PROMOTION OF
PUBLIC PROCUREMENT OF
INNOVATION
FOR RESOURCE EFFICIENCY AND
WASTE TREATMENT

State of the Art of Emerging Solutions

Grant Agreement N°	642451	**Acronym**	PPI4Waste	
Full Title	Promotion of Public Procurement of Innovation for Resource Efficiency and Waste Treatment			
Work Package (WP)	WP2			
Authors	Chacón, Lorenzo (IAT), Rodríguez, Rocío (IAT), Furphy, Anne (IAT), Aguiler Olga (IAT)			
Reviewers	All PPI4Waste Partners			
Document Type	Report			
Document Title	State of the Art of Emerging Solutions			
Dissemination Level *(mark with an « X » in the column to the far right)*	CO	Confidential, only for partners of the Consortium (including the Commission Services)		
	PU	Public	X	
	PP	Restricted to other programme participants (including the Commission Services)		
	RE	Restricted to a group specified by the Consortium (including the Commission Services)		

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642451

Table of Contents

1. Introduction

1.1. Objective

The PPI4Waste project is based on an integrated approach which defines needs, goals, and improvement opportunities of functional performances. This project will complete the cycle of preparation activities, and will test the feasibility and implementation of Public Procurement of Innovation (PPI) processes in urban waste management. It will also make procedural knowledge of innovation procurement widely available. This can be accomplished through the establishment of a purchasing community, accessibility of state-of-the-art solutions to a considerable number of procurers, capacity building, and a feasibility assessment for the uptake of PPI in the waste sector.

The state of the art PPI4WASTE project aims to facilitate the identification of innovative solutions with high potential for PPI process. It acts as a complementary step after the definition of common needs which was previously identified from the waste public sector in Europe. The project will set the ground for PPI preparation in the urban waste management field. This state of the art project analyses and describes how emerged common needs are currently approached in the EU context.

In this sense, the state of the art is designed as an orientation paper which will facilitate meeting demand and will offer innovative solutions for municipal waste management. It will also help in determining potentially available solutions to be shared and discussed through market dialogue with the offer side.

The purpose of this document is to give an overall picture of the state of waste management in the European Union, in line with common needs identified, and not focusing on individual country performance. Although geographically close to each other, the countries in the EU differ significantly from each other regarding innovation. The amount of municipal waste generated varies significantly across member states, and applied waste management models vary substantially among member states. One of the main consequences of this is that waste management innovation can be understood in different ways among Member States and even among regions; while one solution can be innovative in one region it may be non-innovative in another region.

This project uses the broader definition of innovation adopted by the OECD[1]. There is a clear recognition that innovation encompasses a wide range of activities in addition to R&D. The latest (third, from 2005) edition of the Oslo Manual defines innovation as the implementation of a new or significantly improved product (good or service)or process, a new marketing method, or a new organisational method in business practices, workplace organisation, or external relations. Innovation, thus defined, is clearly a much broader notion than R&D and is therefore influenced by a wide range of factors, some of which can be influenced by policy drivers, for example, and can occur in any step of the waste management chain.

The PPI4Waste approach in the project implies that innovation performance differs from one country to another, and includes not only transformative innovation, but also incremental innovation to

[1] http://www.oecd.org/berlin/44120491.pdf

existing practices. This is so that it considers a wide spectrum of options and is as comprehensive as possible.

1.2. Municipal waste management on Europe

The current situation in municipal waste management in Europe varies significantly between Members States (European Commission, 2008). In fact there are broad differences regarding waste production, collection models and treatment techniques applied as well as regarding the implementation of European Directives on waste.

The waste hierarchy[2], establishes by the Waste Framework Directive[3], constitutes the general European´s approach for waste management by Member States in order to boost recycling and reduce the use of resources.

According to Eurostat, in 2013 43% of municipal solid waste was recycled, while 31% of waste was landfilled and the rest (26%) was incinerated (Eurostat, 2015c).

Figure 1: Development of municipal waste management in 27 European countries, 2000 – 2013 (Source: Eurostat, 2015c)

Although recycling practices have been increasing each year, as shown in Figure 1, and in general term recycling is preferred over other practices, landfilling is still a widely used choice in waste management. Figure 2 gives an insight into the differences situation of European countries regarding the evolution in the implementation of the waste hierarchy.

[2] The Article 4 of the Waste Framework Directive establishes that the following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal.

[3] Directive 2008/98/EC of the European PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives

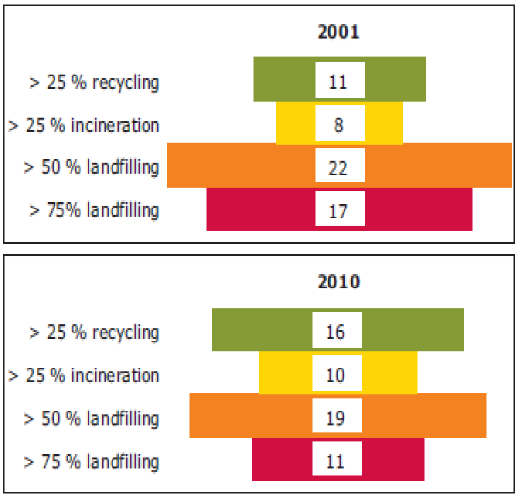


Figure 2: Number of countries at different levels of the municipal waste management hierarchy, 2001 and 2010 (Sources: European Environment Agency, 2013; Eurostat, 2015c)

In Europe, municipal waste management can be performed through different models, depending on if the responsibility of the waste management is public, private or shared in some cases.

Public service is often responsible for the municipal waste management. In this case municipalities must create and maintain an effective system for managing their waste, including collection, transport, treatment and disposal, which can be carried out either by themselves or through contracts with the private sector. In most cases, local authority is responsible for the collection, transport and treatment of municipal solid waste (Baltic Sea Region Programme, 2013). However, when the "Extended Producer Responsibility Principle" applies, the waste generator is the final responsible of the complete waste management.

Another situation that is common in some European regions is the informal waste collection, in Romania for instance, is a standard practice, as an informal business. Concretely, this is the case of Cluj – Napoka, where, although local authorities are responsible for waste management, there is a group of people, called pickers, dedicated to pilfer recyclables from recycling bins. On the other hand, itinerant pickers go to households to ask for recyclable waste or to buy them at a very low price. By last, landfill pickers are dedicated to finding and collecting recyclable waste from landfills (Pop, I. N. et al., 2015).

In the majority of Member States, waste management is public, although some tasks are shared with private companies, as shows the table below.

Country	Treatment Responsibility	Collection & transport responibility
Austria	Public	Public
Belgium	Public	Public
Denmark	Public/private	Public/private
Finland	Public	Public
Germany	Public	Public/private
Hungary	Public/private	Public
Ireland	Private	Private
Italy	Public	Public

Lithuania	Public	Public
Norway	Public	Public
Poland	Public	Public
Portugal	Public	Public
Spain	Public	Public
Sweden	Public	Public
The Netherlands	Public/private	Public/private

Table 1: Waste management responsibility (Source: CEWEP, 2012 and 2014)

Waste collection schemes

In Europe, there are different collection schemes depending on the degree of source separation of recyclable fraction. For instance, dry recyclables can be collected together and separated from residual waste, or completely separated in mono – material streams, or even mixed in the residual waste stream. On the other hand, bio – waste can also be collected separately from dry recyclables and residual waste, but in general terms there are four schemes for recyclables mainly applied in Member States (Cimpan, C. et al., 2015a).

- Single – stream collection scheme: all dry recyclables (plastic, metal, glass and paper and cardboard) are collected together into a single stream. Some alternatives can include glass and/or bio – waste collected separately. At national level, this is the primary applied collection scheme in Greece, while in Ireland, separate collection of bio – waste is also carried out and in Malta and Romania, glass is collected separately (BIPRO/CRI, 2015).

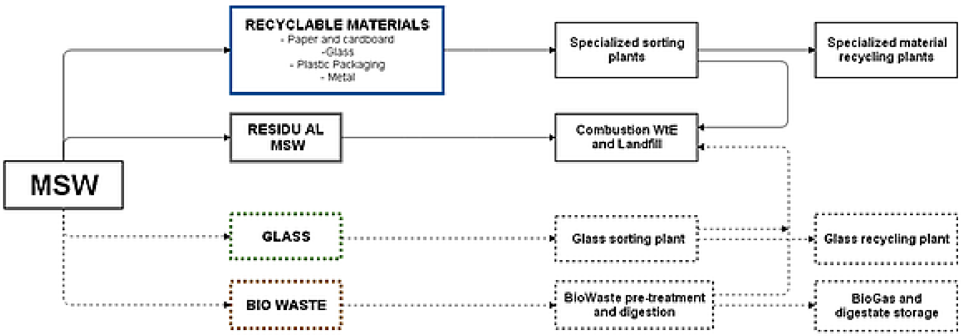


Figure 3: Single - stream collection scheme (modified from Cimpan, C. et al., 2015a and 2015b).

- Dual – stream collection scheme: dry recyclables are collected in two different streams; paper and cardboard are collected separately as “fibres” and the other recyclables, plastic, metal, and glass, are collected commingled in one stream as “non – fibres”. Other options which include separate collection for bio – waste are possible (Cimpan, C. et al., 2015a).

  Dual stream is broadly applied in United Kingdom, where plastic and cardboard are collected in one bin and glass, plastic, and metal are collected commingled in a different bin, apart from the residual waste stream. In this case, separate collection of bio – waste is also applied (BIPRO/CRI, 2015).

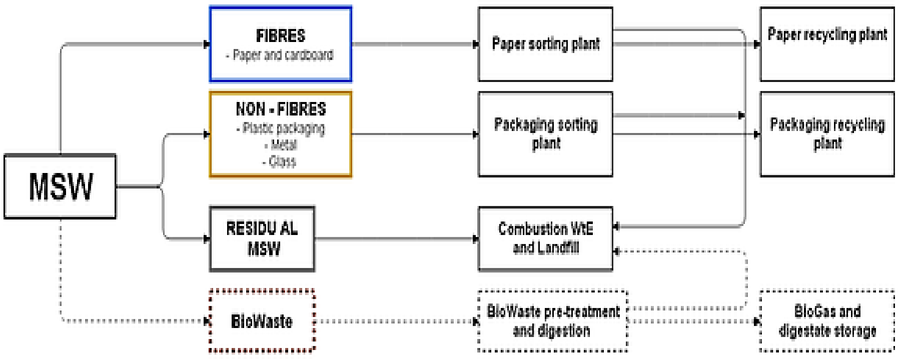


Figure 4: Dual - stream collection scheme (modified from Cimpan, C. et al., 2015a and 2015b).

- Mono – stream collection scheme: a source separation is carried out in order to obtain a separate stream for each recyclable fraction, one stream for paper and cardboard, one for glass and one for lightweight packaging which includes plastic and metal packaging and also multilayer packaging which includes plastic, metal and cardboard. Bio – waste fraction can also be collected separately. After collection, each stream is treated in a material recovery facility (MRF) This collection system is applied in most Member States (Cimpan, C. et al., 2015a), either with separately collected bio – waste (i.e. Belgium, Germany, Luxemburg, Hungary, Italy, and Slovenia) or together with residual waste stream (Bulgaria, Croatia, Cyprus, France, Lithuania, Poland, Portugal, and Spain) (BIPRO/CRI, 2015).

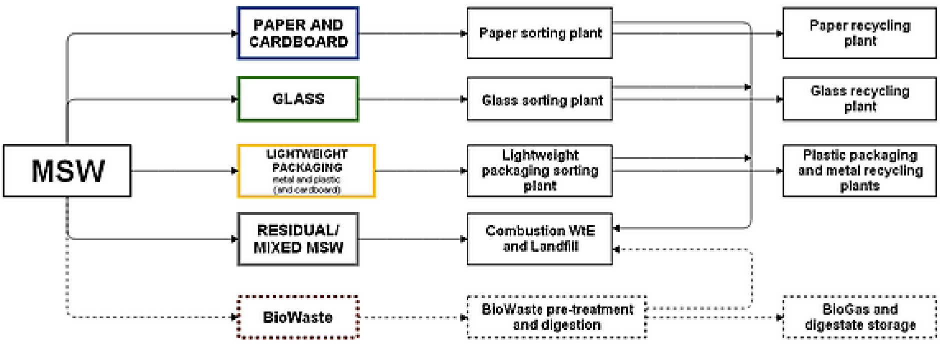


Figure 5: Mono – stream collection scheme (modified from Cimpan, C. et al., 2015a and 2015b)

- Mixed MSW collection scheme: all or some of the recyclable fractions have no separate collection and are collected commingled with the residual fraction, which means that recyclable materials may be present in significant quantities in residual or mixed MSW stream. Recyclables collected through this collection scheme are highly contaminated and need intensive further treatment in the material recovery facilities (MRF).

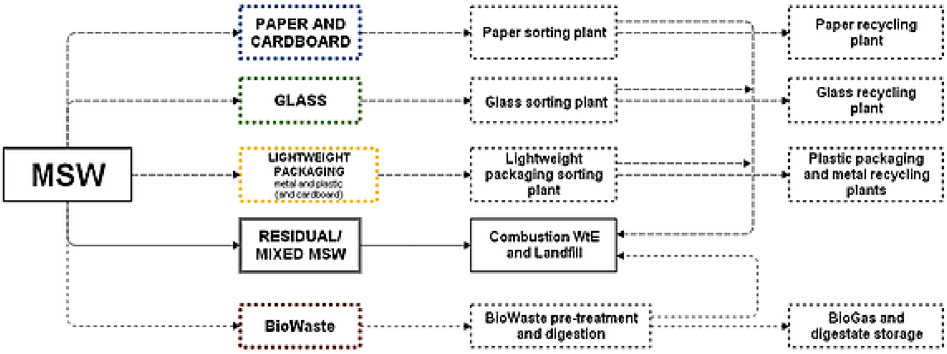


Figure 6: Mixed MSW collection scheme (modified from Cimpan, C. et al., 2015a and 2015b).

Bulky waste usually is not collected through conventional systems due to their size. In some parts of Europe like Spain, these wastes are collected separately by local services several times a year, but in other cases, the only way of collecting is in civic amenity sites. For this reason, bulky waste is not included in these systems.

Apart from these four systems, another way for separately collecting municipal solid waste is a completely segregated collection of dry recyclables and bio – waste, in which each recyclable fraction, paper and cardboard, glass, plastic, and metal, and bio – waste is collected in separate streams. This type of source separation is carried out in Member States like Austria, Netherlands or Sweden.

The collection systems vary widely, not only between countries but also between municipalities, because normally, local authorities are responsible for the choice and implementation of waste collection system (BIPRO/CRI, 2015).

The European Commission has carried out an analysis[4] about collection systems applied by both countries and capitals. In some cases, the system applied in the capital has little differences with the primary system applied at national level but in other, the system is completely different.

In some Member States such as **Bulgaria** and **Croatia**, where the mono stream collection is the primary system applied, there are little differences in the collection way applied in their capitals. **Sofia** applies the same systems but in lightweight packaging stream, only plastic is collected, there is not separate collection for metal, while in some regions of **Zagreb** a pilot project allows the separate collection of bio – waste.

Mono stream collection also is the primary scheme in **France, Lithuania,** and **Poland** however, the systems applied in their capitals are completely different. In **Paris**, dry recyclables are collected commingled except glass, which is collected separately, through the single – stream collection system and although there is not a separate collection for bio – waste, in some regions there are composters where citizens can dispose their bio – waste. In the capital of Poland, **Warsaw**, dry

[4] BiPRO/CRI 2015, Assessment of separate collection schemes in the 28 capitals of the EU, Final report, November 2015

recyclables and bio – waste are also collected by the single – stream collection system, and in **Vilnius**, dry recyclables are collected completely segregated.

In other Member States like **Ireland**, **Malta**, **Romania**, and **Greece** single – stream collection scheme is mainly applied to collect dry recyclables, but bio – waste is collected commingled into the residual stream. In Ireland and Malta, the system applied in their capitals is the same, but in Romania, glass is collected separately from the other dry recyclables and in **Bucharest**, all dry recyclables are collected together. On the other hand, in some regions of **Athens**, a pilot project is being applied in order to collect bio – waste separately.

Some capitals apply systems with lower degree of separation than the system applied at national level, for example, while in **Finland** dual – stream collection is applied in **Helsinki**, only paper and cardboard are collected separately and the rest of dry recyclables and bio – waste are only collected separately after a certain amount.

Table 2 summarizes the prevailing waste collection systems applied in Member States and their capitals.

Member States	Collection scheme system	Capitals	Collection system and fractions collected separately
Belgium Germany Hungary Italy Luxembourg Slovenia	*Mono – stream collection scheme*	Brussels Berlin Budapest Rome City of Luxembourg Ljubljana	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (metal and plastic) Glass Bio – waste
Cyprus Portugal Spain	*Mono – stream collection scheme*	Nicosia Lisbon Madrid	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (metal and plastic) Glass
Bulgaria		Sofia	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (only plastic) Glass
Croatia		Zagreb	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (metal and plastic) Glass Bio – waste (pilot project in some regions)
France		Paris	*Single – stream collection scheme:* Recyclable materials (paper and cardboard, metal, and plastic) Glass
Lithuania		Vilnius	*Complete segregation:* Paper and cardboard

			Plastic Metal Glass
Poland		Warsaw	*Single – stream collection scheme:* Recyclable materials (paper and cardboard, metal, and plastic) Glass Bio – waste
Latvia	*Mono – stream collection scheme*	Riga	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (only plastic) Glass
Ireland	*Single – stream collection scheme*	Dublin	*Single – stream collection scheme:* Recyclable materials (paper and cardboard, metal, plastic and glass) Bio – waste
Malta		Valletta	Recyclable materials (paper and cardboard, metal and plastic) Glass
Romania		Bucharest	Recyclable materials (paper and cardboard, metal, plastic and glass)
Greece		Athens	Recyclable materials (paper and cardboard, metal, plastic and glass) Bio – waste (pilot project in some regions)
United Kingdom	*Dual – stream collection scheme*	London	*Dual – stream collection scheme:* Fibres (paper and cardboard) Non – fibres (plastic, metal and glass) Bio - waste
Finland	*Dual – stream collection scheme*	Helsinki	*Recovery from residual/mixed stream collection scheme:* Paper and cardboard Glass (limited) Metal (limited) Residual/mixed MSW Bio – waste (limited)
Czech Republic	*Recovery from residual/mixed stream collection scheme*	Prague	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (only plastic) Glass
Estonia		Tallin	*Recovery from residual/mixed stream collection scheme:* Paper and cardboard Residual/mixed MSW Bio – waste
Slovakia	*Recovery from residual/mixed stream collection scheme*	Bratislava	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (only plastic) Glass
Austria	*Complete segregation*	Vienna	*Complete segregation:* Paper and cardboard Plastic Metal Glass Bio - waste

Netherlands		Amsterdam	*Mono – stream collection scheme:* Paper and cardboard Lightweight packaging (only plastic) Glass
Sweden	*Mono – stream collection scheme*	Stockholm	*Recovery from residual/mixed stream scheme:* Bio - waste
Denmark	*Complete segregation*	Copenhagen	*Complete segregation:* Paper and cardboard Plastic Metal Glass Garden waste

Table 2: Waste collection systems and separated streams in Member States and capitals (Source: BIPRO/CRI, 2015)

Separate collection systems

The implementation of these four waste collection schemes is carried out through different collection systems: property – close systems, which involve the kerbside and the door – to – door collection systems, bring systems or civic amenity sites (CAS) (Dahlén, L. and Lagerkvist, A., 2010).

- Property – close systems, in which a recovery of around 50% of the recyclable material can be achieved (European Commission, 2014), can be categorized into the two following categories (Xevgenos, D., et al., 2015). These systems are mainly applied in Member States such as Belgium, Luxemburg, Slovenia or The Netherlands, among others, to collect all dry recyclables, bio – waste and residual waste (BIPRO/CRI, 2015).
    - Kerbside collection system. In this system, bins are placed on the sidewalk, outside buildings, so residents can deposit their waste in them. In countries such as Austria, France, Germany or UK, among others, kerbside system is the most common collection system and specifically there are several European municipalities where selective collection is done exclusively through that system, such as Capannori (IT), Limerick (IE), Lisbon (PT) or Verdu (Spain) (Xevgenos, D., et al., 2015).
    - In the door – to – door collection system, the waste is also deposited by residents into bins located on sidewalk. This system is almost identical to kerbside system with the difference that for apartments, door – to – door means that residents put their waste bags outside their door and a collection service is responsible for depositing them in containers on the sidewalk.
- Bring system is the prevailing system to collect most of all, dry recyclables from municipal solid waste in some countries such as Spain, Portugal or Croatia, although this system is present in most Member States as a secondary choice (BIPRO/CRI, 2015). The system permits that citizens bring their segregated waste in drop off collection points placed at the neighbourhood level or at household waste and recycling centres (HWRCs) (WRAP, 2009).
- Civic amenity sites (CAS), also called household waste recycling centres (HWRCs), are facilities specially prepared for public can deposit the recyclable fractions. Normally, this

system is used as an additional recyclable collection system, getting increasing the recycle ratio (BIPRO/CRI, 2015).

Figure 7 shows the percentage of use of different collection systems, only systems applied by municipalities (or their contractors), in the capitals of Member States. Data shown are based on available data on amount of waste collected separately, and the different fractions collected separately. Bio – waste fraction is included in those capitals where it is collected separately. On the contrary, bulky waste and other like hazardous waste or inert waste are not included. Note that not all capitals are present in the graph. Nicosia, Riga, Stockholm, Tallinn, Vienna, and Warsaw are excluded due to incomplete available data. Other systems mean private systems or systems applied by producers or their contractors.

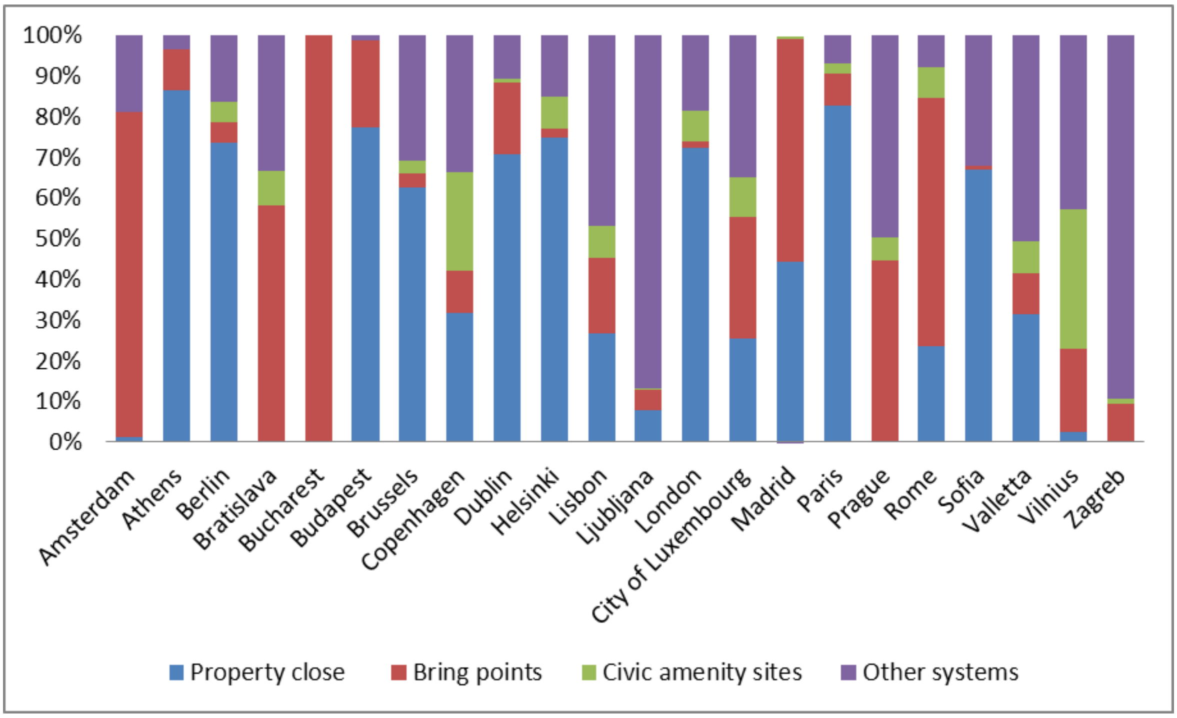


Figure 7: Implementation percentage of collection systems (source: BIPRO/CRI, 2015)

1.3. Scope

This document addresses the main needs of public bodies in charge of municipal waste management identified within PPI4Waste project[5]. Three of these needs are related with specific waste streams, bio-waste management, plastics separation, and bulky waste management, while the other two can be considered as transversal needs, separate collection systems and decision support systems. In order to contextualize these needs in the framework of European policies on waste, this document has been structured to focus on the specific waste streams while transversal needs are generally addressed within them. In essence, this structure is expected to provide a practical overview of how innovation can support public bodies to face challenges in municipal waste management.

[5] These needs have been identified by mean the methodology described in the deliverable D2.2: Report on Agreeing Common needs.

BIO-WASTE

According to the Waste Framework Directive, bio-waste includes biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants. That does not include other biodegradable waste such as paper, cardboard, wood or sewage sludge.

Within bio-waste two main streams of waste are identified (European Commission, 2008):

- Green waste: waste from parks, gardens, etc. That waste contains usually 50-60% of water and high composition of on lignocellulose materials.

- The so called kitchen waste. That waste contains up to 80% of water a low quantity of lignocellulose materials.

Bio-waste collection and bio-waste treatment were identified in task 2.2. of PPI4Waste as two of the main areas of needs for public buyers in charge of municipal waste management.

Bio-waste collection was identified as an area where public buyers expect to invest funding in short and medium terms focused mainly on to set up separate collection systems.

Bio-waste treatment was identified as main area needing improvement for several reasons:

- Increase bio-waste treatment capacity in current facilities.
- Improve the performance of current solutions applied, as anaerobic digester.
- Set – up new facilities for appropriate treatment of bio-waste coming from expected separate bio-waste collection systems.

According to these needs, PPI4WASTE puts the focus in bio-waste management for the so called kitchen waste, which, according to European Commission are more often collected and treated as part of the mixed municipal solid waste (European Commission, 2008).

PLASTIC SEPARATION

Sorting and plastic separation is one of the common needs identified within the PPI4Waste project in order to increase the material recovery rate and to obtain a cleaned material to produce good quality products.

Certain purity is necessary to use plastic waste as a recyclable material and optimize the result of recycling (European Commission, 2013); hence, it is not only necessary to separate plastics from other waste streams but also to sort different types of plastic. Due to these needs, source separation and separate collection systems, as well as waste management systems which involve separation techniques in material recovery facilities (MRFs), are essential to improve material recovery.

It is estimated that in 2014 almost 26 Mt of plastic waste were generated (Plastics Europe, 2015). The construction sector is the second largest consumer of plastic in Europe, but, although its consumption is around 21% per year, it only generates 6% of the total plastic waste per year, because the durability of the plastic products used in construction makes this type of waste last between 30 and 40 years. In other plastic consuming sectors, the degree of plastic waste generation is similar. In particular, agriculture, electrical and electronic equipment (EEE) and the automotive industry in Europe generate respectively around 3%, 7% and 5% of the total plastic waste generated each year (Hopewell, Dvorak and Kosior, 2015). However, plastic waste generation from these areas is increasing at a slower rate than plastic packaging waste, which represents the majority of the total plastic waste generated in Europe (Al-Salem, Lettieri and Baeyens, 2009), with a share of 63%. This is because a significant amount of plastics packaging are single-use products with a short lifespan. In essence, the packaging sector contributes 73% to the generation of plastics wastes from households (DG Environment, 2011).

Bulky waste

There is not a single definition at European level for bulky waste so that there are different meanings depending on the agency or country that describe it. The European Environmental Agency provides a general definition for bulky waste[6], describing it as *"large items of waste material such as electric appliances, furniture, large car parts, trees, etc."*

In general terms, waste is considered as bulky waste if it has any special physic characteristic and/or it requires a different collection method. For instance WRAP[7], describes bulky waste as "any waste whose weight exceed 25 kg and/or any waste that cannot be deposited in general bins provided for household waste or into a cylindrical container of 750 mm in diameter and 1 m in length". The Association of Cities and Regions for Recycling and Waste Sustainable Management (ACR+) compiles, in the Bulky Waste Factsheet, several definitions of bulky waste from different European regions:

- Waste which is not collected selectively, as well as, waste that is collected at clean points and large articles collected from private addresses (Brussels region).

- Large size waste which is collected together and cannot be collected by common ways is considered bulky waste (Ile-de-France region and Lisbon).

- Waste which is collected in determined areas such as re-use centres or clean points and/or some specific waste (Tallin).

Although there is no specific European Directive on bulky waste, it is considered as part of municipal waste as it appears on the European Waste list[8], where bulky waste is included in category 20 of municipal waste. Furthermore, the municipal waste definition by Eurostat includes households and similar wastes, as well as, bulky waste (Eurostat, 2012). Some typical categories considered as bulky waste are, for example, furniture, mattresses, and some WEEE like white goods as described in the new amending of the Directive 2008/98/EC.

---

[6] http://glossary.eea.europa.eu/EEAGlossary/

[7] Waste and Resources Action Programme, United Kingdom.

[8] Commission Decision of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and Council

According to the needs identified within the PPI4Wasteproject, it is necessary to find innovative ways in which bulky waste can be handled and managed as part of a circular economy. Due to the fact that bulky waste is part of municipal wastes, it must be managed following the guidelines of the European Legislative Framework on waste that includes both management according to waste hierarchy and the obligation to carry out a separate waste collection when it is necessary to achieve the targets of recycling and re-use.

Bulky waste requires special management system because, due to its physical characteristics and dimensions, it cannot be collected under the same systems used for the rest of municipal waste. Since collection of municipal waste is usually carried out by the local authorities PPI4WASTE will focus on the collection of bulky waste and how to improve and increase the recovery of that waste carrying out a separate collection.

2. STATE OF THE ART

1.4. 2.1. BIO-WASTE MANAGEMENT

DRIVERS FOR INNOVATION

Bio-waste management plays a key role in the framework of municipal waste systems addressed to promote a high material recovery of bio-waste and it also is a key factor for other waste streams since separate collection of bio-waste is essential to prevent contaminating of dry recyclable materials. In this way, an adequate bio-waste management contributes to increase the preparation for re-use and recycling. Likewise, an appropriate bio-waste management reduces greenhouse emissions from waste.

In recent years, the European Commission has put emphasis on improving bio-waste management throughout Europe by several means:

In 1999 the **Landfill Directive** set up a set of objectives to reduce biodegradable waste sent to landfills.

In 2002 the **Sixth Community Environment Action Programme** proposed to develop specific legislation for biodegradable waste.

In 2008, the European Commission published **the Green Paper on the management of bio-waste in the European Union** aiming to explore options for the further development of the management of bio-waste.

In 2008, the Framework Directive on Waste included several recommendations for bio-waste management.

In 2010, the Communication from Commission on future steps in bio-waste management in the European Union established recommendations on the way to reap the full benefits of proper bio-waste management and described the main potential courses of action at EU and national level and how to better implement them.

Through those initiatives and actions, the European Commission identified potential environmental, economic and social benefits to improve bio-waste management in Europe and recognized the role of environmental policies as a key instrument to boost it.

Policy drivers
Currently there are several European policies and directives that include specific objectives and/or calls to improve bio-waste management in Europe. Additionally, there are objectives for the global municipal waste and for specific types of waste that interconnected with bio-waste management.

The **Directive 1999/31/EC on the landfill of waste,** aims to prevent and reduce the negative effects on the environment from landfilling by introducing technical requirements for waste and landfills.

This Directive established intermediate and long-term targets for reducing the amount of biodegradable municipal waste landfilled.

- No later than five years after the date laid down in Article 18 (1)[9], biodegradable municipal waste going to landfills must be reduced to 75% of the total amount (by weight) of biodegradable municipal waste produced in 1995 or in the last year before 1995 for which standardised Eurostat data is available.
- No later than eight years after the date laid down in Article 18 (1), biodegradable municipal waste going to landfills must be reduced to 50% of the total amount (by weight) of biodegradable municipal waste produced in 1995 or in the last year before 1995 for which standardised Eurostat data is available.
- No later than fifteen years after the date laid down in Article 18 (1), biodegradable municipal waste going to landfills must be reduced to 35% of the total amount (by weight) of biodegradable municipal waste produced in 1995 or in the last year before 1995 for which standardised Eurostat data is available.

The **Waste Framework Directive** called for Member States to take measures, as appropriate, and in accordance with Articles 4 and 13 of the Directive, to encourage:

(a) The separate collection of bio-waste with a view to the composting and digestion of bio-waste.
(b) The treatment of bio-waste in a way that fulfils a high level of environmental protection.
(c) The use of environmentally safe materials produced from bio-waste.

Additionally, there are objectives for the global municipal waste and for specific types of waste that inter-connect with bio-waste management.

According to the Waste Framework Directive, by 2020, the preparing for re-use and the recycling of waste materials such as paper, metal, plastic and glass from households, and possibly from other origins as long as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50% by weight. Likewise, the Directive called for Member States to take measures to promote high quality recycling and, to this end, shall set up separate collections of waste that are technically, environmentally, and economically practicable and appropriate to meet the necessary quality standards for the relevant recycling sectors. In this way, separate collection of bio-waste is a critical factor to prevent contamination of dry recyclable materials.

The Circular Economy Package, launched in December 2015, proposes to modify the European Directives related to waste management, in particular regarding the recycling targets. The future discussion and possible approval of new targets and other measures by the European Parliament and

[9] Note: The date laid down in Article 18(1) is referred to the transposition of the Directive in each member state. According to this Directive, biodegradable waste is defined as any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, as well as paper and paperboard.

the Council of the EU will have direct influence on national, regional and local policies on waste. These proposals reinforce the improvement of bio-waste management in several ways:

- **The proposal for a Directive of the European Parliament and of the Council amending Directive 1999/31/EC on the landfill of waste** introduced a call for Member States to take the necessary measures to ensure that by 2030, the amount of municipal waste landfilled is reduced to 10% of the total amount of municipal waste generated. Estonia, Greece, Croatia, Latvia, Malta, Romania and Slovakia may obtain five additional years for to achieve these objectives.

- **The proposal for a Directive of the European Parliament and of the Council amending Directive 2008/98/EC on waste** reinforces the call for Member States to take measures for appropriate bio-waste management, and in this way, to obtain quality compost and to contribute to the achievement of targets for dry materials (paper, metal, plastic and glass).

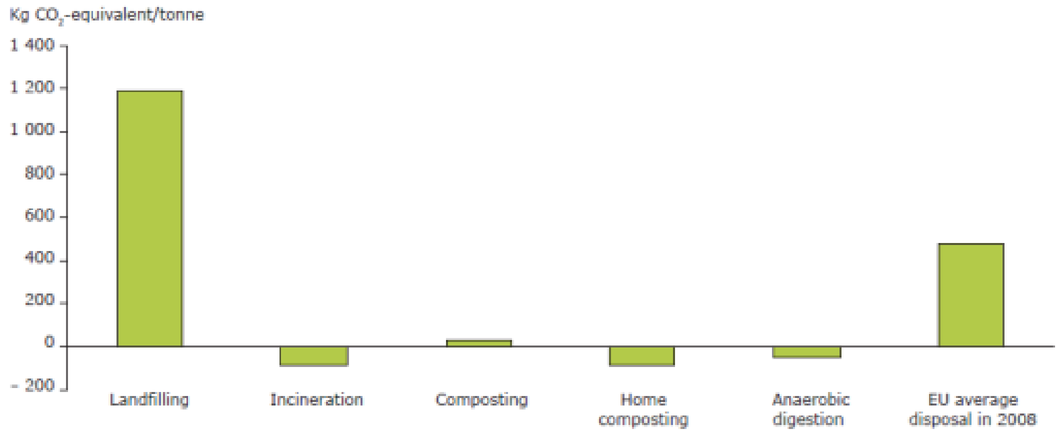
Environmental benefits

Improving municipal bio-waste management can reduce the GHG emissions by means of cutting direct emission from waste management activities, mainly methane from landfills, as well as avoiding emissions through resource recovery (using waste as a secondary material or energy source) and replacing the use of virgin materials or fuels (European Environment Agency, 2011).

The European Environment Agency estimates that if all countries (EU 27) fully meet the Landfill Directive's waste diversion targets, potential life-cycle GHG emissions from municipal waste management in 2020 could be cut by 62 million tonnes CO2-e (European Environment Agency, 2011).

Separate collection, recycling, and energy recovery from bio-waste are key measures to reduce greenhouse gas emissions, especially in countries where landfills are still the prevailing option for disposing of municipal solid waste.

As shown in the following figure, a reduction of GHG emissions can be achieved by means of using appropriate treatment options. For example, in 2008, 44 million tonnes of organic matter were composted, emitting 1.4 million tonnes of CO2-e. On the contrary, if digestable bio – waste fraction would have been subjected to anaerobic digestion, producing useful biogas, it could have cut 2 million tonnes of CO2-e from Europe's emissions and in this way, it would have contributed to European targets of CO2 and biofuels as well as to soil improvement if digestate is used on soil.



Note: Emissions cover only the waste management stage of the life cycle.

Fig 8: Net emissions (kg CO2-equivalent) per treatment option for one tonne of kitchen and garden waste. (Source: European Environment Agency, 2011).

Likewise, separate collection of bio-waste is a way of valuing this material as a resource and closing the organic matter cycle. The compost derived from bio-waste separate collection can stabilise or improve the soil organic matter content and promote its biological activity, addressing the problem of degrading soil quality in Europe (European Commission, 2010). It should be taken into account that the organic matter balanced content is the basis of soil fertility.

Moreover, compost implementation to the soil modifies the soil´s physical, chemical and biological properties long-term, which means in environmental positive terms as (MAGRAMA, 2011):

- Soil erosion reduction.
- Pest control and therefore, the necessary reduction of applying pesticides.
- Water retention improvement, reducing the irrigation requirement and the risk of flooding.
- Improving the structure which facilitates the soil management.

Around 10% of phosphate fertilizers, 9% of potassium fertilizers, and 8% of lime fertilizers, (European Commission, 2011) which are required in agriculture, can be replaced by compost. This would contribute to the non-renewable resource preservation, as well as the decrease of the phosphate and nitrate leaching into the groundwater.

Economic advantages

The implementation of the separate collection of bio-waste involves a priori added costs to the collection and waste treatment, but it has to be taken into consideration that there are several options to bio-waste management; all of these options have different economic implications in such a way that, when analysed through the application of the global model and management instruments, the new setting should not necessarily entail rising costs.

Also, it has to be taken into consideration that, in general, the implementation of the separate collection of bio-waste results in an improvement of the separate collection from the other fractions.

This also entails indirect economic benefits, particularly those resulting from a larger quantity and quality of other fractions collected resulting in a revenue increase provided by the sale of recovered materials.

Finally, if effective bio-waste management is carried out, it is possible to obtain quality compost which can also entail a source of financial gain derived from its sale.

The European Commission carried out two impact evaluation studies about the potential economic benefits and environmental impact reduction derived from the introduction of compulsory separated collection and biological treatment, via composting or anaerobic digestion in the EU countries (EU-27). The study analysed the overall economic benefits for the society of two different scenarios:

Scenario 1: Under this scenario, 88 million tonnes of waste are removed from residual waste treatment facilities compared to the baseline. By 2020, 27 million tonnes of additional biowaste treatment capacity will be needed annually at the EU27 level in order to accommodate this shift.
This scenario results in a net benefit (abstracting from collection costs) of almost 3 billion EUR for the EU27 over the period 2013-2020. 80% of these benefits results from environmental improvements.

Scenario 2: Under this scenario, 36.5% separate bio-waste collection is implemented by 2020. By 2020, 21 million tonnes of waste will be removed from residual waste treatment facilities compared to the baseline. By 2020, 5 million tonnes of additional bio-waste treatment capacity will be needed annually at the EU27 level in order to accommodate this shift. This scenario results in a net benefit of almost 668 million EUR for the EU27 over the period 2013-2020. Almost 80% of this benefits results from environmental improvements.

Current situation in Europe

The production of bio-waste in the European Union is between 118 and 138 million tonnes per year of which around 88 million tonnes are originated from municipal waste (European Commission, 2014). Bio-waste constitutes usually between 30% and 40% of the total municipal waste although this percentage vary in broad range between countries.

As shown in Figure 9, the Mediterranean countries have a higher proportion of bio-waste in the composition of their municipal waste.

% of bio-waste in total municipal waste	Countries
Less than 20 %	Lithuania, Norway and Slovenia
Between 20 % and 30 %	Bulgaria, Denmark, Ireland, Hungary, Latvia and Switzerland
Between 30 % and 40 %	Germany, France, Italy, Sweden, United Kingdom, European average
Between 40 % and 50 %	Austria, Belgium, Czech Republic, Estonia, Finland, Luxembourg, the Netherlands, Poland, Romania and Spain
Between 50 % and 60 %	Greece, Portugal, Slovakia
Between 60 % and 80 %	Malta

Source: ETC/SCP, 2011; and data provided by countries to the ETC/SCP in 2012, ETC/SCP, 2012a.

Note: Bio-waste includes food and garden waste but not wood, paper and cardboard, and textile waste. Member State data on the composition of municipal waste were for either 2008, 2009 or 2010. The European average is calculated based on the 28 countries included in the table.

Figure 9: Bio - waste share in MSW in EU - 28 in 2008 – 2010 (European Environment Agency, 2013)

According to the European Commission and based on European Environment Agency studies, a variety of approaches for bio-waste management are applied by EU Member States. In this way, three groups of countries are identified taking into account their strategies for diverting municipal waste away from landfills and their rates of landfilling, material recovery, and incineration.

- Countries relying heavily on incineration of waste diverted from landfills, accompanied by a high level of material recovery and often advanced strategies promoting biological treatment of waste. These countries generally started to take measures to divert waste from landfills before the adoption of Directive 94/62/EC on packaging and packaging waste and the Landfill Directive.

- Countries with high material recovery rates but relatively little incineration, with some of the highest composting rates in the EU. These countries generally started to take measure to divert waste from landfill before the option of Directive 94/62/EC on packaging and packaging waste and the Landfill Directive.

- Countries relying on landfills, where diversion of waste from landfills remains a major challenge due to lack of alternatives.

In this way, different operations and treatments for biodegradable wastes are applied in the European Union.

In response to policies focused on promoting high material recovery of bio – waste and hence, the separate bio – waste collection for achieving high recycling and preparing for re – use rates, Member States have put efforts in meeting the targets laid down in the European Waste Framework Directive (WFD).

According to data available in the Statistical Office of the European Commission, the amount of total municipal solid waste landfilled has diminished since 1995. In that year, the amount of municipal waste landfilled was 144 million tonnes, while in 2014 the amount was reduced to 66 million tonnes despite MSW generation is higher. This means that between 1995 and 2014, the disposal of MSW in landfills has fallen by 54% and in 2014, the landfilling rate was 27,5% of total MSW generated (Eurostat, 2015c).

Collection schemes

Currently in Europe, bio – wastes are either collected as commingled with residual waste stream or as a separated fraction. In this sense, waste collection schemes described in *"Municipal Waste Management on Europe"* section are applied in different Member States for collection of bio – waste.

At the European level, it is estimated that approximately 45 kg per capita and per year of bio – waste is separately collected (BIPRO/CRI, 2015), through the application of intensive separate collection systems, including food waste from households, garden waste, and waste from food industry (European Commission, 2010).

For separate collection of bio – waste, in Europe there are different systems that can be applied, although this waste is collected mainly by the following two systems (JRC, 2013):

- The door-to-door collection system provides a separate bin for bio – waste collection, located close to households.

- The bring systems permit users to deposit bio – waste into drop – off containers or at household waste and recycling centres.

Below, Table 3 shows the current situation regarding the prevailing system for bio – waste stream in each Member State, although this systems can vary widely at national and regional level.

Country	Bio – waste collection way	Primary collection system
Austria	Separate collection	Door – to – door
Belgium	Separate collection	Door – to – door
Bulgaria	Commingled with residual stream	Door – to - door
Croatia	Commingled with residual stream	Door – to - door
Cyprus	Commingled with residual stream	Door – to - door
Czech Republic	Separate collection	Door – to - door
Denmark[10]	Separate collection only for garden waste	Door – to – door
Estonia[11]	Separate collection	Door – to – door
Finland[12]	Separate collection	Door – to – door
France	Commingled with residual stream	Door – to – door
Germany	Separate collection	Door – to – door
Greece	Commingled with residual stream	Door – to – door
Hungary[13]	Separate collection	Door – to – door
Ireland	Separate collection	Door – to – door
Italy	Separate collection	Door – to – door
Latvia	Commingled with residual stream	Door – to – door
Lithuania	Commingled with residual stream	Door – to – door
Luxembourg[14]	Separate collection	Door – to – door
Malta	Separate collection only for garden waste	Civic amenity sites
Netherlands	Separate collection	Door – to – door
Poland	Commingled with residual stream	Door – to – door
Portugal	Commingled with residual stream	Door – to – door
Romania	Separate collection only for garden waste	Door – to – door
Slovakia	Separate collection	Civic amenity sites
Slovenia	Separate collection	Civic amenity sites
Spain[15]	Commingled with residual stream	Bring Points

[10] In Denmark, door – to – door is the primary system applied for garden waste collection, but not for kitchen waste
[11] In Estonia, door – to – door is the primary system applied for bio – waste separate collection, but secondary in sparsely populated areas
[12] In Finland, door – to – door is the primary system applied except in sparsely populated areas, where is Civic Amenity Sites (CAS)
[13] In Hungary, bio – waste are collected separately by doo – to – door system but only on demand
[14] Door – to – door is the primary system for separate collecting kitchen waste in specific green bags. For collection of garden waste, bring point is the primary system although almost all municipalities also provide door – to – door collection.

Sweden	Separate collection	Door – to – door
United Kingdom[16]	Separate collection	Door – to – door

Table 3: Current situation about bio - waste separate collection systems by Member State (BIPRO/CRI, 2015)

Bio – waste treatment options

According to the waste hierarchy, prevention is the first option. However, it is not possible to prevent the totality of bio – waste generated. For this bio – waste whose prevention has been unavoidable, Member States should apply the best treatment option in accordance with the waste hierarchy and the specific waste conditions. Material recycling operations such as composting are the second preferred choice for bio – waste management, followed by energy valorisation and landfilling as the last option.

In order to valorise the organic fraction of bio – waste, there are several treatments that involve both material recycling and energy recovery, some of which may only be applied for bio – waste source separated to avoid the risk of contamination (JRC – IES, 2011). Below, a brief description for each treatment method and a general overview about current situation is provided.

Treatment methods for source – separated bio – waste collection

<u>Composting</u>

Composting is a bio – waste treatment based on the aerobic degradation of waste by microorganisms, in order to produce compost that can be used as an organic fertilizer, among other applications (JRC, 2013; JRC – IES, 2011).

For compost applications as fertilizer, growing media or soil improver, bio – waste must be source separated for keeping contamination levels as low as possible. However, some technologies are being developed to increase the quality of compost from bio – waste collected from commingled streams (JRC, 2013).

There are several composting techniques such as open or closed composting, composting with or without forced aeration, etc. Although closed composting is more expensive, it requires less space, is faster, and is stricter in terms of emissions (European Commission, 2008). Depending on the composting technique, the process duration ranges from a week to several months (JRC, 2013).

Material recovery by composting has grown by 5,3% until 2014, which yielded a total increase in the percentage of composting application of 170% since 1995 (Eurostat, 2015).

[15] In some Spanish regions such as Catalonia, Guipuzcoa, Cordova and some municipalities of Navarra, separate collection of bio – waste is allowed, primary by bring points

[16] In UK, garden waste is collected in almost all municipalities but kitchen waste only in 50%. Commingled collection of garden waste and kitchen waste is applied as a secondary choice and CAS is a tertiary choice only for garden waste.

Anaerobic digestion

Anaerobic digestion is a biological treatment in which a methanogenic bacterium decomposes organic matter contents in bio – waste into chemical compounds in the absence of oxygen, in a wide range of temperatures and pH values (JRS – IES, 2011). This treatment can be used as an alternative to or in combination with composting, and it generates two products.

On the one hand, the process generates a methane – rich biogas (45 – 80% methane content) stream (JRC, 2013), which contains carbon dioxide and water vapour that can be applied for generating electricity and/or heat, or it can be enriched in methane for use it as a fuel or substitute for natural gas, reducing greenhouse gas emissions (GHG) (JRC, 2013, European Commission, 2008).

On the other hand, the residue from the process, the digestate, can be used directly as a fertilizer or can be composted in which case, the matter must be stabilised and sanitised and in this case, the resulting compost is comparable in quantity and composition to compost from bio – waste composting (JRC – IES, 2011).

For the use of digestate as a fertilizer, it is important that bio – waste is source separated in order to avoid the risks of contamination. In addition, the high moisture content of bio – waste from kitchen and comparable, makes these wastes ideal for anaerobic digestion, while ligneous elements such as green waste are not degradable by anaerobic digestion (JRC – IES, 2011).

Pyrolysis and gasification

Pyrolysis and gasification are promising emerging thermal treatments for municipal waste in general and particularly for bio – waste.

Pyrolysis process; the organic fractions in the waste are decomposed under pressure and in the absence of oxygen. It is important that the bio – waste are collected separately to avoid the elimination of organic matter and thus increase process efficiency. The main outputs of this treatment is a liquid residue, a solid char which is required to be landfilled or to undergo additional processing, and a gaseous stream which can be used for generating electricity.

Gasification: gasification operates at a higher temperature and in presence of oxygen. The product obtained is a gas stream that can be applied in electricity generation, and a char.

These two treatments can be applied in combination, because the solid char produced in the pyrolysis process can be turned into a gas. However, both technologies still present technical challenges for bio – waste treatment and some of them are still in a pilot stage and use large scale facilities (annual capacity about 10.000 tonnes). Despite this, pyrolysis and gasification of waste are expected to become more widely used in the future (JRC – IES, 2011).

Fermentation

As an alternative to anaerobic digestion for biogas production, some types of bio – waste can become second generation biofuels through emerging techniques based on fermentation process. Biofuels produced by fermentation require an additional step to convert waste material in fermentable waste, especially green and garden waste that contains lignocellulose material (JRC, 2013).

Treatment methods for mixed waste collection of bio – waste

Mechanical biological treatment and stabilization

Mechanical – biological treatment (MBT) is a treatment that involves both a biological treatment and mechanical process such as a sorting step (European Commission, 2008). Combination of these mechanical and biological processes allows for biodegradable waste extraction through specific treatments, such as anaerobic digestion, among other.

In a MBT facility the mixed or residual MSW is subjected to a mechanical separation into two fractions, a biodegradable fraction, which is later treated in any of the biological processes described above, and a non – biological fraction, which is generally landfilled or incinerated (JRC, 2013).

Incineration

Incineration is a thermal treatment that consists of the burning of the wastes normally to reduce their volume and hazard, and also to capture or destroy harmful substances. However, incineration can involve energy recovery when the heat produced in the combustion is recovered for diverse uses (JRC – IES, 2011). However, not all types of bio – waste are suitable for energy recovery, especially, food waste are not appropriate for incineration with energy recovery because of their low calorific value.

Landfilling

Landfilling means the disposal and storage of waste at the end of its useful life after undergoing previous treatment, or where it is not possible to apply an alternative treatment. This treatment involves a series of environmental risks derived from the leachates and biogas generated. So it is necessary to implement technical measures such as a bottom liner, top soil cover, as well as gas and leachate collection and treatment systems. But despite of these measures, the potential environmental impacts remain high.

Although landfilling is still a management option for municipal solid waste, particularly for bio – waste, recycling of bio-waste is being carried out increasingly thanks to the implementation of EU policies and bans about landfilling of bio degradable waste. About 66Mt have been recycled in 2014, which means a total increase of 41Mt. Bio – waste valorisation through these treatments has increased by 17% between 2007 and 2014, being the amount composted and digested in 2014 about

75 kg per capita. Austria has the highest amount of composted and digested waste among Member States, totalling 175 kg per capita in 2014, while Bulgaria only composted and digested 8 kg per capita in 2014 (Eurostat, 2015c).

Figure 10 shows the current situation regarding percentage of composting and digestion of MSW in the year 2013.

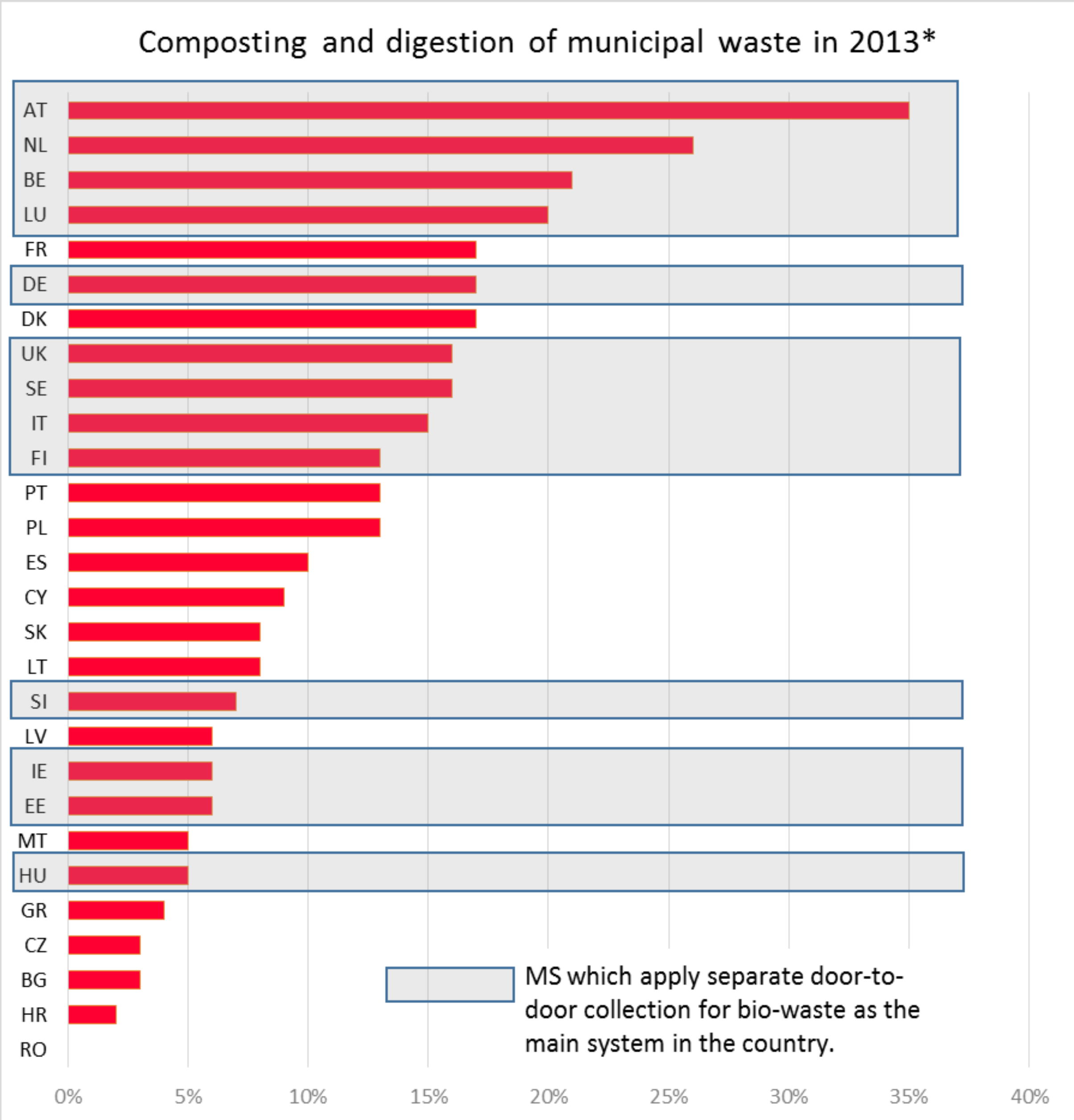


Figure 10: Composting and digestion of MSW by Member State in 2013 (BIPRO/CRI, 2015)

The following table shows a baseline scenario predicting the amount of bio – waste according to each type of treatment in forthcoming years.

Year	Landfill	Incineration	MBT	Composting	Anaerobic digestion	Total bio – waste collected
2013	21.192	14.829	16.559	30.989	5.122	88.692
2014	20291	14.940	17.504	31.712	5.663	90.116
2015	19.551	15.338	17.781	32.552	6.136	91.319
2016	17.588	15.485	19.134	33.467	6.628	92.301
2017	16.971	15.785	19.160	34.232	7.141	93.288
2018	16.548	15.861	19.218	35.040	7.620	94.286
2019	15.812	16.233	19.243	38.878	8.128	95.294
2020	14.666	16.341	20.244	36.667	8.503	96.311
TOTAL	142.586	124.813	148.843	270.425	54.941	7411.607

Table 4: Baseline scenario. Kilo tonnes of bio - waste treated by different treatments in EU - 27 between 2013 and 2020 (DG Environment, 2011a)

General trends in innovative solutions

Trends in separate collection

As it was viewed in the previous chapter, some Member States have already implemented bio - waste separate collection, but the countries that collect commingled bio - waste are carrying out pilot experiences and pilot projects to implement a separate collection and to develop and establish a bio - waste collection policy.

The separate collection of bio - waste is necessary to increase the rate of recovered material as well as the quality of recovered material, which will determine subsequent recycling and the use of the obtained products. In this way, the major tendencies in innovation are related with new management models that will generate a stream of bio - waste with the minimum amount of improper waste and the development of technologies that enable the production of high value - added products.

One of the main aspects that marks the management of bio - waste is that the establishment of management models that are economically, socially, and environmentally sustainable strongly depends on various local conditions, such as the distribution of production, the composition, the climate, and the potential use of products obtained from bio - waste treatment: methane, compost, electricity, heat, etc. Because of this, innovative solutions have been developed for the treatment of bio-wastes adapted to local conditions, and tools have been developed to support decision-making, allowing for the implementation of adequate management systems. In 2011, the European Commission published the guide "Supporting Environmentally Sound Decisions for Bio-Waste Management" developed by the Institute for Environment and Sustainability of the Joint Research Centre. This guide aims to support decision-making in the management of bio - waste under the approach of Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA).

In terms of management models, there is a tendency towards the development of centralized or decentralized models according to local characteristics, such as the distribution of producers, the existence of infrastructure, or the availability of other organic waste that can be jointly treated.

In relation with decentralized systems, there has been a development of solutions that enable the treatment of bio - waste in households, generally through various types of compost bins, so that the compost obtained can be used in the garden of the house itself. Furthermore, in small communities, there is a tendency to develop solutions to the joint treatment of different organic wastes, not only bio - waste. These solutions have the aim of obtaining more efficient processes, through for example, anaerobic co-digestion of various types of wastes.

In centralized systems, where large quantities of waste are treated, there is a tendency for evolution of the current implemented techniques, such as the composting or the anaerobic digestion. This evolution aims to make these techniques, as well as the search of models that can exploit the synergies with other processes, more efficient.

In terms of composting, there is a tendency to search for solutions that enable the automation of the process with a particular focus on the emission of wastewaters and smells. In many cases, these systems are closed systems that allow the control of water circulation and management. The so-called in-vessel composting systems are a clear example.

On the other hand, and because of the need to find alternatives to fossil fuels, the anaerobic digestion systems are becoming more relevant. In this field, there are different lines of innovation aimed at improving the efficiency of these systems. Among these lines of innovation, several initiatives can be identified (Budzianowski, 2015), which address the following:

- Management models that ensure the supply of raw materials, bio - waste, for proper operation.
- New monitoring systems and the control of operating parameters of these systems, mainly for large plants.
- Development of new operation techniques, such as reactors operating in two stages in order to improve microbiological digestion processes.
- Co-digestion of various types of organic waste.

Another important aspect related with anaerobic digestion systems is the conditioning of biogas. There are different tendencies in this field in order to reduce the presence of constituents, like the H2S, as well as adjusting its calorific value, reducing the concentration of CO2. This line identifies new solutions (Budzianowski, 2015) based on different techniques: biological methods, adsorption, absorption, membranes or cryogenic methods.

It is noteworthy to emphasize the development of new solutions that facilitate and enhance the use of biogas produced for the generation of electricity and heat, injection into the gas grids, and also as a transport fuel or a fuel for chemical production. In this sense, there are new developments in turbines, gas engines, or fuel cell technologies, as well as developments in the conversion of biogas into biomethane, biosyngas and biohydrogen and biomethanol.

In addition, the relevance of the development of bio-refineries for obtaining high value-added products (bio-based products) from different raw materials (including biowaste) should be noted. In this regard, there are new innovative solutions oriented to the integration of the bio-refineries and anaerobic digestion systems.

Finally, it is noteworthy to emphasize the new solutions based on the gasification and pyrolysis processes. The gasification process is able to convert organic waste from MSW into carbon monoxide, carbon dioxide, methane, and hydrogen, with high energy content and free of pollutant emissions, at controlled amounts of oxygen. Meanwhile, pyrolysis decomposes chemically organic material without oxygen at very high temperatures, obtaining syngas.

In comparison with the conventional incineration process, gasification has a greater potential thermal efficiency thanks to the application of gas turbines in the process. However, the application of this technology in a large – scale setting is hampered and the experience in MSW management is limited, thus it is important to continue the development of both treatments in this field.

POTENTIAL INNOVATIVE SOLUTIONS

Integrated system biogas production from biowaste and wastewater treatment

The innovative integrated system MBR – AD has been the object of the INTER – WASTE project. The INTER – WASTE project is a demonstration project cofinanced by the European Commission through the LIFE+ programme.

The INTER – WASTE project aimed at demonstrating the application of an integrated system for management of biowaste, wastewater and sewage sludge in low-density population areas and isolated areas.

The innovative nature of this system relies in the integration of two known technologies, a membrane bioreactor (MBR) and an anaerobic digester (AD), in a single system capable of treating urban wastewater and sludge biodegradable organic matter fractions, leading to the production of renewable energy from biogas and organic fertilizer.

In this process, the urban wastewater is treated with a biological treatment in a bioreactor equipped with ultrafiltration membranes that concentrate the sewage sludge and obtain treated water free of solids.

Furthermore, the organic waste fractions are mixed with sewage sludge. The resulting mix feeds the anaerobic digester, which produces biogas that, after a post-treatment, can be used for electrical energy generation. Finally, the digestate waste is treated, which facilitates its use as an organic fertilizer.

The system consists of four main units:

- The water treatment unit includes a membrane bioreactor (MBR), a homogenization system of the previously fed wastewater as well as a sludge recirculation system.
- An anaerobic digestion system for the treatment of biowaste that, in addition with the digester system, also integrates a mixing and homogenization system of the sludge from the water treatment with organic waste fractions and a heat exchanger.
- A treatment unit for cleaning and compression of the obtained biogas. This unit is composed by a temporary storage for the biogas and a combined heat and power production unit.

- A digestate treatment system, which includes storage, phase separation of digestate liquor and a solar drying system.

This system provides economic benefits: operating costs are reduced because of the integration in a unique system for water treatment and organic waste. Furthermore, an economic performance on products obtained in the conversion of waste is also achieved.

This solution, applicable in municipalities and island communities, has been tested as a part of the project INERT - WASTE in a small area in Cyprus. In this demonstration pilot, the system has been able to treat approximately 600 kg of organic waste fractions and 150m3 of wastewater per day, from which a daily production of about 125m3 of biogas is obtained. This makes the system self-sufficient and provides electricity to20 households.

More information is available at:

http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3480&docType=pdf

Innovative system for bio - waste separation and cleaning

The innovative waste separation system has been developed with the aim of achieving a better and more efficient sorting of the organic matter contained in municipal waste.

This system has been tested under the project SEPARATE, co-financed by the European Commission through the CIP program. This project was aimed to test and demonstrate the advantages of the separation system in order to facilitate its market penetration.

The waste separation system aims to facilitate the collection of clean organic matter from municipal waste, so that further processing and obtaining of quality products can be facilitated.

This system is applicable to waste streams resulting from separate collection of bio-waste as well as waste streams in which bio-waste is collected with other types of waste.

The waste separation system is based on the use of two innovative technologies: a hydraulic high-pressure dam and a subsequent cleaning process.

The hydraulic dam is the cornerstone of the unit. The dam is fed with waste, which is separated into two fractions through the application of high working pressures with a very high environmental efficiency, specifically 98%. Firstly, a soluble organic fraction whose behaviour can be approximated to the one that liquids have is obtained and, secondly, a nonorganic dry fraction is obtained.

The cleaning process is responsible for eliminating persistent organic matter impurities, limiting their contents as much as possible. This process consists of two stages. In the first stage, the organic fraction is separated from the coarsest impurities through a cyclone separator. Subsequently, the organic matter passes through a silt tank, where the organic matter is separated from the finest impurities, obtaining a homogeneous paste suitable for various applications and high quality products can be obtained from these applications.

The main advantages of this system are:

- High efficiency in the separation of the matter of organic matter (> 98%).
- Improvement of the subsequent anaerobic digestion processes:
  - Major production of biogas due to broken cell structures of organic matter.
  - Lower maintenance costs and improved biogas digester performance (<0.5% plastic and inert materials remain in organic fraction)
  - Lower investment costs through shorter retention times

This solution has been commercialized by the DB Technologies group, under the trade name "OREX".

More information is available at: http://www.dbtechnologiesbv.nl/

1.5. 2.2. Plastic separation

Drivers for innovation

A successful plastic separation and sorting system is essential in order to increase the rate of recovered material from municipal wastes. In this sense, waste policies and potential environmental and economic benefits can act as drivers for innovation to boost plastic separation.

Policy drivers

In Europe, several objectives for plastic waste recycling and recovery have been imposed since 1994 by legislative means on waste, and they have served as drivers for innovation in separating, sorting, and recycling solutions. Specifically, member states must carry out a separate collection if it improves the process, if it facilitates the recovery of waste, or if it is necessary to achieve the recycling and recovery targets established in the legal framework, providing that separate collection is technically, environmentally, and economically viable.

Currently there are several European policies and directives that include specific objectives and/or calls to improve plastic management in Europe. Additionally, there are objectives for global municipal waste and for specific types of waste interconnected with plastic waste management.

The Directive 1994/62/EC on packaging and packaging waste established the following objectives:

- By June 30th 2001, 50% to 65% of the weight of packaging waste had to be recycled or incinerated with energy recovery. This percentage had to reach 60% before 31 December 2008.
- By June 30th 2001, between 25% and 45% by weight of all packaging materials had to be recycled, with a minimum of 15% for each type of material.
- By December 31st 2008, 55% to 80% by weight of packaging waste should be recycled, with a specific target of 22.5% of plastic packaging waste to be recycled.

The Directive 2008/98/EC on waste sets a number of milestones about waste recycling and preparation for reuse.

- Article 11 establishes that Member States should take appropriate measures to encourage high quality recycling by establishing a separate waste collection where appropriate. By 2015, separate collection of paper, metal, glass, and plastic had to be achieved.
- By 1st January 2020, recycling and preparing for reuse of MSW must be increased by at least 50% by weight, according to paragraph 2.a) of Art. 11.

The recently adopted Circular Economy Package included several proposals for amending a number of Directives on waste. These proposals reinforce the improvement of plastic management in several ways.

The economy package proposes to amend the Directive 1994/62/EC on packaging and packaging waste, by tightening some of the quantitative targets.

- In article 6, it is proposed that the minimum recycling target is raised to 65% of total packaging waste, to be reached by the end of 2025, with a minimum of 55% for plastic packaging waste in particular.

- The same article proposes that the total packaging waste recycling reaches a minimum of 75% by 2030.

On the other hand, the Circular Economy Package proposes to amend the Directive 2008/98/EC by establishing new incentives and introducing new recycling targets.

- In article 11, it is proposed that the minimum target for preparing for re-use and recycling is increased to 60% of the weight of municipal waste by 2025 and to 65% by 2030.

In the current Directive on packaging and packaging waste, under article 6, energy recovery was encouraged as preferable option to waste management when it is a more profitable option, both economically and environmentally than the material recycling. This article sets minimum percentages for energy recovery higher than that of recycling, to which Member States must comply by the end of 2008. However, energy recovery is no longer the focus on the new proposed directive. The proposed Directive only sets new targets for recycling and adds a new article, Article 6a, paragraph 2 (b). According to this article, a percentage of packaging waste that has not been subjected to a recycling process and that is subject to energy recovery or landfilled can be included as recycled on the calculation of the attainment of targets laid down, provided that the percentage is below 10%.

Environmental benefits

Plastic materials continuously cause environmental problems throughout their life cycle, not only during the production phase, in which greenhouse gases are generated, but also during the waste management phase. In 2015, although part of plastic waste was recycled or incinerated with energy recovery, it is estimated that 50% of plastic waste was still landfilled (Wong, S., Ngadi, N., Abdullah, T. and Inuwa, I., 2015) causing a considerable accumulation of plastic waste in the environment.

On the other hand, improved separation and sorting systems paired with the recycling rate would reduce the consumption of renewable and non-renewable natural resources for industrial plastic production. Furthermore, greenhouse gas emissions are also reduced, since the energy consumption involved in the production of virgin plastic materials is much greater than consumption derived from the production from recycled materials (European Environment Agency, 2013). Furthermore, recycling is considered one of the best waste management systems in reducing CO_2 emissions. Approximately 1,45 tonnes of CO2 can be saved per each tonne of recycled plastic (Hopewell, J., Dvorak, R. and Kosior, E., 2009). As a specific example, a study[17] carried out in Spain demonstrated that mechanical recycling in Spain is able to avoid 620 kg CO_2 eq. per tonne.

Additionally, it is necessary to take into account the relatively recent emergence of bioplastics, which are plastics derived from renewable resources (European Bioplastics, 2016). Although plastic products from oil continue to dominate the market today, the bioplastics market increased by about 10% in 2009 in Europe and it is estimated that their consumption will increase annually by 20% (BIO IS, 2011b). Biodegradable plastics can complicate the management of waste because currently waste treatment systems are not able to separate effectively enough bioplastics from petroleum-based plastics (European Commission, 2013). Therefore, the development of bioplastics can be considered as one of the drivers for innovation, in this case, with regard to the technical amendments to the existing management systems of plastics.

Economic advantages

The economic success of plastic waste recycling depends heavily on an effective separation of waste streams (Luijsterburg, B. and Goossens, H., 2013) as well as the classification of different types of waste. At the same time, this separation should be done quickly and affordably, meaning the benefits of the recycled product should exceed the costs of the recycling process.

Recovery and recycling of plastic waste means their life cycle can be extended and they would become raw materials, allowing them to return to the industrial and commercial cycle, reducing consumption and therefore, the production costs in terms of raw materials, energy and water resources, necessary for the production process (Sevigné-Itoiz, E., Gasol, C. M., Rieradevall, J. and Gabarrel, X., 2015). For this purpose, it is particularly important to improve waste management systems as well as waste separation and sorting techniques as tools for increasing the recycling rate. Another important benefit of improving collection and separation systems is the increased efficiency of both processes that reduce their costs (Deloitte, 2015).

CURRENT SITUATION IN EUROPE

Some notions regarding the current state of compliance, the goals as well as the current situation in terms of management systems are given in the following section.

Policy targets

As a result of the implementation of the aforementioned European regulations, Member States have achieved most of the targets set in these policies, according to the data collected by the Statistical Office of the European Commission.

Statistics show that, according to the recommendations given by the Directive 1994/62/EC in relation to an increase in the recycling of packaging waste and the recovery and incineration with energy recovery, the objectives have not only been reached but also have successfully passed on.

[17] Contribution of plastic waste recovery to greenhouse gas (GHG) savings in Spain (Sevigné – Itoiz, et al., 2015)

Specifically, in 2012 the rate of incineration with energy recovery was 78.5% and the rate of recycling of packaging waste was 64.4%. However, analysing the individual recovery rate for each Member State, it can be seen that not all countries were able to meet the goals. While in 2012, Portugal, Italy, Greece and Cyprus had not yet reached the proposed target by 2008, Malta failed to reach even the rate proposed for 2001 (Eurostat, 2015a).

Between 2006 and 2014 the amount of plastic waste deposited in landfills has decreased by 38%, which represents an average annual decline around 5% (Plastics Europe, 2015).

In this context it is necessary to highlight that for calculating the fulfilment of the targets set out in Directives it is important to consider the imports and exports of waste, either for recycling and preparing for re–use. In 2012, exports of plastic waste in particular experienced significant growth in the EU; 55% of plastic waste collected in the smaller countries was exported, which affects to the achievement of the targets for each Member State involved. In this way article 6 of the new proposal to amend the Directive 1994/62/EC on packaging and packaging waste establishes that the amount of packaging and packaging waste sent to another Member State shall only be included in the target calculation of the country where it was collected.

Figure 11 shows plastic packaging waste management statistics in 2014.

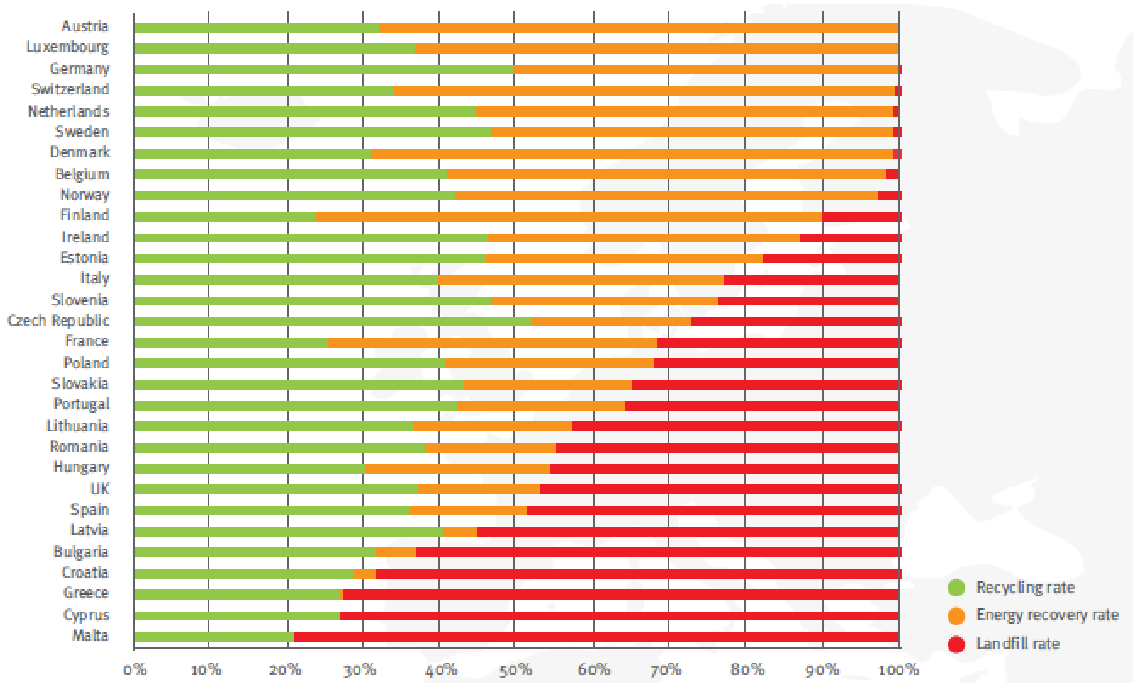


Figure 11: Plastic packaging recycling, energy recovery and landfill rates by Member State in 2014 (Plastics Europe, 2015)

Plastic packaging waste management models

There are different management models in Europe, based on either a source separate collection or a commingled collection in order to carry out waste separation and sorting.

Regarding the responsibility for the management of plastic waste from households, in most cases and in most Member States, producers are responsible for recovery and preparing for re–use of post–consumer plastic packaging waste (on the basis of producer responsibility principle), although plastic waste management activities in the majority of Member States is shared between municipalities and private entities.

In order to comply with policy targets the producers can create according to the extended producer responsibility[18] scheme an association for managing their packaging waste, which will be responsible for the complete waste management to its final disposal, through the foundation of Integrated Management Systems (IMS), and will be ultimately responsible for the fulfilment of the targets set out in the Waste Framework Directive (WFD). In Europe, an association was founded in 1995 in order to be the European coordinator for system management of packaging waste. This organisation, PRO Europe (Packaging Recovery Organisation Europe), mainly uses the Green Dot System which was the first packaging waste management system implemented in Europe and has become an internationally recognised model for the proper implementation of producer responsibility. Currently, in 28 countries packaging recovery organisations, such as ARA (Austria), Eco Emballages (France), Repak (Ireland), Nedvang (The Netherlands), Ponto Verde (Portugal) or Ecoembes (Spain), among other, apply the Green Dot System (PRO Europe, n.d.). In the same line, EXPRA (Extended Producer Responsibility Alliance), founded in 2013, is a non – profit organisation responsible for the management of packaging and packaging waste from industry, which aim is to ensure the recovery and recycling packaging waste in the most economically and environmentally efficient way. EXPRA is working towards this objective in 16 Member States.

On the other hand, plastic packaging waste can be completely source–sorted (in this model collaboration of citizens is a key issue) or can be separated of MSW into a fraction which contains other mixed recyclable waste. Specifically, the household plastic packaging waste can be collected in the four different schemes, described in the previous section 1.2. Municipal waste management on Europe.

- Mono stream collection scheme, where plastic waste is collected commingled with metal and/or multilayer packaging, in a separate stream from other recyclables.

- Single or dual collection schemes, where plastic waste is collected as part of a dry recyclable stream which contains other types of recyclable.

- Recovery from residual/mixed municipal solid waste collection scheme, where plastic waste is not collected separately from mixed MSW.

Table 5 shows the current status regarding collection system, as well as collection and sorting responsibility for each Member State.

[18] The introduction of extended producer responsibility in the Waste Framework Directive is one of the means to support the design and production of goods which take into full account and facilitate the efficient use of resources during their whole life-cycle including their repair, re-use, disassembly and recycling.

Country	Collection and sorting	Collection System
Austria	ARA	Door – to – door
Belgium	Fost – Plus	Door – to – door
Bulgaria	Ecopack	Door – to - door
Croatia	Eko – Ozra	Bring points
Cyprus	Green dot Cyprus	Door – to - door
Czech Republic	Eko – Kom	-
Denmark	Private operator	Door – to – door
Estonia	ERO	-
Finland	PYR	-
France	Eco – Embalages	Door – to – door
Germany	Dual System Deutchland, GmbH	Door – to – door
Greece	HE.R.R.Co	Door – to . door
Hungary	Oko Panon	Door – to – door
Ireland	Repak	Door – to – door
Italy	CONAI	Door – to – door
Latvia	Latvijas Zalais pinkts	Door – to – door
Lithuania	Zaliasis taskas	Bring points
Luxembourg	Valorlux	Door – to – door
Malta	Green pak	Door – to – door
Netherlands	Nedvang	Door – to – door
Poland	Rekopal	Bring points
Portugal	Ponto Verde	Bring Points
Romania	Eco – Rom Ambalaje	Door – to – door
Slovakia	Envipak	-
Slovenia	Slopak	Door – to – door
Spain	ECOEMBES	Bring Points
Sweden	FTI	Bring Points
United Kingdom	ValPak	Door – to – door

Table 5: Packaging waste collection by country (Sources: PRO Europe, n.d.; BIPRO/CRI, 2015)

After collection, the plastic packaging waste stream or lightweight packaging waste stream is sorted in material recovery facilities (MRFs), where plastic packaging waste is separated from other waste and then sorted by polymer type.

The typical sorting process in material recovery facilities in Europe involves several sorting steps, including manual dismantling and sorting by automated processes, density or size separation, optical separation or magnetic separation, among other, although there is no general way of designing the sorting process (Plastics Europe, n. d.).

General trends in innovative solutions

In response to common needs identified and in order to comply with targets established in the European legislative framework, Member States tend to apply innovative solutions.

Trends in collection models

Many Member States have already implemented waste management models that involve separate collection for different recyclable fractions in order to improve the quality of recycling. Although there are several ways to collect plastic packaging waste and completely separate collection of plastic packaging waste provides better results in subsequent recycling, the costs associated with this type of collection are much higher. As an alternative, in some Member States, there is a tendency toward a collection of plastic mixed with metal and multilayer packaging, mainly through a door – to – door system. Specifically, fifteen Member States collect plastic packaging and metal in a single stream as lightweight packaging, while only five Member States collect plastic waste completely separate. This collection system is a good way to achieve a balance between the costs associated with management and the quality of the separated fractions, therefore improving the subsequent recycling (BIPRO/CRI, 2015).

For the collection of packaging waste, separate bins is the most common option, however some Member States have implemented other ways such as coloured transparent bags for separating packaging waste. or multi – compartment bins that are a widely used solution to separate the different fractions of recyclables, including packaging waste in countries such as Sweden or Denmark, (Noedic Council of Ministers, 2015).

On the other hand, in some countries, the installation of underground containers to deposit the different waste fraction such as plastic waste (or lightweight packaging waste) is a growing trend. Theses bins, in some cases, are provided with a pneumatic transport system, which improves the hygiene and safety of the collection operation conditions and also reduces the need for collection vehicles and therefore the need for specially prepared compartmented vehicles and for collecting the separated waste into different fractions.

Pneumatic waste collection presents a promising means for improving the separation of waste at the source.

Other innovation trend is the development and implementation of smart management systems for waste and plastic waste collection. These systems presents an innovative way for waste service and helps to optimize waste management through the development and implementation of specific information and communication technologies on separate collection and transport steps. In this sense these management systems use ICT technologies (optical sensors, radiofrequency identification system, etc.) in order to optimize waste management by identifying the type of waste, the filling level of the container, as well as the place and exact time when people dispose each waste fraction and the users identity (Jofra, M., García, L., Anthouli, A. and Koukosia, L., 2015). These tools allow waste managers to visualize the status in real time and automatically manage the time of collection and transport route.

Finally social innovation and collaboration and interaction between citizens, municipalities, and municipal waste management services is being reinforced in Europe as a way to advance toward better organised waste management system that increases separate collection and recycling efficiency.

Trends in innovative technologies and equipment

Another important stage in a waste management system is the separation and sorting in materials recovery facilities, where a high degree of waste separation can be achieved. Therefore, many of the technological advances in the field of waste management have focused on improving the process as well as the techniques and equipment involved in this stage, turning it into an increasingly automated process.

Specifically, optical splitters are a preferred solution to identify and classify different types of polymers. In this way new auto-sort sensors provided with a spectrometric sensor based on the near infrared spectroscopy (NIR) allows a quick and precise separation of the different polymer fractions. NIR is the most used technique in the materials recovery facilities, as a final step in the separation of plastics from other materials, as well as in the subsequent step of polymer classification. In some cases, in order to achieve better separation rates, some sorting plants have implemented recirculated NIR sorters through which it is possible to increase the separation efficiency from 85% to 87,7% (ECOEMBES, n.d). In addition, other optical techniques are being developed for the classification of polymers such as colorimetric or visible spectrum techniques. Raman spectroscopy is an automatic technique used to identify the type of polymer based on their molecular structure (Brunner, S., Fomin, P. and Kargel, C., 2015) by using a monochromatic laser light. However, Raman spectroscopy must be complementary to NIR spectroscopy.

Although the NIR sorters are able to identify the majority of plastic packaging and polymers, black plastics are coloured using carbon black pigment, which does not allow the material to be identified in the same way. Because of the high degree of difficulty in sorting black polymers, black or dark plastic packaging wastes are usually landfilled or incinerated (Bp – Sorting, n. d.) and may only be recycled for lower quality materials that do not require sorted plastic. In this sense, **optical separators based on a new hyperspectral imaging sensor system containing a special mid-wave infrared range detector (MWIR)** are being developed for black plastics sorting in material recovery facilities. In the next section, a potential solution is described.

Another limitation of the process of plastic packaging waste separation and classification is the difficulty of recovering plastic film waste. Due to the extremely lightweight nature of this waste, it is not only difficult to recover, but it can damage the separation equipment because the waste can get caught in the equipment. Therefore, new developments in automatic plastic film separation equipment are being implemented in packaging sorting plants, which are able to achieve a recovery rate of 90% (FilmSort, 2015). In this regard, the FilmSort project has developed and commercialised automatic equipment, which is capable of separating PE plastic film waste. The following section describes the case.

Finally, regarding the removal of metals within plastic waste, innovations are being developed in order to increase the separation of non-ferrous materials such as aluminium, magnesium, or silver.

POTENTIAL INNOVATIVE SOLUTIONS

Black polymer sorting

This innovative solution has been developed in the framework of the BP SORTING project, co – funded by the European Commission through the Eco – innovation program.

This demonstration project was aimed at developing an innovative solution for the improvement of the sorting process of plastic waste and, in particular, for the increase in the recovery of black or dark plastics for recycling.

This solution involves sorting plastics and black or dark polymers using specialized equipment and a camera. Currently, these plastics and polymers cannot be separated by automatic equipment commonly used for plastics sorting in sorting facilities or in recycling plants, and are therefore landfilled.

To this end, a new identification system was developed; it contains a new hyper spectral image sensor with a special detector MWIR (Mid – Wave Infrared Range) and spectrographic components that, through the application of algorithms, achieve better sorting results of black polymers. This equipment uses the technology of hyper spectral imagery, based on a high spectral resolution. This technology allows for successful identification and sorting of the polymers and black materials on the basis of physical and chemical properties, whereas conventional systems for plastics sorting works with NIR technology. What makes the use of this equipment more interesting is its additional capacity to identify and sort many types of polymers, including black and dark-colored polymers that conventional systems with NIR technology are unable to recognize.

The use of this sorting system not only benefits with regard to the increase of the ratios of material recovery and recycling, but also has environmental and economic benefits, as it allows the possibility to reduce the costs of the landfill waste disposal and increases the valuable material recovery by 1 – 5%. This solution, applicable in sorting process and waste separation of plastic packaging, has been traded by the Steinert group, under the name of "UniSort BlackScan".

More information is available on the following websites:

www.bp-sorting.com/technology
www.steinertglobal.com/

Wall – B sorting robot

This innovative solution has been developed as an alternative to the automatic equipment frequently used for the separation and sorting of plastic packaging waste. The Wall – B prototype is an urban waste separation robot with artificial vision, which combines the development of smart robotics with the need to improve the efficient management of solid urban waste. The robot is designed to distinguish and recover light packaging waste such as plastics, cans and bricks, between the household services. The construction of this equipment is based on three basic components; a robotic arm, a vacuum gripping system, and a computing device able to recognize different types of material through complex algorithms and artificial vision technology.

Robot design and technology are intended to be incorporated in treatment plants of solid urban waste with lines of treatment consisting of a flow of recoverable material, between 100 and 500 tons per year, in which the installation of an optical separator is not practical from an economic perspective. According to the results obtained by the developer company, Sadako Technologies, this equipment is not only capable of recognizing and recovering this kind of waste for future sale and recycling, but also, is able to do it in an economic and environmentally efficient way.

This solution has been implemented in the light packaging waste sorting process of the Environment Competency Center and Ecoparc 4 Waste Treatment Center in Barcelona, Spain, for testing efficiency and equipment performance. Apart from technology, it is an innovative system due to the fact that the separation and sorting process in treatment plants can be automated, replacing the manual sorting stage. In this regard, it is estimated that incorporating this equipment to the Ecoparc 4 plant will make it possible to recover, in the first stage of implementation, more than 125 tons annually of plastic packaging PET that previously have not been recovered, with an economic performance higher than 50.000 € per year.

More information is available on the following website:

www.sadako.es

1.6. 2.3. Bulky Waste Management

Drivers for innovation

There are different factors that act as drivers for innovation in the management and handling of bulky waste, identified as part of municipal waste. Specifically, some political, economic and environmental factors driving the increase in material recovery and minimizing the amount of bulky waste landfilled are set out below.

Policy drivers

Bulky waste such as white goods waste, mattresses and furniture turned into waste are covered by the European list of waste[19] as part of municipal solid waste. There are several objectives set under European legislation on waste which are applicable to generally bulky waste.

The Directive 2008/98/EC explicitly supports reuse and preparing for reuse and calls on Member States to takes measures to promote the re – use of products and preparing for re – use activities (e. g. by encouraging re – use and repair networks, using economic instruments, procurement criteria, quantitative objectives, etc). In particular, Member States shall increase to a minimum of 50% by weight, the recycling or preparation for reuse of municipal waste by 2020.

The Directive 1999/31/EC on landfills defines a series of discharge limits that Member States should adopt. In this regard, Member States should ensure that municipal waste and therefore bulky waste is not accepted in landfills of inert waste and shall ensure that the amount of waste going to landfill is shrinking.

The proposed amendment to Directive 1999/31/EC includes waste that has been collected separately as inadmissible waste in landfills and proposes a new target for the disposal of municipal waste. According to Article 5 of the proposal, the amount of municipal waste going to landfills by 2030 should be reduced to 10% of total municipal waste generated, except for countries with low infrastructure that may extend the minimum to be achieved by 2030 to 20% and will have 5 more years to reach the 10% limit.

According to the proposed amendment of Directive 2008/98/EC on waste, it is proposed that the recycling or preparation for reuse is at least 60% by weight of municipal waste by 2025 and 65% by 2030.

In the case of waste of white goods, included in the category of WEEE, measures and specific objectives set out in the directive 2012/19/EC on WEEE:

- Article 5 establishes that the amount of WEEE disposed of as unsorted municipal waste should be minimal, ensuring a high level of separate collection and proper treatment of this

[19] Commission Decision of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and Council

waste. To this end, Member States should establish systems for collection and return points for WEEE from private households.

- Likewise, the WEEE that has been collected separately cannot be removed without first having undergone proper treatment, according to Article 6 of this Directive.

- As for the collection of this waste and in compliance with the principle of producer responsibility, Article 7 sets certain goals. From 2016 the minimum percentage of collection of WEEE should be 45% of WEEE generated, increasing the minimum to 85% for 2019. In the case of countries lacking infrastructure, the minimum is reduced to achieve a minimum collection of between 40 and 45% from 2016. In addition, the deadline for achieving the targets set for 2019 was delayed until 2021.

- Article 8 establishes the obligation of Member States to ensure proper treatment of all WEEE selected and separated at source, including preparation for reuse, recycling and recovery as well as removal of fluids and selective treatment.

- In addition, certain minimum recovery targets set out in Annex V are set, depending on the categories of EEE set out in Annex I, Member States must be in accordance with Article 11 of this Directive. Specifically, for large household appliances such as refrigerators, washing machines, etc. (white goods), in category 1 of Annex I, minimum values are set for recovery and recycling at 80% and 75% respectively, applicable until 14 August 2015. As of August 15, 2015 until August 14, 2018, these minimum percentages increase to 85% for recovery and 80% for recycling.

Other municipal wastes included in the category of bulky waste are mattresses and furniture. In this case, there is no exclusive European legislation governing this type of waste, but because they are considered bulky waste, they are included in the category of municipal waste, according to the European waste list. Some member countries of the European Union are beginning to implement legislation governing the management of this waste and in particular, are developing policies extending responsibility schemes for several kinds of bulky wastes. This is the case of France, for example, which already regulates its furniture waste through the Decree nº 2012 – 22[20]. This Decree aims to achieve three main objectives:

- Reduce the amount of furniture waste sent to landfills.
- Increase recycling of furniture up to 45% in 2015.
- Promote eco-design for these items.

In Luxembourg, although there is not a specific law, in 2000, the first National Waste Management Plan (PNGD, 2000)[21] established certain targets to be achieved by 2005, including a target for reduction of household bulky waste by 30% per inhabitant. However, the second General Waste

[20] Décret nº 2012 – 22 du 6 janvier 2012 relatif à la gestion des déchets d´éléments d´ameublemnt.
[21] PNGD, 2000: Plan national de gestion des déchets. Le gouvernement du Grand – Duché du Luxembourg. Ministère du Développement durable et des infrastructures. Administration de l´environnement. Décembre 2000

Management Plan, published in 2010 (PGGD, 2010)[22], does not set specific quantitative targets, but also outlines certain recommendations for specific waste fractions, including household bulky waste. Specifically, the PGGD sets these general objectives:

- Reduce the amount of household bulky waste generated per habitant.
- Reduce the amount of household bulky waste landfilled.
- Reinforce the selective collection of different fractions of bulky waste, especially through the creation of a network of recycling centres.
- Promote reuse through the establishment of "the second hand shops" located in recycling centres.

Spain also includes specific targets for preparation for reuse and recycling of waste textiles and furniture in the Waste Management Framework State Plan for the period 2016 - 2020. In particular, it should reach 50% of preparation for reuse and recycling by 2020, of which 2% are furniture, textiles, etc.

Environmental benefits

The increase in material recovery for recycling or re – use minimizes the depositing of bulky waste in landfills and has a number of environmental benefits which results in increased efficiency of bulky waste management as well as the use of resources, reducing the amount of waste supported by the environment (European Environment Agency, 2013) and a lower carbon footprint (European Commission, 2014).

Due to the heterogeneity of the bulky waste fraction, it is difficult to assess the environmental impact of the bulky waste stream in general. However, there are several studies which assess the impact and the environmental benefits of recovery, re – use and recycling for each category of bulky waste, such as furniture and large appliances such as washing machines, etcetera.

In the cases of furniture waste, basing on a modest scenario which predicts a minimum reuse target of 30% by 2025 and 35% by 2030, it is estimated that GHG emissions, specifically CO_2 emissions, could be reduced in 3 Mt CO_2 eq. and 3,5 Mt CO_2 eq. per tonne of furniture reused, in comparison with the amount of CO_2 emitted when waste furniture is landfilled. Considering an ambitious scenario where 40% and 45% of waste furniture are reused, by 2025 and 2030 respectively, 30,7 Mt of GHG emissions could be avoided. In this scenario, GHG emissions as well as the consumption of natural resources are reduced. For instance, in this scenario, the use of water could be reduced by 61 megaliters (Beasley, J. and Georgeson, R., 2014).

On the other hand, a study carried out by WRAP[23] assesses the benefits of reuse electrical items. Specifically, the report is focused on washing machines and televisions. Taking the case of washing machines as an example, the current level of reuse in UK, about 10%, means that approximately, 2,6 Mt CO_2 eq. are saved each year. Analysing an ideal scenario for each end – of – life treatment where

[22] PGGD, 2010: Plan général de gestion des déchets. Le gouvernement du Grand – Duché du Luxembourg. Ministère du Développement durable et des infrastructures. Administration de l´environnement. Janvier 2010
[23] WRAP, 2011: Benefits or Reuse. Case Study: Electrical Items. Final report

100% of waste from washing machines are reused, prepared for reuse, recycled, or landfilled, recycling seems to be a better choice in terms of GHG emissions, while in terms of energy demand, direct reuse and preparation for reuse provide the best environmental benefits.

From the point of view of the recovery and reuse of bulky waste and municipal waste in general, dependence and consumption of raw materials from nature (European Commission, 2014b) is reduced and the environmental impact the production phase of new products (ACR+, 2014).

Economic advantages

The improvement in bulky waste management models through innovation in management systems not only has a positive effect on the environment, but also has certain economic advantages. Furthermore, the implementation of more efficient technologies for bulky waste contributes to the decrease in the cost of their treatments.

Recovery and recycling of materials from bulky waste means they would become raw materials, allowing them to return to the industrial and commercial cycle, reducing consumption of natural resources and therefore, the production costs in terms of raw materials, energy and water resources, necessary for the production process.

On the other hand, reuse and recycling activities of bulky waste can contribute to create new jobs (ACR+, 2014). Taking a modest scenario as a reference, in 2025, a minimum target for recycling of 55% would mean the creation of 442.350 additional jobs, while 30% of reuse could create about 179,000 additional jobs (Beasley, J. and Georgeson, R. 2014).

CURRENT SITUATION IN EUROPE

This section is intended to provide a general vision of the situation related to the generation and management of bulky waste in Europe. The available data of the generation and management of this waste present significant differences among the countries, due to the lack of a specific European legislation for this waste. For that reason, in order to try to have a vision of this topic, it is necessary to consult the data of determined countries.

The reduction of the amount of waste generated as well as the increase of the recovery rate of bulky waste through an improvement of the waste collection system are crucial to achieve the waste hierarchy and to contribute to the achievement of the targets for recovery, including reuse and recycling established in the European legislation of municipal waste.

The Managing Municipal Solid Waste report by the European Environment Agency provides data for the management and generation of different waste streams for each Member State that includes specific data for bulky waste streams in some countries. In Austria, it is estimated that 259,100 tonnes of bulky waste were generated in 2009 which represents about 7% of total household waste generation. In Denmark, the bulky waste generation has experienced a significant rise in the last years. In detail, several studies reported that, between 2011 and 2012, each person generated between 150 and 250 kg of this type of waste (Larsen, Petersen and Christensen, 2012). The data in

Sweden is similar: the generation of bulky waste per person was 161 kg in the same year.

As seen in the previous section, there is a political influence for an improvement of the bulky waste management system, mainly associated with the European legislation of municipal waste and several waste flows, for example, the WEEE.

In the case of the so-called “white goods”, regulated by the Directive 2012/19/EU on WEEE, the statistics show an increase of the quantity of recovered waste and, although the tendency is positive, it is essential to mention that the temporal limit for the consecution of the first objectives established in that Directive has not been achieved yet.

In 2012, the total quantity of WEEE generated in Europe reached 9 million tonnes, and 3.5 millions of tonnes were collected. That means that the collection rate of the WEEE for 2012 was 38.5%, which was far from the minimum percentage of collection of 45%, established for 2016 in the Article 7 of the Directive (Eurostat, 2015b).

Figure 12 shows the percentage of WEEE collection in different Member States from 2009 to 2011, in comparison with the set objectives in Article 7 of the Directive.

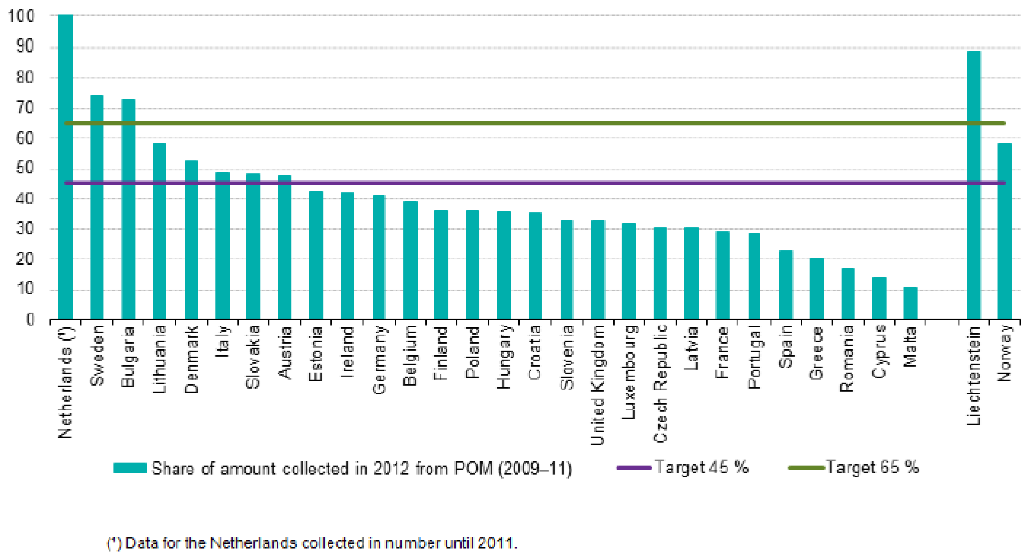


Figure 12: Ratio of collection for WEEE (2009-2011) (Source: EUROSTAT, 2015b)

In 2012 approximately 4.5 Mt of white goods were put on the market in Europe. Figure 13 shows the amount of white goods generated in comparison with the amount of white goods collected in 2012 by Member State.

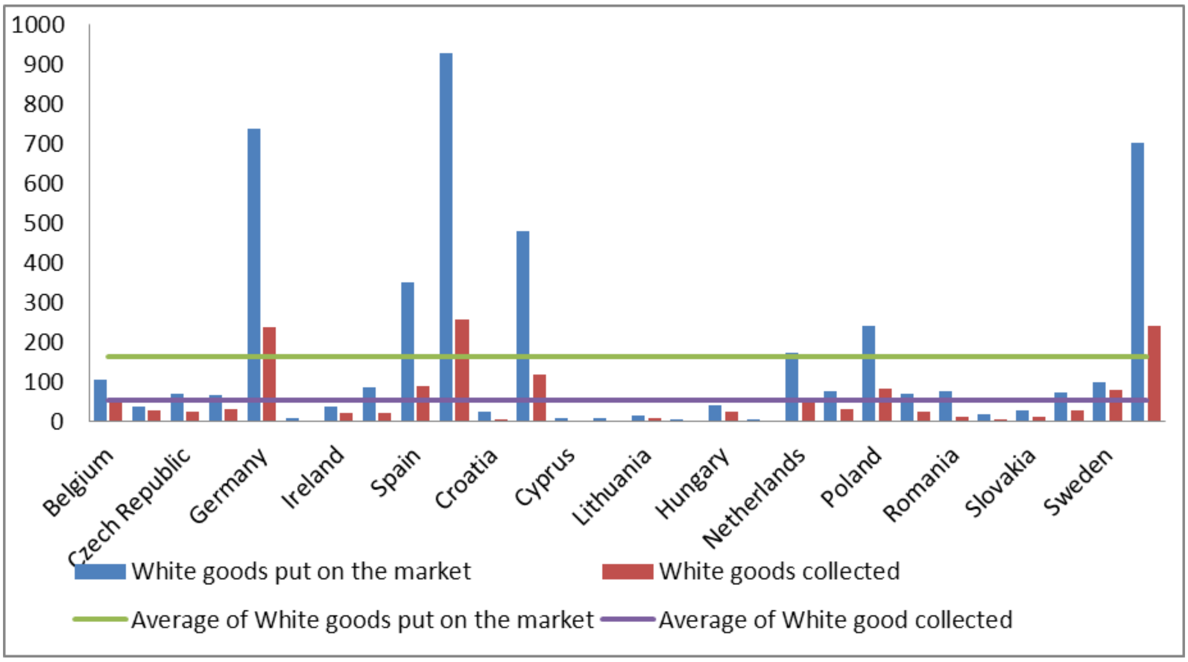


Figure 13: White goods put on the market and collectd in EU – 28 in 2012 (Source: Eurostat, 2015b)

In relation with furniture, and in accordance with the European Federation of Furniture Manufacturers, EU furniture, as a part of household bulky waste, accounts for more than 4% of the total MSW generated. Specifically, in 2011 about 10 million tonnes of furniture waste were generated (Beasley, J. and Georgeson, R., 2014). In France, the amount of waste furniture generated per year is about 2.7 million tonnes (European Environment Agency, 2013).

In the UK in 2011, approximately 670,000 tonnes of furniture were collected through some of the established waste collection systems, and in the same period, a total of 164,474 tonnes of waste from mattresses were collected (WRAP, 2012).

Bulky waste management models

Due to the special characteristics of bulky waste, such as their size, this waste has to be collected separately from the rest of domestic waste (Berlin Senate Department for Urban Development and the Environment, 2013). As a consequence, different alternatives of collection of this waste have been established in different countries, regions and/or municipalities in Europe.

Another important issue of the management of bulky waste is processing after its collection. In general, two different means of waste management are identified. One of them is direct dumping in landfills or the incineration with or without energy recovery. The other one is waste treatment after its collection from waste-sorting facilities, in which waste can be prepared for its reutilization or to be treated to separate the different recyclable waste streams, which will be submitted into recyclable or incineration operations and discharge in the last case. Figure 13 shows a scheme of the bulky waste management (R4R, 2013).

Regarding the responsibility of the management of bulky waste, this falls to the local authorities, while there is a tendency to apply systems based on extended producer responsibility schemes for different types of bulky waste.

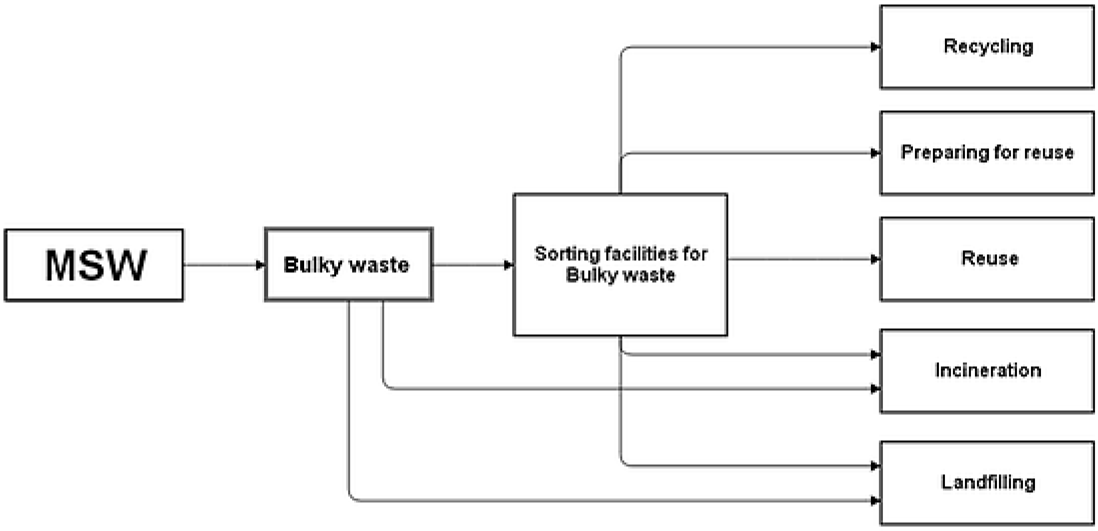


Figure 14: Scheme of the bulky waste management (modified from Regions for Recycling, 2013)

Bulky waste collection systems

The door-to-door collection system is the most extended waste collection system in Europe, although the waste collection systems vary among countries, regions, and municipalities. All the main waste collection systems applied in Europe are described below.

- **Door-to-door collection system:** the system is similar to the door-to-door system applied for the collection of other types of municipal waste. However, in this case, it is an internal service in which a private company or a municipal service will be in charge of collecting bulky waste in the home by previously arranging the collection and transport to separating plants or, when appropriate, the dumping of waste in landfills (Eunomia, 2014).

- **Kerbside collection system:** municipalities place special containers for this type of waste near to the kerb, where residents deposit their bulky waste and agree on a frequency of collection, which can vary from case to case.

- **Household waste recycling centres (HWRCs):** it is the most widely-used collection system among European countries. This type of collection permits that the residents can deliver waste directly to the recycling centre, without any cost for them (Avfall Sverige, 2014).

- **Special waste collection services:** in some cases, by previously arranging the place and date, there are several municipalities that normally organize three or four bulky waste collections per year. For the waste collection, several special containers are placed in determined places, some days before the waste collection.

In Germany, the advance of the management systems of municipal waste has permitted a progressive reduction of the quantity of municipal waste, bulky waste included, intended for landfills. Specifically, in 2012 in Berlin, 103,000 tonnes of bulky waste were entirely treated in recycling operations (Berlin Senate Department for Urban Development and the Environment, 2013). Four times per year, special waste collection systems are established for home bulky waste such as furniture, mattresses, or lamps, which are too large to be deposited in containers. However, this waste collection system does not accept “white goods”. These are collected through the door-to-door system or in HWRCs (Berlin Senate Department for Urban Development and the Environment, 2013).

In Denmark, almost all of the total quantity generated of this waste (90%) is collected for free in HWRCs, where residents can deposit waste there (Larsen, A., Petersen, C. and Christensen, T., 2012).

In Sweden, the responsibility of the bulky waste management is shared between the municipalities and the producers. On the one hand, residents pay a municipal rate for the municipal waste collection, in which the cost of bulky waste collection and its treatment in recycling centres is included. On the other hand, a fee is paid to the producer, something implicit in the purchase price of the product.

In 2010, 1.5 million tonnes of bulky waste were collected. The majority of them, around 90%, were accepted in HWRCs, and just 10% were picked up through the Kerbside collection system (Avfall Sverige, 2014).

It is estimated that, in the United Kingdom, between 2010 and 2011, around 1.5 million tonnes of bulky waste were collected, of which 42% was furniture, 10% was mattresses and 10% was “white goods”. The remaining 65% of the total of bulky waste was accepted in HWRCs, while the rest was collected through the Kerbside collection system (WRAP, 2012).

General trends in innovative solutions

With the objective of moving forward in the management of bulky waste and, in general, to improve their waste collection system in order to comply with the European legislative framework on wastes, there is a general tendency in the Member States of the European Union towards the search and application of new solutions, not only in waste collection systems, but in new ways of management and advanced technologies.

Trends in bulky waste management models

Considering the nature and size of bulky waste as well as its consideration as a part of solid urban waste, its management can distort the ordinary management of household waste. In this regard, there is a clear trend among the Member States towards a management model, which permits the reuse of this type of waste or, where appropriate, the recycling.

Due to the complexity of the bulky waste collection, special systems and arranged waste collections are required. In this regard, it tends to a management model that involves the residents themselves in the management of this waste, encouraging and promoting the delivery of waste to household waste recycling centres (HWRCs) or facilities for waste collection, without any cost for the user.

In the case of WEEE, it tends to a management system that relies entirely on the producer, in accordance with the objectives of the Directive 2012/19 / EC of WEEE, which promotes the segregation of waste, not only by collecting WEEE separately from other municipal waste, but also by establishing a separate and different collection for each category of WEEE, so that the correct treatment of each fraction is ensured.

Due to the nature of WEEE and the specific needs of storage and transport, which can vary depending on the particular type of WEEE, a type of management is being increasingly applied in which users return the EEE at the end of its useful life or deliver the applies in specific locations suitable for their proper management, without any cost to users. Another way of returning WEEE is through the distributors themselves. That is, the distributor is the person who removes the WEEE and is responsible for its management when providing a new EEE with the same features and the same function.

Similarly, in France, a furniture and textile waste management, involving the management of mattresses, is being implemented, which is based on the principle of extended producer responsibility. The model is based on the creation of organizations funded by furniture and textiles manufacturers focused on promoting the reuse and recycling operations of these wastes (Beasley, J. and Georgeson, R., 2014).

On the other hand, according to the tendency to reuse, the use of social institutions or charities as a way to manage waste is increasingly widespread. These associations collect waste or used articles, which their users throw away, in order to recondition and distribute them for the neediest population, or sell them as a profit for social purposes. This form of "management" of waste ends this condition, returning them into useful second-hand products (Junghard, E., 2011).

Trends in bulky waste collection systems

Despite the existence of different bulky waste collection systems, the application of some of these systems sometimes leads to the accumulation of waste in areas which are not intended for this purpose, or even illegal dumping of these wastes. The delivery of this type of waste at civic amenity sites or household waste recycling centres (HWRCs) is an efficient waste collection system which avoids the problems of accumulation in public places. However, it is not always possible to set up these centres. As an alternative for the traditional waste collection systems and as a solution to the lack of HWRCs, the implementation of a network of mobile civic amenity sites is being carried out in some European regions, which allows residents to deposit their bulky waste, without any cost for them, in temporarily set collection points in public spaces, serving a similar function to the one that a HWRC has.

The implementation of this waste collection system is intended to be a solution for the lack of civic amenity sites while limiting the bulky waste collection through the Kerbside collection system and the possible illegal discharges arising from this system. In addition, this system is intended to achieve a number of objectives, such as the increase of the recovery and recycling ratio, provide a better service to residents, and ensure that they are involved to a greater extent in the selective collection of waste (R4R, 2013).

In the case of WEEE, there is a clear trend towards the implementation of innovative systems that allow such separate collection of this type of wastes. In this regard, smart containers, as a demo mode, have been implemented in some areas of Europe, which allow users to deposit their WEEE and, at the same time, classify them through the identification system of such containers. The following section describes the solution.

Trends in innovative technology and equipment

After collecting bulky waste through waste collection systems which do not involve separate collection in various fractions, the bulky waste stream is sent to sorting facilities, where the waste is separated into different recyclable fractions, textile, metals, plastics. However, the heterogeneity of the bulky waste stream makes the classification process difficult.

In order to increase the recycling rate in the bulky waste stream and to improve the sorting process, certain modifications in the facilities and classification processes are developed, not only technical changes but also some "administrative" ones.

There is a trend to implement sorting process in two stages. In the first stage, the pre–classification one, the bulky waste input stream is pre-classified in order to remove fractions that cannot be afterwards classified in bulky waste sorting centres, such as carpets and large furniture. Later, the remaining fraction is sent to bulky waste sorting centres, where it is subjected to a mechanical sorting process into various fractions destined for recycling units (R4R, 2014a).

Furthermore, bulky waste may contain a considerable amount of valuable material, which is not easy to separate. In most cases, the fraction of valuable material present is small compared to the volume of these residues, and it is not usually accessible in waste streams. Therefore, the initial treatment in the sorting plant should incorporate a crushing process of the material which will recycle the valuable fractions more easily.

Although the classification processes carried out in materials recovery facilities (MRFs) tend to be increasingly automated, facilitating the sorting process and increasing the efficiency of separation of materials in bulky waste sorting centres is mostly performed manually. Therefore, there is a growing trend towards the automation of the sorting process of this type of waste, especially towards the use of automated equipment based on optical sorting. For this purpose, the use of optical sorters, which are also used in packaging sorting plants, is being generalized. These automatic devices have greater flexibility than most other classification systems, combining the colour detection with improved information about the material, resulting in a multifunctional system that optimizes the efficiency in a wide variety of applications.

POTENTIAL INNOVATIVE SOLUTIONS

Identification determination traceability integrated system for WEEE

This collection system has been developed in the framework of the project IDENTIS WEEE, co-funded by the European Commission through the LIFE+ programme.

The IDENTIS WEE project was a demonstration project aimed at improving, within the management systems framework of municipal waste, the separate collection of waste from electrical and electronic equipment (WEEE) through the implementation of innovative solutions which allow them to intercept and collect separately this type of waste, thereby contributing to optimise the global flow of municipal waste.

The specific objectives pursued by the project:

- Increase the quantity and quality of WEEE collected separately.
- Provide innovative services to citizens and distributors, ensure traceability of the separate collection of WEEE, and optimise the management thereof.
- Reduce the difference between the amount of electrical and electronic equipment distributed on the market and the WEEE collected separately, integrating existing WEEE collection systems with innovative solutions.
- Improve the knowledge concerning effective systems of WEEE separate collection and support the Exchange of useful data for the achievement of strategic objectives.

Under this demonstration project, various types of innovative containers were implemented, specially equipped, and designed to hold different categories of WEEE.

These containers are equipped with the following features:

- A digital system to recognize, through an identification card, the user depositing WEEE.
- Weight and recognition systems that use photographs of the WEEE deposited.
- A monitoring system of fill level, which allows for planning the emptying of containers as well as planning the transfer of WEEE to sorting plants and/or recycling centres.

The testing of prototypes has demonstrated that satisfactory results can be achieved regarding the collection and integral management of WEEE. Furthermore, it provides important environmental benefits by reducing the amount of waste sent to landfills. It also has a number of direct advantages for the users, including the proximity and ease of delivery, as well as the possibility of financial incentives for the users through their ID card, which can help to promote the WEEE proper management.

This innovative solution applies to the collection of different WEEE categories, including the bulky WEEE (among them we can emphasize the White goods) in different areas of the municipality through the development of several specific prototypes for each category and location:

- The WEEE points, aimed at collecting small WEEE in the streets.
- The WEEE shops, situated in shopping centres where can be placed small WEEE.
- The WEEE parking, situated in areas near distribution and sale points of WEEE in areas frequented by users, where small and big WEEE is deposited.
- The WEEE mobile, a mobile station managed by an operator for the collection in different points of different types of WEEE, especially for the “White goods” delivery.

The Hera group has marketed an advanced model, “the shop EVO”, which gathers the main guidelines and some suggested improvements, implemented in some shopping centres.

More information is available on the following websites:

www.identisweee.net
www.reciclaresvida.es
www.gruppohera.it

<u>Re – use of bulky waste stream</u>

The PRISCA project - Pilot project for re-use of waste, starting with the bulky waste stream, was a project co-funded by the European Commission through the LIFE+ programme.

The PRISCA project was aimed at testing a model for the implementation of re-use centres. The project was focused on reducing the amount of reusable elements in the urban solid waste streams, which currently are landfilled, increasing the recovery ratio and reuse of this kind of waste. Through this aim, the project proposes an alternative bulky waste management model, based on reuse of bulky waste or discarded objects, introducing them again in the market as second-hand goods. This project also proposes the creation of facilities exclusively dedicated to collecting bulky waste and preparing them for a new destination.

Two preparation centres for reuse were launched under this project, one in Vicenza and the other in San Benedetto del Tronto, both of which are in Italy.

In Vicenza, the bulky waste is intercepted in municipal collection points, whereas the discarded goods are collected through the door-to-door system. Likewise, the centre manages discarded goods coming from donations as well as from liquidation of municipal property. These two flows (bulky waste and discarded goods) are properly managed by a traceability system, through which the process is monitored, ensuring that there is no contact between waste and goods.

In San Benedetto the citizens have two options in order to manage bulky waste and discarded goods:

- Citizens can contact a care centre in order to identify if a product is reusable or if it should even be considered as a waste.

- They can go directly to the recycling centre, which is situated next to the municipal waste collection points.

In both facilities, wastes are discharged in the reception area where an initial examination is performed, after which those wastes which are able to be reused are selected. The articles selected are sent to a workshop where they are disinfected and reconditioned. After this stage, the articles are ready to be reused, and are stored and catalogued until they are distributed for sale as second-hand objects.

The solution implementation has demonstrated that more than 60% of discarded goods and bulky waste can be reintroduced into the market to start a new life cycle after having been submitted to small reparations and operations of conditioning. This solution has environmental benefits derived from the landfill waste reduction as well as the increase of recovered materials. It also yields social benefits by creating jobs.

In both centres a way of managing the bulky waste was found through the operational viability of reuse. This management is possible through a proper system design to maximize re-use potential at a local level.

More information is available on the following website:

www.progettoprisca.eu

3. Bibliography

- ACR+, 2014. ACR+ Observatory on waste recycling performances. [Online]
  Available at: http://www.acrplus.org/index.php/en/publications
  [Accessed 17 12 2015].

- Al-Salem, S., Lettieri, P. & Baeyens, J., 2009. Recycling and recovery routes of plastic solid waste (PSW): A review. Waste Management, Volume 29, pp. 2625 - 2643.

- Avfall Sverige, 2015. Swedish waste management. [Online]
  Available at: http://www.avfallsverige.se/fileadmin/uploads/Rapporter/SWM_2015.pdf
  [Accessed 01 02 2016].

- Baltic Sea Region Programme, 2013. Guidelines for Public Procurement in Municipal Waste Management. [Online]
  Available at:
  http://www.recobaltic21.net/downloads/Public/Project%20results/guidelines_for_public_procurement_in_municipal_waste_management.pdf
  [Accessed 02 12 2015].

- BBI JU, 2016. Annual work plan and budget , s.l.: Bio - based industries. Public Private Partnership.

- Beasley , J. & Georgeson, R., 2014. Advancing resource efficiency in Europe. Indicators and waste policy scenarios to deliver a resource efficient and sustainable Europe, Brussels: European Environmental Bureau (EEB).

- Berlin Senate Department for Urban Development and the Environment, 2013. Municipal waste management in Berlin. [Online]
  Available at:
  http://www.stadtentwicklung.berlin.de/umwelt/abfallwirtschaft/downloads/siedlungsabfall/Abfall_Broschuere_engl.pdf
  [Accessed 01 02 2016].

- BIO IS, 2011a. Assessment of feasibility of setting bio - waste recycling targets in EU, including subsidiarity aspects - Final Report prepared for European Commission DG Environment, s.l.: BIO Intelligence Service, Vito and ARCADIS.

- BIO IS, 2011b. Plastic waste in the Environment - Revised Final Report prepared for European Commission DG Environment, s.l.: BIO Intelligence Service, AEA Technology and Institute for European Environmental Policy.

- BIO IS, 2013. Study on an increased mechanical recycling target for plastics. Final Report prepared for Plastic Recyclers Europe, s.l.: BIO Inteligence Service.

- BIPRO/CRI, 2015. Assessment of separate collection schemes in the 28 capitals of the EU, Final Report, Munich: s.n.

- Bp-Sorting, n.d. Black Polymer Sorting - Technology. [Online]
  Available at: http://www.bp-sorting.com/technology.html
  [Accessed 2015 11 30].

- Brunner, S., Fomin, P. & Kargel, C., 2015. Automated sorting of polymer flakes: Fluorescence labeling and development of a measurement system prototype. Waste Management, Volume 62, pp. 49 - 60.

- CEWEP, 2014. Country Reports on Waste Management. [Online]
  Available at:
  http://www.cewep.eu/information/data/subdir/1187._Country_Reports_on_Waste_Management.html
  [Accessed 01 12 2015].

- Cimpan, C. et al., 2015a. Central sorting and recovery of MSW recyclable materials: a review of technological state-of-the-art, cases, practice and implications for materials recycling. Journal of Environmental Management, Volume 156, pp. 181 - 199.

- Cimpan, C., Rothmann, M., Hamelin, L. & Wenzel, H., 2015b. Towards increased recycling of household waste: Documenting cascading effects and material efficiency of commingled recyclables and biowaste collection. Journal of Environmental Management, Volume 157, pp. 69 - 83.

- CORDIS, 2013. Periodic Report Sumary - BURBA. [Online]
  Available at: http://cordis.europa.eu/result/rcn/54291_en.html
  [Accessed 03 December 2015].

- Council of the European Union, 1999. Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Brussels: s.n.

- COWI A/S, 2013. Report on initial assessment of relevant recycling technologies, Copenhagen: Plastic Zero Project.

- Dahlén, L. & Lagerkvist, A., 2010. Pay as toy throw. Strengths and weaknesses of weight-based billing in household waste collection systems in Sweden. Waste Management, Volume 30, pp. 23 - 31.

- DEFRA, 2013. Advanced Thermal Treatment of Municipal Solid Waste , London: Department for Environment Food and Rural Affairs (DEFRA).

- Deloitte, 2015. Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment. Final Report-Prepared for Plastic Recyclers Europe, s.l.: Bio by Deloitte.

- des Abbayes, C., 2014. Presentation "EU Member States' recycling schemes for matresses and furniture: the French example". Vienna, EUROPUR.

- Ecoembes, 2014. Mejora de eficiencia en plantas de selección de envases. [Online]
  Available at:
  http://www.asplarsem.com/intranet/pdfs/jornada_formacion_2014_mallorca/javier_lopez_ecoembes.pdf
  [Accessed 26 11 2015].

- Eunomia, 2014. Municipal Waste Performance Contracts. A Report for ACR+ and the European Environmental Bureau (EEB), Bristol: Eurnomia Research & Consulting.

- European Bioplastics, 2016. Fact Sheet. What are bioplastics?. Material types, terminology, and labels - an introduction.. [Online]
  Available at:
  http://docs.european-bioplastics.org/2016/publications/fs/EUBP_fs_what_are_bioplastics.pdf
  [Accessed 12 February 2016].

- European Commission, 2008. Green Paper - On the management of bio - waste in the European Union, Brussels: s.n.

- European Commission, 2010. Communication from the Commission to the Council and the European Parliament - On future steps in bio - waste management in the European Union , Brussels: s.n.

- European Commission, 2012. Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste, Brussels: s.n.

- European Commission, 2013. Green Paper: On a European Strategy on Plastic Waste in the Environment, Brussels: European Commission.

- European Commission, 2014a. Waste as a resource. [Online]
  Available at: http://bookshop.europa.eu/en/eu-research-pbKI0313591/
  [Accessed 24 11 2015].

- European Commission, 2014b. Promotion of the reutilization and valorisation of urban bulky waste as alternative sustainable source to innovative applications. [Online]
  Available at:

https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/promotion-reutilization-and-valorisation-urban-bulky-wastes-alternative-sustainable-source
[Accessed 28 12 2015].

- European Environment Agency, 2011. Waste opportunities – Past and future climate benefits from better municipal waste management In Europe, Copenhagen: Publications Office of the European Union.

- European Environment Agency, 2013. Managing municipal solid waste - a review of achievements in 32 European countries, Copenhagen: Publications Office of the European Union.

- European Parliament and Council, 1994. Directive 94/62/EC of 20 December 1994 on packaging and packaging waste. Brussels: s.n.

- European Parliament and Council, 2008. Directive 2008/98/EC of 19 November 2008 on Waste. Brussels, s.n.

- European Parliament and Cuncil, 2012. Directive 2012/19/EU of 4 July 2012 on waste electrical and electronic equipment (WEEE). Brussels: s.n.

- Eurostat, 2012. Guidance on municipal waste data collection. [Online]
  Available at:
  http://ec.europa.eu/eurostat/documents/342366/351811/Municipal-waste-statistics-guidance.pdf
  [Accessed 17 12 2015].

- Eurostat, 2015a. Packaging waste statistics. [Online]
  Available at:
  http://ec.europa.eu/eurostat/statistics-explained/index.php/Packaging_waste_statistics
  [Accessed 20 10 2015]

- Eurostat, 2015b. Waste statistics - electrical and electronic equipment. [Online]
  Available at:
  http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment
  [Accessed 20 10 2015].

- Eurostat, 2015c. Municipal waste statistics. [Online]
  Available at:
  http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics
  [Accessed 20 10 2015].

- Eurostat, 2015d. Waste statistics. [Online]

Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics [Accessed 20 10 2015].

- Fehily Timoney & Co., 2013. All Island Bulky Waste Reuse Best Practice Management Feasibility Study. [Online]
  Available at:
  http://www.rx3.ie/MDGUploadedFiles/file/rx3publications/Bulky_Waste_Reuse_Study_website.pdf
  [Accessed 27 11 2015].

- FilmSort, 2015. FilmSort Layman's Report. [Online]
  Available at:
  http://docs.european-bioplastics.org/2016/publications/fs/EUBP_fs_what_are_bioplastics.pdf
  [Accessed 09 02 2016].

- Gallardo, A. et al., 2010. Comparison of different collection systems for sorted household waste in Spain. Waste Management, Volume 30, pp. 2430 - 2439.

- Hopewell, J., Dvorak, R. & Kosior, E., 2009. Plastic recycling: challenges and opportunities. Philosophical transactions of the royal society, Volume 364, pp. 2115 - 2126.

- IdentisWEEE, 2015. LAYMAN'S REPORT OF THE LIFE IDENTIS WEEE PROJECT. [Online]
  Available at: http://identisweee.net/wp-content/uploads/2015/10/D-1-Laymans-ENG-OK.pdf
  [Accessed 15 02 2016].

- Jimoh, K., Ajayi, A. & Ayilara, O., 2014. Intelligent Model for Manual Sorting of Plastic Wastes. International Journal of Computer Applications, 101(7), pp. 20 - 25.

- Jofra, M., García, I., Anthouli, A. & Koukosia, I., n.d. Desingning an intelligent waste collection system that reduces GHG emissions and involves citizens. [Online]
  Available at: http://uest.ntua.gr/tinos2015/proceedings/pdfs/jofra_et_al.pdf
  [Accessed 03 12 2015].

- JRC - IES, 2011. Supporting Envarionmentally sound decision for bio - waste management. A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA), City of Luxembourg: European Commission.

- JRC, 2013. End - of - Waste Criteria for biodegradable waste subjected to biological treatment (compost and Digestate) - Technical Proposals., Sevilla, Spain: IPTS.

- JRC, 2014. End-of-Waste Criteria for Waste Plastic for Conversion - Technical Proposals. First working document, Seville, Spain: IPTS.

- Junghard, E., 2011. Collection and Reuse Potential of Household Bulky Waste. A Study on Bulky Waste Management in Augustenborg. Lund: s.n.

- Larsen, A., Petersen, C. & Christensen, T., 2012. Bulky waste quantities and treatment methods in Denmark. Waste Management and Research, 30(2), pp. 147 - 154.

- Luijsterburg, B. & Goossens, H., 2013. Assessment of plastic packaging waste: Material origin, methods, properties. Resources, Conservation and Recycling, Volume 85, pp. 88 - 97.

- MAGRAMA, 2013. Gestión de biorresiduos de competencia municipal. Guía para la implantaciñon de la recogida separada y tratamiento de la fracción orgánica, Madrid : Ministerio de Agricultura, Alimentación y Medio Ambiente. Gobierno de España.

- MAGRAMA, n.d. Ministerio de Agricultura, Alimentación y Medio Ambiente. Calidad y Evaluación Ambiental. Prevención y Gestión de Residuos. [Online]
Available at: http://www.magrama.gob.es/
[Accessed 27 January 2016].

- Nordic Council of Ministers, 2015. Guidelines to increased collection of plastic packaging waste from households, Copenhagen: Norden.

- OECD, 2014. Waste Management Services. [Online]
Available at: http://www.oecd.org/daf/competition/Waste-management-services-2013.pdf
[Accessed 02 12 2015].

- Plastics Europe, 2015. Presentation "Plastics - The facts 2015. An analysis of European plastics production, demand and waste data". [Online]
Available at: http://www.plasticseurope.org/Document/plastics---the-facts-2015.aspx
[Accessed 15 02 2016].

- Plastics Europe, n.d. Waste Pre - treatment and sorting. [Online]
Available at: http://www.plasticseurope.org/plastics-sustainability-14017/zero-plastics-to-landfill/waste-pre-treatment-and-sorting.aspx
[Accessed 12 January 2016].

- Pop, I. N. et al., 2015. Informal sector participation in solid waste management - study case: Cluj - Napoka, Romania. ECOTERRA - Journal of Environmental Research and Protection, 12(3), pp. 36 - 41.

- Prisca, 2015. Project for Scale re-use starting from bulky waste stream. Layman's Report. [Online]
Available at: http://www.progettoprisca.eu/
[Accessed 16 02 2016].

- PRO Europe, n.d. Packaging Recovery Organisation Europe s.p.r.l.. [Online]
  Available at: http://www.pro-e.org
  [Accessed 25 November 2015].

- Punkkinen, H. et al., 2012. Environmental sustainability comparison of a hypothetical pneumatic waste collection system and a door-to-door system. Waste Management, 32(10), pp. 1775 - 1781.

- Regions for Recycling, 2013. Municipal solid waste data. [Online]
  Available at: http://www.regions4recycling.eu/upload/public/Reports/R4R_municipal-solid-waste-scope.pdf
  [Accessed 17 12 2015].

- Regions for Recycling, 2014a. Good Practice: A nework of mobile civic amenity sites. [Online]
  Available at: http://www.regions4recycling.eu/upload/public/Good-Practices/GP_ORDIF_mobile-CAS.pdf
  [Accessed 04 02 2016].

- Regions for Recycling, 2014b. Good Practice: Paris region-Improving bulky waste sorting centre performance. [Online]
  Available at: http://www.regions4recycling.eu/upload/public/Good-Practices/GP_ORDIF_bulky-sorting-centres.pdf
  [Accessed 04 02 2016].

- Regions for Recycling, 2014c. Good Practice: Sofia municipality - WEEE collection. [Online]
  Available at: http://www.regions4recycling.eu/upload/public/Good-Practices/GP_Sofia_WEEE-collection.pdf
  [Accessed 04 02 2016].

- REPA, 2010. Assessment of waste management status in Balkan Countries - Romania. 2nd Revision, Bacau: s.n.

- Schiessler, N., Thorpe, E., Jones, W. & Philips, L., 2007. LIFE and waste recycling: Innovative waste management options in Europe. [Online]
  Available at:
  http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/recycling.pdf
  [Accessed 19 11 2015].

- Sevigné-Itoiz, E., Gasol, C. M., Rieradevall, J. & Gabarrell, X., 2015. Contribution of plastic waste recovery to greenhouse gas (GHG) savings in Spain. Waste Management, Volume 46, pp. 557 - 567.

- Sybert, 2011. Waste on a diet. [Online]

Available at: http://sybert.fr/waste_on_a_diet_sybert_resume_(1.pdf
[Accessed 07 02 2016].

- Sybert, 2014a. WASTE ON A DIET is at the halfway mark. [Online]
  Available at: http://sybert.fr/waste_on_a_diet_3_EN.pdf
  [Accessed 07 02 2016].

- Sybert, 2014b. WASTE ON A DIET has arrived at the halfway point. [Online]
  Available at: http://sybert.fr/waste_on_a_diet_4_EN.pdf
  [Accessed 07 02 2016].

- Sybert, 2015a. WASTE ON A DIET is on the right track. [Online]
  Available at: http://sybert.fr/waste_on_a_diet_5_EN.pdf
  [Accessed 07 02 2016].

- Sybert, 2015b. Waste on a diet: An extra year to reach. [Online]
  Available at: http://sybert.fr/waste_on_a_diet_6_EN.pdf
  [Accessed 07 02 2016].

- Thampan, A. & Chandel, M. K., 2015. Bioreactor Landfill Technology. International Journal of Science and Research (IJSR), 4(6), pp. 256 - 260.

- Tomra, n.d. Autosort. [Online]
  Available at: https://www.tomra.com/en/solutions-and-products/sorting-solutions/recycling/products/autosort/
  [Accessed 2015 11 23].

- Wong, S., Ngadi, N., Abdullah, T. & Inuwa, I., 2015. Current state and future prospects of plastic waste as source of fuel: A review. Renewable and Sustainable Energy Reviews, Volume 50, pp. 1167 - 1180.

- WRAP, 2009. Choosing the right recycling collection system. [Online]
  Available at:
  http://www.wrap.org.uk/sites/files/wrap/Choosing%20the%20right%20recycling%20collection%20system.pdf
  [Accessed 04 12 2015].

- WRAP, 2012. Composition of kerbside and HWRC bulky waste, Oxfordshire: s.n.

- Xevgenos, D. et al., 2015. Success Stories for Recycling of MSW at Municipal Level: A review. Waste Biomass Valor, Volume 6, pp. 657 - 687.

- Zero Waste, n.d. Handbook: On alternative waste management schemes. [Online]
  Available at: http://www.med-zerowaste.eu/deliverables/handbook.pdf

[Accessed 11 01 2016].