standard pre-determining the recycled gypsum's quality and the criteria vary from plant to plant. By choosing closed-loop recycling the need for manufacturers to acquire virgin gypsum is reduced. The most advanced plants have substituted up to 30% of virgin gypsum raw materials with recycled gypsum[233].

6.3.2. IDENTIFICATION OF COSTS AND BENEFITS FOR CDW COLLECTION IN REIMERSWAAL

THE INVESTMENT COSTS

Item	Assumption & data source	Unit cost
Investment in additional containers for separate collection	ZRD invested in one additional container at the Reimerswaal CAS for separate collection of gypsum waste. One containers costs € 3,000. This investment was done in 2011.	€ 3,000
	It is assumed the lifetime of a container is over 10 years, and therefore no replacement costs are taken into account.	

[232] ZRD, Waste streams collected at the CAS, https://www.zrd.nl/milieustraten/afvalstromen.htm
[233] Gypsum to gypsum project, 2015, https://gypsumtogypsum.org/gtog/achievements/

	No additional investments in monitoring and or trucks has been done.	

Table 73 - Overview of investments

OPERATING COSTS

Item	Assumption & data source	Unit cost
Additional operational costs at the CAS	The additional operational costs coming from the separate collection of bricks, insulation material and sanitary waste are negligible. Staff is present on site anyways, and does not have more work due to the separate collection.	€ -
Additional transport costs gypsum waste	Similar to the Odense case, ZRD's transport costs for construction and demolition waste are assumed to be € 1 per km of transported waste by truck. This includes labour, fuel and depreciation costs. It is assumed 33 ton trucks are used, which are fully stocked with material. It is assumed the truck drives back and forth, i.e. the return journey is empty .	€ 247 per year
	The reference case between 2011 and 2014 assumes all gypsum waste is sent to the old German mines. The distance from Reimerswaal to the old mines in Thuringia (DE)[223] is ca. 650 kilometre.	
	The reference case between 2015 and 2021 assumes all gypsum waste is sent to the landfill in Sluiskill. The distance from the Reimerswaal CAS to the landfill site is 39 km.	
	The yearly collected quantities of gypsum per inhabitant is known for 2011 – 2018[234]. The inhabitants of Reimerswaal municipality are available for 2011 – 2019[235].	
	In Reimerswaal, 4,9 kg of gypsum waste per inhabitant was collected in 2018. Of the total weight of collected gypsum, 81% is assumed to be recoverable at the sorting and recycling stages, meaning in 2018 of the 110 tons of gypsum 90 tons was sent to recycling.	
	The transport for backfilling the gypsum waste in Germany is more expensive compared to the project case, whereas the transport for landfilling in Sluiskill is less expensive. The additional transport costs are calculated to be € 247 per year.	
Additional gate fee	The gate fee for disposing gypsum waste in old German mines is € 25 per ton[236].	€ 25 per ton
	The gate fee for recycling gypsum waste is assumed to be € 50 per ton in 2018[236]. It is assumed this gate fee was € 75 per ton in 2011 – 2014, decreasing to € 50 per ton in 2015.	
	Between 2011 and 2014 this means the gate fee for recycling is more expensive than the alternative, with € 25 per ton.	

Table 74 - Overview of operational costs

234 Afvalmonitor, 2018
235 Population data Reimerswaal 2019, https://allecijfers.nl/gemeente/reimerswaal/
236 Verras, Afzet Van Materialen Vanaf Slooplocaties In De Circulaire Economie, 2018

REVENUES

Item	Assumption & data source	Unit cost
Savings in gate fee and tax	In the hypothetical reference case, the landfill tax is € 108 per ton (based on the previous high tariff in the Netherlands for landfilling combustible waste). The gate fee for recycling gypsum waste is assumed to be € 50 per ton. Between 2015 and 2020 this means the gate fee for recycling is cheaper than the alternative, € 58 per ton.	€ 58 per ton
Gate fee gypsum	It is assumed the gate fee that citizens pay for disposing gypsum waste in Reimerswaal did not increase due to the separate collection approach.	€ -
Residual value	It is assumed the lifetime of a container is 10 years. The investment in 2011 therefore yields no residual value at the end of the project.	€ -

Table 75 - Overview of revenues

6.3.3. CBA RESULTS REIMERSWAAL

The figure below shows both the total costs (negative) and the benefits (positive) in one overview (not discounted). Given the character of the reference case, the items are split up in additional costs and savings, as these shift after 2014. Lastly, the dotted line shows the benefits minus the costs. It can be seen that in the past (< 2014) it was indeed more beneficial to dispose the gypsum waste abroad compared to recycling. However, from 2015 onwards the benefits of the separate gypsum collection and recycling outweigh the costs, and the operation is financially attractive compared to the reference case.

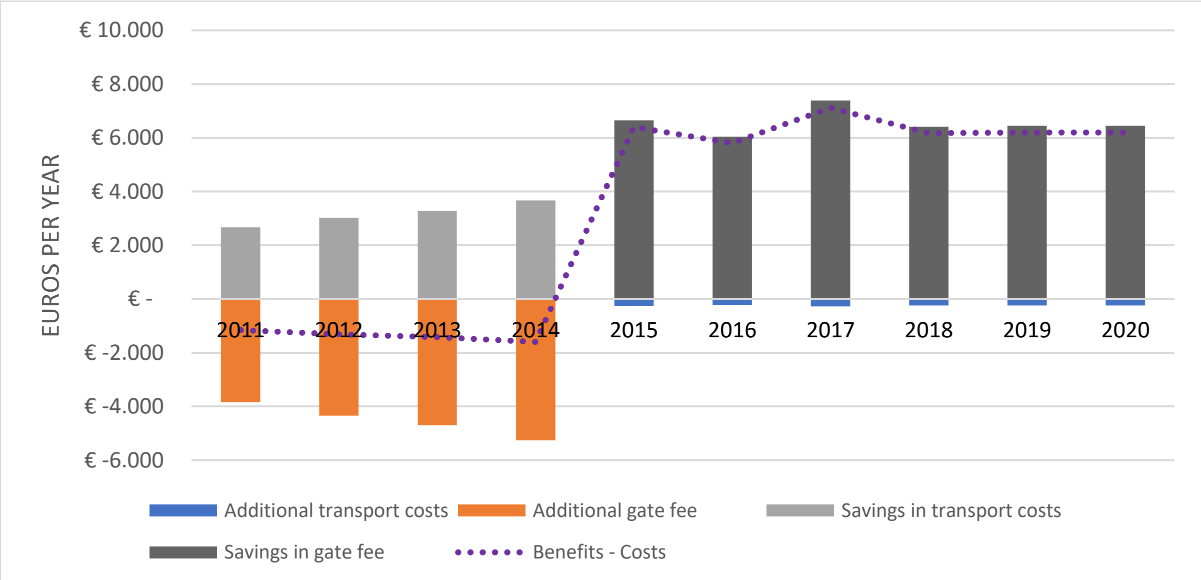


Figure 92 - Overview of the total costs (-) and benefits (+) of gypsum collection in Reimerswaal 2011 – 2020

The graph below shows an overview of the investment costs, the operational costs, the total revenues and the financial net present value (FNPV), in which the costs are discounted and calculated to 2011 values. In the first few years the project appeared not to be viable, especially due to the possibility to dispose gypsum cheaply in Germany. After 2014 this changed, and the project instantly became financially viable as the revenues largely outweigh the operational costs for 2015 and onwards. The investment costs has some impact on the costs in the first project year. However, the FNPV is largely positive throughout the years. For the assumptions made the separate collection of the CDW waste streams is a financially viable operation for Reimerswaal.

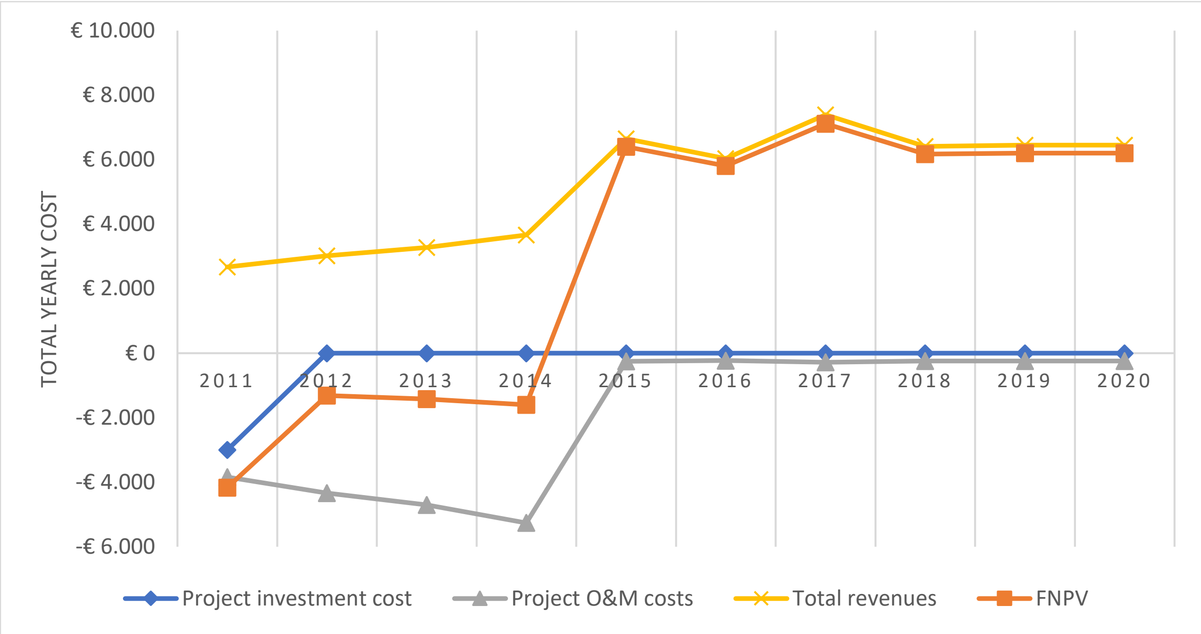


Figure 93 - Overview of financial flows of CDW collection in Reimerswaal 2011 -2020

6.3.4. SENISTIVITY ANALYSIS

In order to highlight the sensitivity of the CBA results and reflect on potential uncertainties in the data, a sensitivity analysis will be performed on the following parameters; i) the transport costs in euro per kilometre; ii) the gate fee for recycling; and iii) the gate fee and/or tax for landfilling. In Table 76 below the results of the sensitivity analysis are presented. The delta values presented are the differences compared to the standard scenario.

Scenario	FNPV	Delta FNPV	B/C ratio	Delta B/C
Standard scenario	€ 21,279	-	2.651	-
Decrease in transport costs of 10%	€ 20,208	- 5%	2.606	-2%
Decrease in gate fee recycling of 10%	€ 26,472	24%	3.279	24%
Increase in landfill gate fee or tax of 10%	€ 27,828	31%	3.171	20%

Table 76 - Sensitivity analysis of Reimerswaal results

Increasing the landfill gate fee (or tax) appears to have the strongest effect on the FNPV, whereas the decrease in the recycling gate fee results in the largest increase in benefit cost ratio. For every 1% of increase in landfill tax, the FNPV goes up with 3.1%, and the benefit/cost ratio with 2%. The decrease in transport cost shows a decrease in both FNPV and benefit cost ratio, which is explained by the large savings coming from transport in the project case that are now being decreased.

6.3.5. EVALUATION AND CONCLUSION

Looking at the Reimerswaal case, it can be concluded that with a limited investment ZRD managed to implement a financially viable practice for separate collection and recycling of gypsum waste. For waste collectors such as ZRD, it is financially more attractive to dispose gypsum waste at gypsum recyclers, as shown in Table 77 below. This is caused mainly by the high ‘hypothetical’ landfill tariff and low recycling gate fee. The values in the table are calculated based on 2018 figures.

Evaluation	
Total investment	€ 3,000
Investment per inhabitant	€ 0,13 per inhabitant
Total disposal cost recycling bricks	€ 55,02 per ton
Total disposal cost landfill bricks	€ 121,30 per ton

Table 77 - Evaluation of Odense results

COLLECTORS CONSORTIUM

PNO CONSULTANTS www.pnoconsultants.com	BIPRO www.bipro.de	VTT www.vttresearch.com
VITO NV www.vito.be	UNIVERSITEIT LEIDEN www.centre-for-sustainability.nl	ACR+ www.acrplus.org
EUROCITIES www.eurocities.eu	WEEE FORUM www.weee-forum.org	ZERO WASTE EUROPE www.zerowasteeurope.eu

WWW.COLLECTORS2020.EU

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 776745