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PRELIMINAR MARKET ANALYSIS
Foundation Knowledge Innovation Market

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Abstract

The following deliverable is the first draft for deliverable 8.1 of the Plasticircle project, to be submitted in three instalments (month 6, 18 and 36) of the project implementation. Deliverable 8.1, Market Analysis for treatment of plastic waste market, is conceived as a study of the actual treatment of the plastic packaging waste market needs and size in order to better define the approach for commercialisation of the solutions / solutions developed in the framework of the PlastiCircle project.

The objective of the present document is to present an i overview of the state of the art of plastic waste management and treatments, including specific description for the areas dealt with by the project and its related solutions, namely collection, transport, sorting and recycling of plastic packaging waste.

Partners short names

1. ITENE: INSTITUTO TECNOLÓGICO DEL EMBALAJE, TRANSPORTE Y LOGÍSTICA
2. SINTEF: STIFTELSEN SINTEF
3. RTT: RTT STEINERT GMBH
4. AXION : AXION RECYCLING
5. CRF : CENTRO RICERCHE FIAT
6. UTRECHT : GEMEENTE UTRECHT
7. INNDEA : FUNDACION DE LA COMUNITAT VALENCIANA PARA LA PROMOCION ESTRATEGICA EL DESARROLLO Y LA INNOVACION URBANA
8. ALBA: PRIMARIA MUNICIPIULUI ALBA IULIA
9. MOV: MESTNA OBCINA VELENJE
10. SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA Spain
11. POLARIS: POLARIS M HOLDING
12. INTERVAL: INDUSTRIAS TERMOPLÁSTICAS VALENCIANAS S.A.
13. ARMACELL : ARMACELL Benelux S.A.
14. DERBIGUM : DERBIGUM N.V.
15. PROPLAST : CONSORZIO PER LA PROMOZIONE DELLA CULTURA PLASTICA PROPLAST
16. HAHN : HAHN PLASTICS Ltd.
17. ECOEMBES : ECOEMBALAJES ESPAÑA S.A.
18. KIMbcn : FUNDACIÓ KNOWLEDGE INNOVATION MARKET BARCELONA
19. PLAST-EU: PLASTICSEUROPE
20. ICLEI: ICLEI EUROPASEKRETARIAT GMBH

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1. Executive Summary

The following deliverable is the second draft for deliverable 8.1 of the PlastiCircle project, to be submitted in three instalments (month 6, 18 and 36) of the project implementation. Deliverable 8.1, Market Analysis for treatment of plastic waste market, is conceived as a study of the actual treatment of the plastic packaging waste market needs and size in order to better define the approach for commercialisation of the solutions / solutions developed in the framework of the PlastiCircle project.

The objective of the present document is to present an initial overview of the state of the art of plastic waste management and treatments, including specific description for the areas dealt with by the project and its related solutions, namely collection, transport, sorting and recycling of plastic packaging waste.

More specifically, this preliminary document will provide a state of the art of the economic, social, legislative and technical environment in which the project will be developed. The following information will be presented:

- Identification of the operational and legislative arrangements to be taken into consideration
- Identification of similar initiatives and projects addressing similar needs and objectives as the PlastiCircle project
- Identify both the added value of the Plasticircle project face the other initiatives and the opportunities for knowledge transfer among them.
- Analyse the market conditions and current developments for the Plasticircle solution.
- Set of conclusions and recommendations aimed at guiding the development of the project in its implementation and pilot stages.

Taking into consideration that the following is the initial draft of a deliverable that will be submitted in month 36, and that for its development it will be fundamental the information collected in regards of the solutions developed in the project and the subsequent pilot process, the information provided below is very likely to be updated, upgraded and modified in the course of the project.

2.Introduction: the PlastiCircle project

Plastics are used to manufacture an incredible number of products we use every day, such as beverage and food containers, trash bags and grocery bags, plastic cup and utensils, children's toys and diapers, and bottles for everything, from mouthwash and shampoo to glass cleaner and dishwashing liquid. And that is not even counting all the plastic that goes into furniture, appliances, computers and automobiles.

Among the typologies mentioned above, plastic packaging is present in most of the environments of our daily lives. Almost every industry and most consumable goods rely on the use of plastic packaging. The commercial use of plastic packaging and its preeminent use are based on their combination of flexibility, strength, lightness, stability, impermeability and ease of sterilisation[1]. As it is mentioned by the Association of Plastics Manufacturers, the main benefits of plastic packaging are the lightness of the packaging material, its capacity to preserve and conserve food without altering their properties, its convenience and innovative developments (i.e. inclusion of chips and conducive materials in new plastic packaging solutions) and its safe and hygienic capacities. All these factors make plastic packaging a suitable and valuable solution for almost all commercial and industrial uses and have mainstreamed their use.

Traditionally, the popularity of plastic packaging solutions has been associated with another side of the coin, namely, the environmental impact of plastic packaging use. The accumulation of plastic packaging, especially in landfills and its subsequent impact upon marine environments, the polluting effect of plastic manufacturing and incineration are commonly referred as negative impacts.

Moreover, plastics and plastic packaging accumulations represents a nightmare for local and municipal authorities, prompting local governments to implement specific policies aimed at the collection, transport and management of local plastic waste.

However, the abovementioned must not hide the fact that the plastic packaging industry does also offer important opportunities for innovation, sustainability and the promotion of a more effective approach towards circular economy parameters. A lot is happening around the plastic packaging industry aimed at improving the environmental, social and economic impact of plastic solutions. Efforts in new and innovative plastic packaging solutions (such as the design of bottles that allow for a more shipping efficiency, down gauging rigid plastic containers, etc), the development of more energy efficient plastic packaging production processes, and the involvement of the plastics industry sector in environmental and

1 http://www.plasticseurope.org/use-of-plastics/packaging.aspx

sustainability initiatives are just small examples of the process.

But perhaps, the main cultural change that is taken place around the plastics management vision is the need to create a new integrated and community based effort towards a better use, design, management and treatment of plastics. It is within this community based and integrated approach that the PlastiçCircle project is conceived. The PlastiCircle project is a collaborative project that aims to generate a significant improvement in the plastic waste management chain, from a circular economy approach, with the vision of reintroducing plastic waste within the value chain. The project represents thus, a social redefinition of plastic waste management, through the development of specific actions for the collection, transport, sorting and recycling of plastic waste. In other words, circular economy and community involvement are enforced to ensure that plastic waste is managed in a more clever way and that it is reintegrated within the value chain, reducing its environmental impact and generating economic and social opportunities.

Aware that more than 25.8 million tonnes of plastic waste are produced per year in the EU282 (50 kg per EU citizen), with only 29.7% being recycled, something that represent an important market loop and going against EU legislation on waste the Plasticircle has been conceived as a collaborative response to this situation and launched within the framework of the European Programme H2020 and will be implemented over the period 2017 – 2019[2].

Also aware of the low recycling rates and the technical difficulties of the process the Plasticircle project aims to develop and implement a holistic process to increase packaging waste recycling practices. To achieve its objective, the Plasticircle project will focus on innovation in the different stages associated with the treatment of plastic packaging waste: collection (to increase the amount of packaging collected), transport (to reduce the costs of recovered plastic), sorting (to increase the quality of recovered plastic), and recovery in value-added products.

In this context the Plasticircle project has been launched within the framework of the European programme H2020 and will be implemented over the period 2017-2019.

2.1 Project Objectives

As mentioned above, the main objective of the Plasticircle project is to improve the plastic waste management process and to better integrate it within the circular economy of plastics approach. To do this, four main stages associated with plastic packaging treatment will be addressed: collection, transport, sorting and

[2] PlasticsEurope, 2015. Plastics – the Facts 2015 An analysis of European latest plastics production, demand and waste data.

recycling.

- **Collection**. The project will integrate and validate an innovative packaging collection system which increases the amount of plastic packaging waste collected. This system will be able to identify the quantity and quality of packaging generated by each family/citizen, with a view to implementing compensation policies to encourage optimal collection ("the better you separate, the less you pay" approach). Also, information to citizens on how well they segregate in comparison with others will be considered as a tool to improve collection. To achieve this, efforts will centre on designing smart containers equipped with different technologies: a user identification system, identifiable labels for deposited garbage bags, data transmission by LoRa/SigFox, and anti-fraud measures. The system will be competed with a characterization protocol to randomly evaluate the quality of segregation of unitary bags.

- **Transport**. The Plasticircle project will develop, integrate and validate an innovative transport process from municipalities to sorting plants that will decrease the final price of recovered plastic. The Plasticircle transport system is based on sensors which will recognise the filling levels of containers in real time, thus automatically optimizing collection routes through a truck traceability system. The system will be completed with pressing systems in the waste collection trucks, with a view to maximizing the amount of plastic waste transported per route. Efficient driving will also be considered. It should be noted that the whole system on collection and transport will be connected through an IoT cloud platform based on the external communication capacity of the containers (connection to CAN-Bus17).

- **Sorting**. The project will develop, integrate and validate an innovative sorting process for separating plastic waste into the optimal fractions to be subsequently recovered (i.e. PET, rigid PE, PE film, rigid PP, PP film, and plastic mixes). It should be noted that multilayer materials, which are gaining importance in the packaging sector, will be included in the fraction of plastic mixes. The improvements will be based on optical Near-Infrared-Hyperspectral-Imaging technology and specifically on the adaptation of material feeding system, identification ranges and ejection systems. Innovation in sorting will be focused on the improvement of the purity of the six plastic fractions mentioned, and specially the elimination of PVC and bio-plastics (increasing plastic fraction which has a negative influence in the recyclability of conventional plastics). Tera-Hertz imaging and hyperspectral snap shooting will be integrated with this aim.

- Moreover, PlastiCircle will also focus on film sorting which currently present technical problems on material detection and ejection (separation). Detection problems come from a continuous increase of number of polymers used in the packaging sector, whereas ejection problems come from the material feeding based on conveyor belts (state-of-the-art). This drawback will overcome in

PlastiCircle by an innovative system with a layout based on air-flow for material feeding and therefore free of conveyor belts.

- **Recovery**. The project will develop and validate innovative products based on the fractions previously sorted. The products developed will be foam boards for wind turbines/roofing structures/sandwich panels (PET), automotive parts like engine covers (PET), bumpers and dashboards (rigid PP/PP film), bituminous roofing membranes (rigid PE/PE film), garbage bags (PE film), asphalt sheets/roofing felts (rigid PP/PP film) and urban furniture like fences, benches and protection walls (plastic mixes). The manufacturing of these products will be based on extrusion, injection and compression moulding.

2.2 Project Expected Impact

The project work programme has defined a set of specific impacts that will need to guarantee the success, the uniqueness and the sense of urgency of the project rationale. In this sense the following indicators have been established in order to assess both the impact of the project and the added value offered by the Plasticircle system face other initiatives.

Impact	Indicator	Agents Involved
Improvement of the EU plastic value chain	500-1400 new companies / 11.900 – 33.000 new jobs	Plastic producers /converters, waste managers equipment firms, consumers, public bodies
Promotion of plastic packaging recovery	Reduction of 1.59MT of landfilled and incinerated waste / Reduction of associated environmental impact	Local administration, plastic manufacturers, plastic converters, citizens.
Better plastic waste quality	Separation of plastic waste into the optimal fractions to be subsequently recovered (PET, rigid PE, PE film, rigid PP, PP film, and plastic mixes). The volume of quality materials achieved through the process will be used as indicator.	Plastic producers /converters, waste managers equipment firms, consumers,

Optimised production of recycled goods	Sorts and typologies of secondary products developed from recycled plastic	Recycling firms and manufacturers,
Encourage recovery over plastic landfilling and incineration	Alignment with the waste hierarchy established in the Waste Framework Directive 2008/98/EC	Waste managers, consumers / citizens, public administration representatives
Creation of new business opportunities in the plastic sector	Increased number of manufactured eco-innovative solutions	Producers, converters, waste management, equipment and software

Table 1 Project impact

3. Plasticircle General Context

3.1 Main concepts and definitions of plastic waste management

During the development and improvement of the project market of analysis a specific glossary will be used of which a brief listing can be found below:

PLASTIC	Material that contains as an essential ingredient a high polymer: polyethylene, terephthalate, high density polyethylene, vinyl, low density polyethylene, polypropylene.
PLASTIC WASTE	Discarded plastic after intended use is over
WASTE MANAGEMENT	The collection, transportation, reduction, recovery, recycling, composting disposal.
MANUFACTURER	Person or unit or agency engaged in production of plastic raw material to be used as raw material by the producer.
PRODUCER	Person(s) engaged in manufacture or import of carry bags or multilayer packaging or plastic sheets.
GRINDER	General term for devices that chop large items into flakes that are nominally fractional inches in dimension.
OPTICAL SORTER	Type of machinery used to automate the process of identifying and sorting recyclable materials into their different categories for baling.
NEAR INFRARED	Type of optical sorting machinery wherein the light used is near infrared (NIR)

SORTER	light and the detection made is of plastic type.
COMPACTOR	Type of equipment that uses pressure to densify and contain recyclable material.
MULTI-LAYERED PACKAGING	Any material used or to be used for packaging and having at least one layer of plastic as the main ingredients with one or more layers of materials such as paper.
RECYCLING	Process of transforming segregated plastic waste into a new product or raw material for producing new products.
REPROCESS	Converting used materials into new materials that can be used.
WASTE GENERATOR	Every person or group of persons or institution, residential and commercial establishments.
WASTE MANAGEMENT	Collection, storage, transportation reduction, re-uses recovery, recycling, composting or disposal of plastic waste in an environmentally safe manner.
COLLECTOR	Party or parties that aggregate postconsumer, commercial and or post-industrial materials from the public and sells to the reclaimers. Collectors can collect materials from the curbs of households or operate drop-off centres where the public can bring recyclables.
CONVERTER	Business that buy raw material and convert it into finished goods. In the case of plastics, plastic pellets of specific polymers are melted and processed into items such as fibres, films, sheets and rigid packaging, along with durable and semi-durable goods.
RECLAIMER	The commercial entity that accepts aggregated and postconsumer material and perform a series of operations to allow them to return to commerce as useful raw materials or used into new finished items.
CURBSIDE RECYCLING	Collection method whereby householders place specified used items in special containers adjacent to containers of household waste for periodic collection by others.
DROP-OFF	Form of collection of household recyclables wherein the householder takes the items to a central aggregation point.
DROP-OFF RECYCLING SITE	Facility, often serving rural areas, where the public can actively deliver recyclables into the recovery stream.
MULTI-LAYERED	Any material used or to be used for packaging and having at least one layer of plastic as the main ingredients with one or more layers of materials such as

PACKAGING	paper.
RECYCLING	Process of transforming segregated plastic waste into a new product or raw material for producing new products.
PLASTIC RECYCLING FACILITY	Industrial location that sorts nixed plastic items into streams of discrete plastic resin types. A PRF can also conduct preliminary recycling operations such as size reduction to plastic fake.
PLASTIC SCRAP	Material that did not meet the quality requirements for fully acceptable product. The scrap can be pellets that did not meet specifications of converted goods. The scrap can be ground to repro and used again or sold or disposed, depending on levels of degradation and contamination.
POSTCONSUMER	The status after an item has been used for its intended use. This intended user may be at another industrial site or as transportation packaging or by household consumers.
RESIN IDENTIFICATION CODE	Coding system placed on plastics to identify the polymer

Table 2 Main Concepts

PLASTIC	Material that contains as an essential ingredient a high polymer: polyethylene, terephthalate, high density polyethylene, vinyl, low density polyethylene, polypropylene.
PLASTIC WASTE	Discarded plastic after intended use is over
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PACKAGING	paper.
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3.2 Plastic waste generation

Data currently available show that distribution of plastic in Europe is increasing and it is expected to increase in the following years. This will be reflected, therefore, in an associated need for innovative and effective recycling and management industry to provide an answer to all associated requirements[3]. Figure 3 shows the distribution of global plastic materials production. China is the largest producer of plastic materials with more than 27% of global production* (only thermoplastics and polyurethanes), followed by Europe and NAFTA.

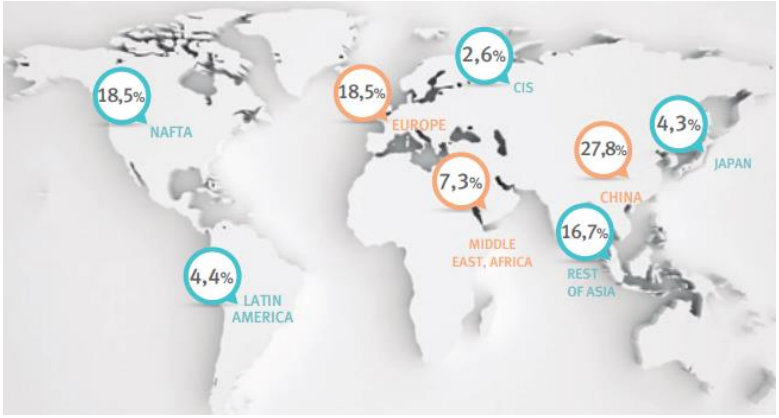


Figure 1 Source: Plastics Europe

[3] http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf

According to IBISWorld the industry of virgin plastic grossed at about 109.9 billion dollars in 2015, with an industry growth rate of 2.5% per year between 2010 and 2015 and is expected to grow at an annualized rate of 1.1% per year between the year 2015 and the year 2020. This industry is projected to see a revenue of 117.7 billion dollars per year by the year 2021 (Witter, 2015). These figures advance that the production and consumption of plastics, including those related with the packaging industry, will show a steady increase despite the regular calls for consumption limitation. According to the same study published by IBIS World IBISWorld six main industries are identified as the primary industrial consumers of virgin plastic resins, namely:

- Plastic Pipe and Parts Manufacturing: this plastic pipe industry primarily uses PVC or plastics marked with the number three. This industry grosses about 17.9 billion dollars per year and is expected to see an annualized growth rate of about 2.2% per year through the year 2020 (Yucel, 2015).[4]

- Plastic Film, Sheet and Bag Manufacturing - This industry is primarily fed by plastics marked number two and four. The industry grosses 44.6 billion dollars per year and is project to grow an annualized rate of 3.4% through 2020 (Blau, 2015).[5]

- Polystyrene Foam Manufacturing - This industry is largely built around food containers and uses entirely plastic marked number 6. The industry grosses 9.4 million dollars per year and has a projected annualized growth rate of -1.6% through the year 2020 (Petrillo, 2014).[6]

- Laminated Plastics Manufacturing - These plastics are primarily used in automobile applications and other durable machinery so recycling is not as big of an issue for them. This industry grosses 3.7 billion and has a projected growth rate of 2.7% through the year 2019 (Morea, 2014).[7]

- Urethane Foam Manufacturing - This industry is concerned with foam cushioning in furniture and automobile applications. This material has traditionally been landfilled and there is very little literature available on whether this material can be recycled. This industry grosses 9.5 billion per year and has a projected annualized growth of 2.6% through the year 2020 (McKitterick, 2015).[8]

What we can gather from these performance projections is that with the major exception of polystyrene, products and packaging made from resins marked three through seven will continue to be produced at a steadily increasing rate. Any action taken should accelerate the expansion of the recycling manufacturing industry in combination with a general trend of an increasing percentage of plastic being

[4] Yucel, Ibraham. (2015, April). IBISWorld Industry Report 32612: Plastic Pipe and Parts Manufacturing in the US. IBIS World
[5] Blau, Gavan. (2015, April). IBISWorld Industry Report 32611: Plastic Film, Sheet & Bag Manufacturing in the US. IBIS World
[6] Petrillo, Nick. (2014, December). IBISWorld Industry Report 32614: Polystyrene Foam Manufacturing in the US. IBIS World
[7] Morea, Stephen. (2014, August). IBISWorld Industry Report 32613: Laminated Plastics Manufacturing in the US. IBIS World
[8] McKitterick, Will (2015, January). IBISWorld Industry Report 32615: Urethane Foam Manufacturing in the US. IBIS World

recycled in an attempt to outpace the increase in plastic waste production.

	Chemical Name	Pre-Recycling	Post-Recycling
1	Polyethylene Terephthalate (PET)	Bottles, film, food packaging, synthetic insulation.	Food and beverage containers as well as different strands of fibers, as seen woven into clothing and carpets
2	High Density Polyethylene (HDPE)	Containers, toys, housewares, industrial wrapping and film, gas pipes.	Packaging, decking, housing fixtures like paneling, flooring and tiles, crates like recycling bins, or sturdier structures like fencing or dog and bird houses.
3	Polyvinyl Chloride (PVC)	Window frames, pipes, flooring, wallpaper, bottles, cling film, toys, guttering, cable insulation, credit cards, medical products.	Recycled PVC can be used in similar applications as virgin PVC, but the cost of recycling can be high. Used in pipes, construction materials, , housing pieces such as tiles, siding and flooring, loose-leaf binders, packaging and traffic cones.
4	Low Density Polyethylene (LDPE)	Film, bags, toys, coatings, containers, pipes, cable insulation.	Shipping envelopes, plastic lumber and housing fixtures like tiles and flooring, trash cans and trash bags.
5	Polypropylene (PP)	Film, battery cases, microwave containers, crates, car parts, electrical components.	Many applications including battery cases, lights and many types of cables.
6	Polystyrene (PS)	Electrical appliances, thermal insulation, tape cassettes, cups, plates.	Food handling products, like plates, cups and silverware, electrical applications such as light fixtures,Polystyrene insulation
7	Other	Various items	Various Items

Table 3 Source: Waste Market Efficiency

According to recent statistics more than more than 25.8 million tonnes of plastic waste are produced per year in the EU28[9] (50 kg per EU citizen), with only 29.7% being recycled (39.5% is energy recovery, 10.19 Mt; 30.8% is land filled, 7.95 Mt2).

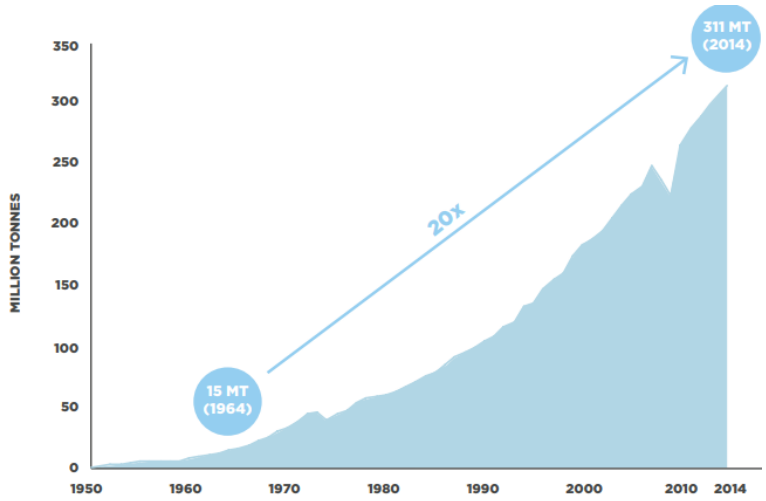


Figure 2 Growth in plastic production 1950-2014

Source: http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf

9 PlasticsEurope, 2015. Plastics – the Facts 2015 An analysis of European latest plastics production, demand and waste data

Packaging will constitute the main area of plastic consumption in the following years, with estimates considering that the total market size in billions of units will increase from 798 to 819 in Western Europe in the following five years. The same forecast show an accumulated increase of 0.5% between 2014 and 2019 in plastic packaging consumption.

In the next Figure 3, it can see that during 2012 – 2016 the generation of plastic derivated from domestic use have been growing drastically since 2013 raising almost 16,5 millions of tonnes by year.

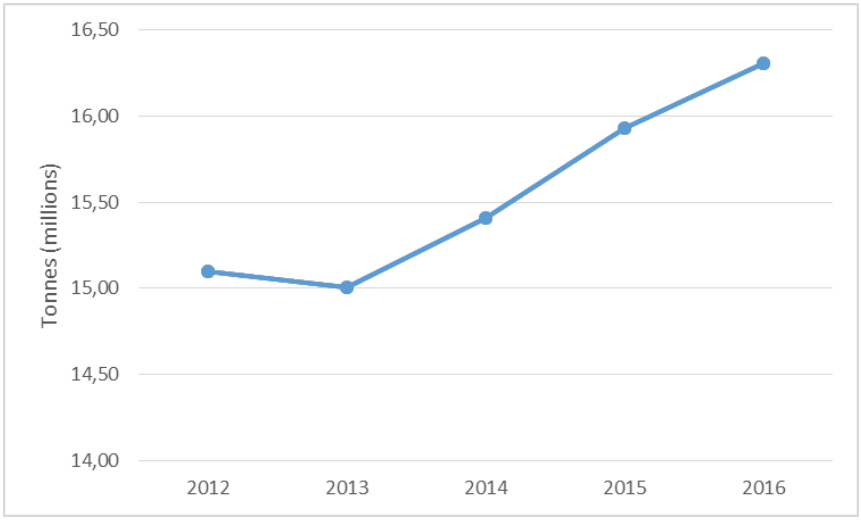


Figure 3 Domestic packaging plastic waste generated European Union[10]

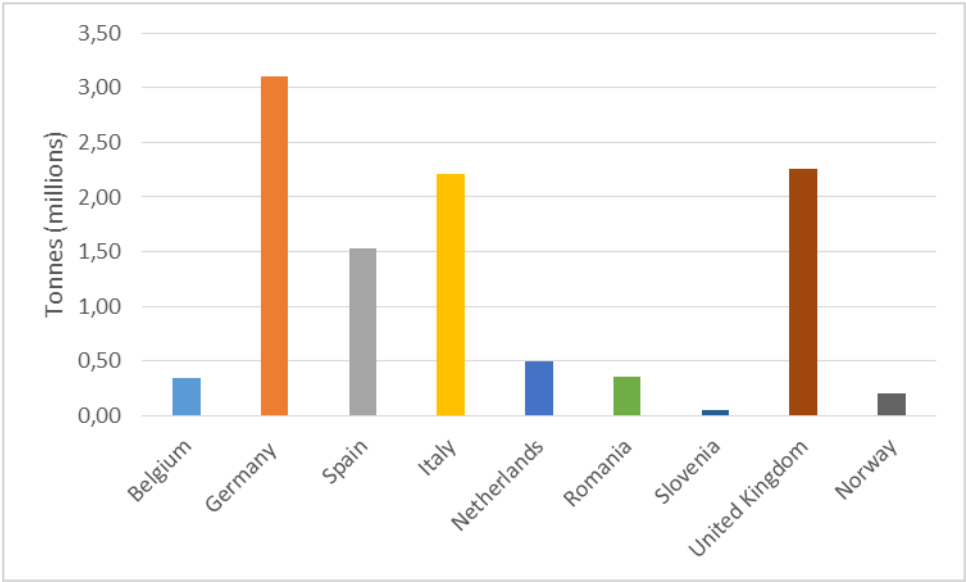


Figure 4 Domestic packaging plastic generated by consortium countries in 2016 [10]
*Romania data 2015

In the Figure 4 Figure 4 Domestic packaging plastic generated by consortium

10 Source: Eurostat – own elaboratión – consulted 11/2018

countries in 2016 [10]it can see the domestic packaging plastic generated by consortium countries around 11 MMtonnes which representd the 64,74 % of the plastics generated in Europe.

According to the most recent studies plastic packaging represents the major part of all plastic waste, approximately 60% of the total plastic waste generated.

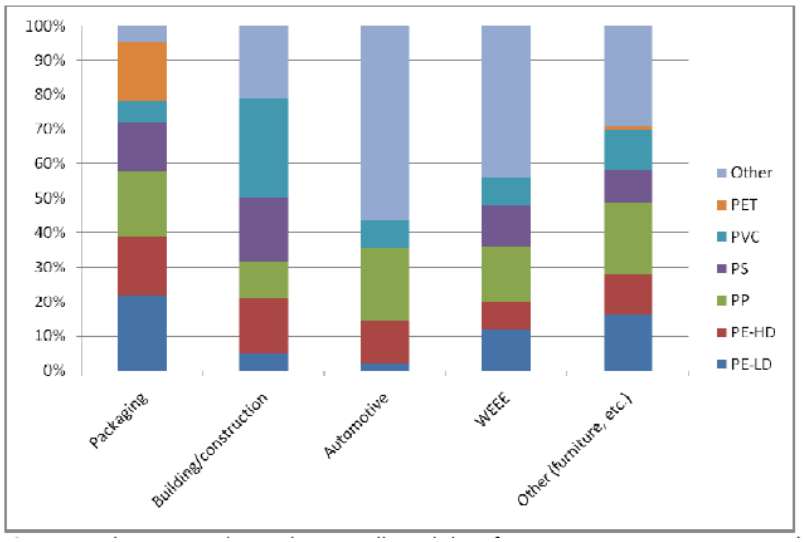


Figure 5 Percentage of plastic waste generation
Source: Plastic ZERO – Public Private Cooperation for Avoiding Plastic Waste

In terms of the main types of plastic consumed by the packaging industry, data shows that the main consumption is related to PE-LD, PE-LLD, PE-HD, PE-MD, PP and PET.

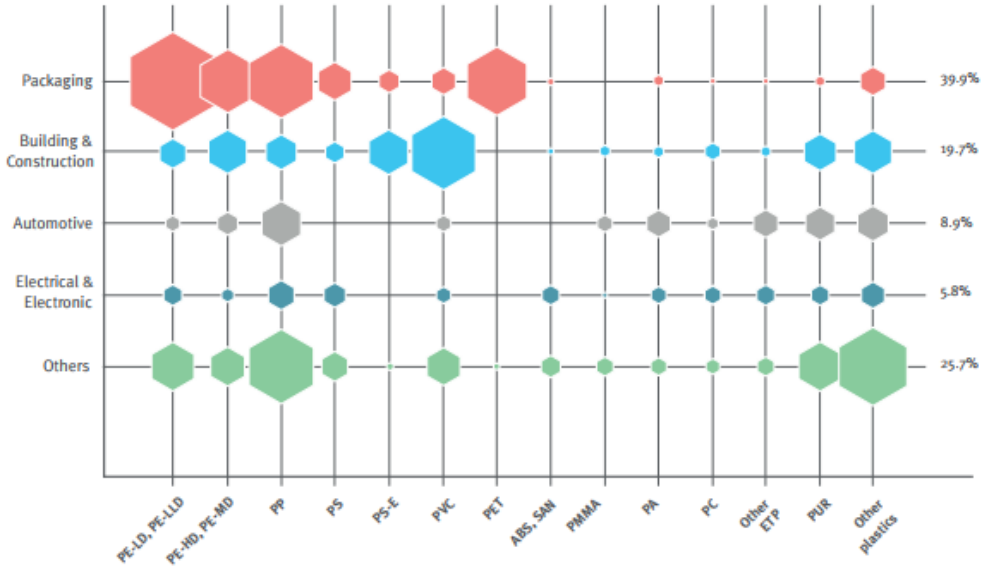


Figure 6 Plastics demand by polymer and market segment

Most of the plastic waste generated in Europe is generated in households. This fact is very important for the Plasticircle approach; household and household owner need to understand their co-responsibility in managing plastic packaging waste and to

actively perform their role as consumers and converters. For this reason, the incentive based approach and the technological approach of the project aimed at guaranteeing citizens privacy and involvement do play a major role.

By domestic packaging products the main use will continue to be plastic bottles, followed by confectionary products and other consumables. PET bottles are expected to maintain a growth rate of about 2.7% in the following years.

The environmental impact of this plastic waste generation is reflected in dramatic figures that indicate the emission of 23.8 MT of CO2 and represents a clear wastage of resources (€582/tonne of recovered plastic represent losses of €10.56 bn.).

The revenues from secondary materials (waste materials or recyclates) can pay for a substantial part of the total cost of waste management schemes in EU Member States. Therefore understanding how the price of recyclate changes over time is an important aspect of waste management. In the figure 5, it can see how the price developments and trade volume of plastic waste has evolutioned last fifthteen years.

However, even though collection and recycling of packaging waste (included plastics) has been growing steadily, there still exist a significant gap between the plastic produced and the plastic recovered.

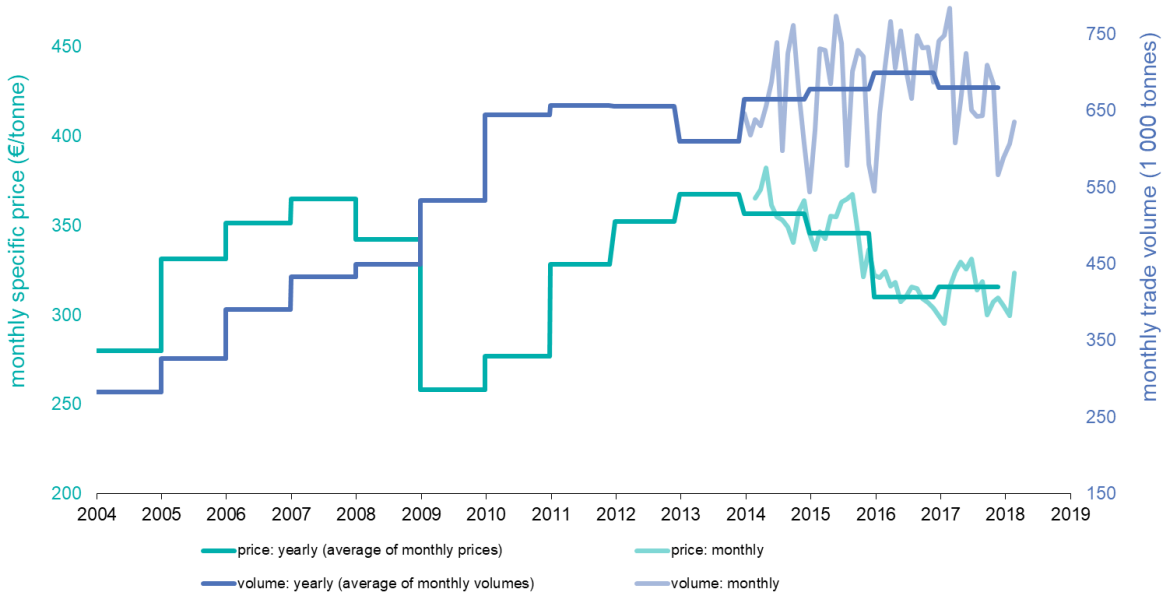


Figure 7 Price Developments and Trade Volume of Plastic Waste[11]

3.3 Plastic waste recovery and collection

The increase mentioned in plastic packaging consumptions, has been coupled thanks

11 https://ec.europa.eu/eurostat/web/waste/prices-for-recyclates

to the important awareness raising efforts and the environmental concerns associated to the problem in a significant increase of packaging waste recovery and collection. These efforts have also been accompanied by an important legislative corpus such as the Circular Economy Package Plan or the new regulatory arrangements at municipal, regional and national level.

The mentioned data suggest that these efforts have resulted in a significant and steady increase of packaging waste collection and recycling from 2005 (data available for 2005). It is important to note that collection of plastic waste has been followed, in parallel, with a steady growth of recycling initiatives, something that highlights an important valorisation of plastic waste.

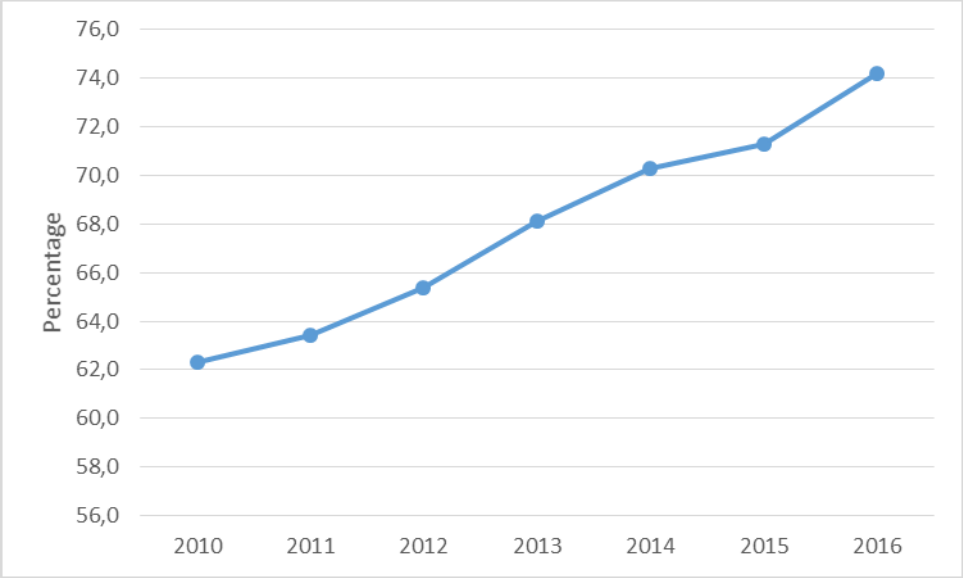


Figure 8 Percentage of domestic packaging plastic waste recovered European Union[10]

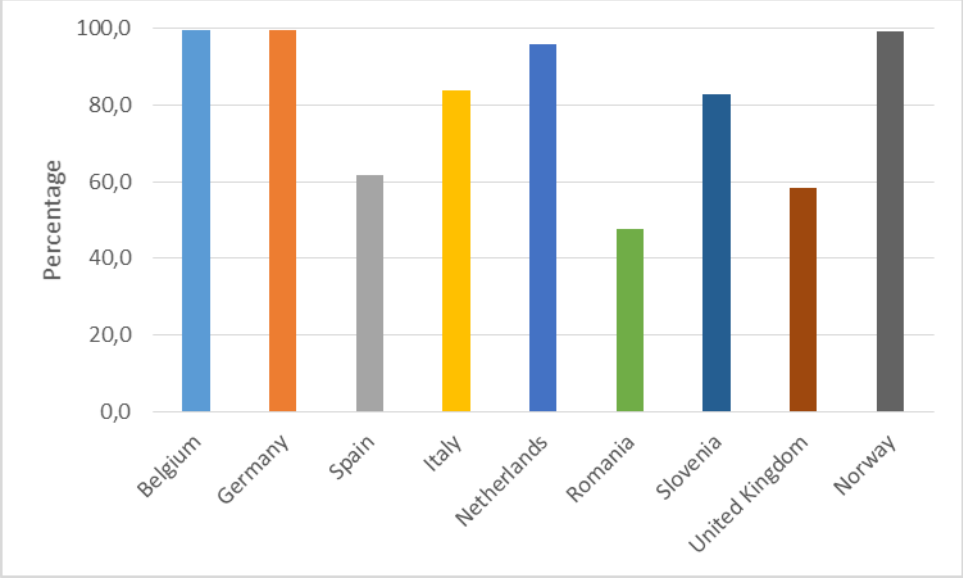


Figure 9 Domestic packaging plastic recovered by consortium countries in 2016[10]

In the Figure 8 and Figure 12, it can see that Europe has a high percentage of domestic packaging waste recovered, around 74 %, which it has been raising during last years, highlighting that the average of consortium countries in 2016 was above of European near to 81%.

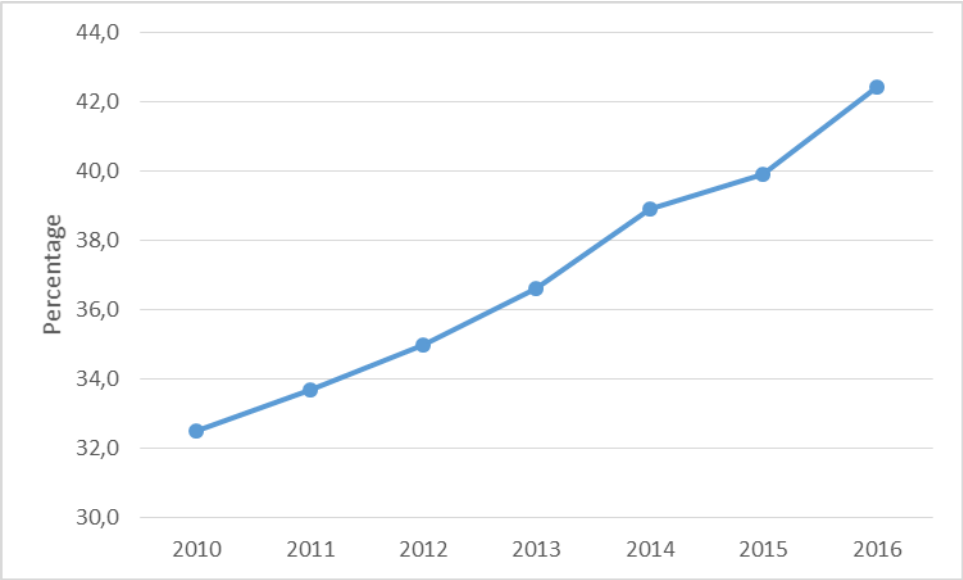


Figure 10 Percentage of packaging plastic waste recycled European Union[10]

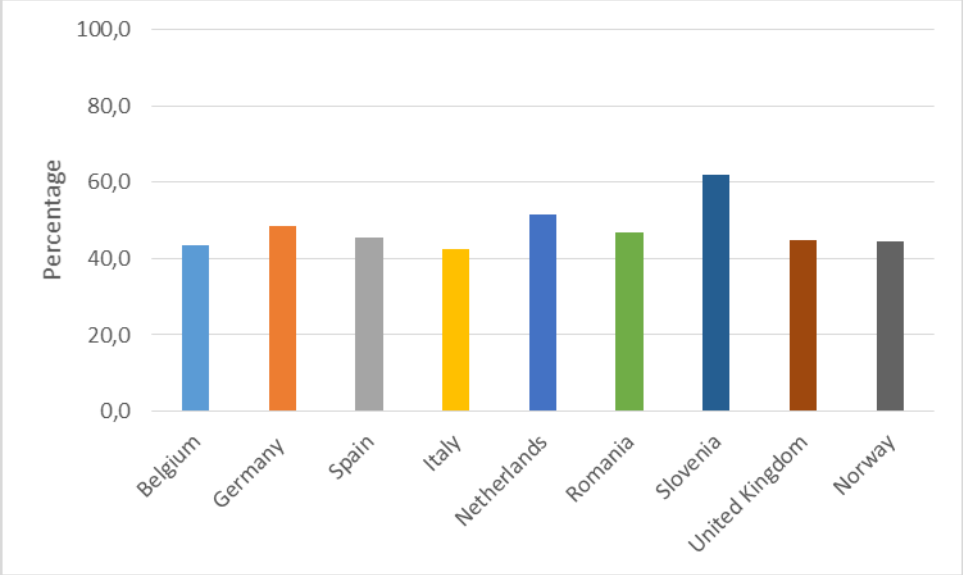


Figure 11 Domestic packaging plastic recovered by consortium countries in 2016[10]

In the Figure 10 and Figure 11, it can see that Europe has a less than fifty percentage in domestic packaging waste recycled, around 44 %, which it has been raising during last years, almost 12 %, highlighting that the average of consortium countries in 2016 was just a little bit above of European, around 47 % and Slovenia has the highest with a 62 %.

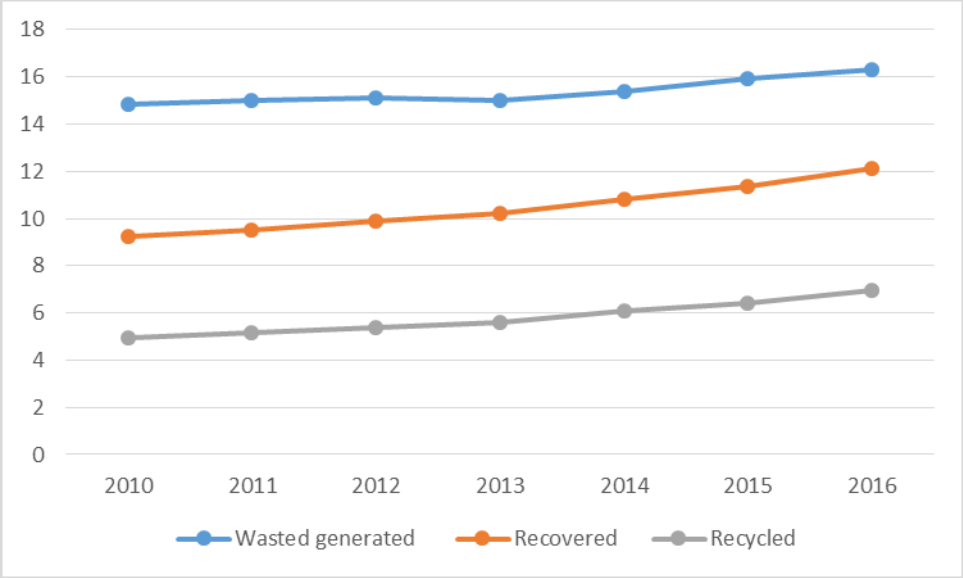


Figure 12 Generation, recovery and recycling for packaging plastic tonnes (millions) , EU, 2010-2016[10]

Figure 12 shows that the generation of domestic plastic packaging has been growing in recent years, plus the ability to recover and recycle has been consistent with this growth. It should be noted that the percentage recycled has increased from 33% to 47% between the period 2010 - 2016.

When analysing the figures segregated by countries, the common pattern of a still significant gap between plastic waste generated and its actual recycling can be observed. Although some countries show higher rates of recycling (i.e. Belgium or Sweden), the average values shown by the figures demand for continued efforts and developments.

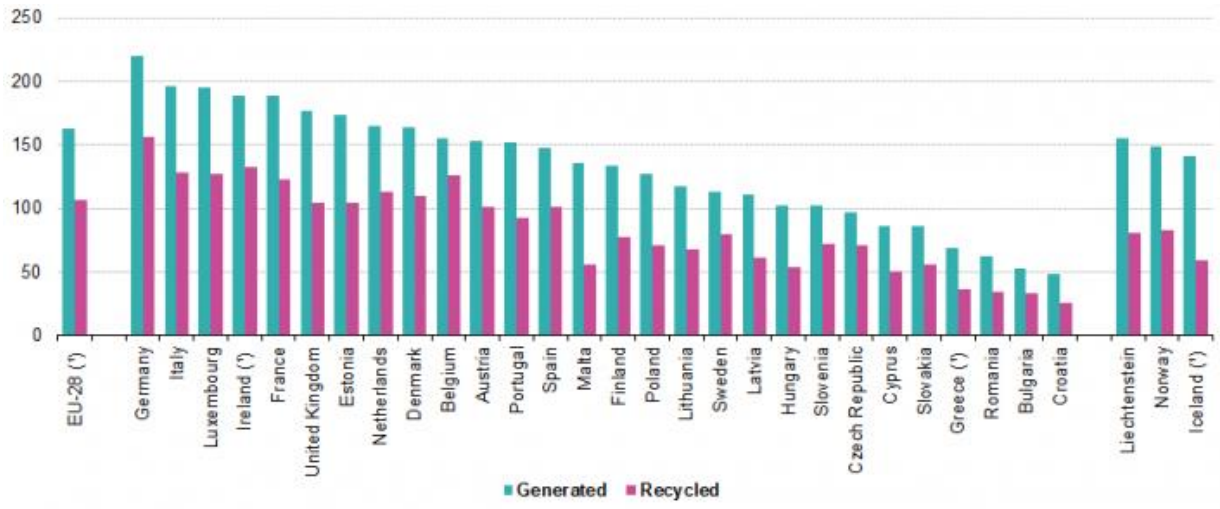


Figure 13 Volume of overall plastic waste generated and recycled

Source: EUROSTAT

One of the reasons that explains the growth in plastic waste collection and recycling is the development and implementation of more effective collection schemes. Our attention will be focused on the most significant practices of plastic packaging waste collection used in communities, namely curb-side collection, drop-off, buy-back and deposit/refund programmes in order to increase the recycling rates.

Below is a description of these four models:

Curbside collection: Curbside collection is considered a low-risk method to reduce waste volumes and increase recycling rates. In curbside collection materials are collected in large bins, coloured bags or small open plastic tubs specifically designed for content. Curbside collection uses co-mingled recyclables to maximise collection. Curbside collection has been a very successful model to recover domestic plastic bottle packaging.

Drop-off: In this method, containers for designated recyclable materials are placed at a central collection location throughout the community. The containers are generally marked as to which recyclable material should be placed in them. Residents are requested to deliver their recyclables to the drop-off location, where recyclables are separated by material type into their respective collection containers. Drop-off recycling programs are more suitable when residents are taking their garbage to a central waste collection facility or transfer station. The main problems with such programmes are that they suffer from unpredictable throughput.

Buy-Back: Most buy-back recycling centres are operated by private companies and pay consumers for recyclable materials that are brought to them. Buy-back centres usually have purchasing specifications that require consumers to source separate recyclable materials brought for sale. These purchase specifications can greatly reduce contamination levels and allow the buy-back centre to immediately begin processing the recyclables they purchase, while providing consumers with an economic incentive to comply with the specifications. Buy-back centres are similar to drop-off centres expect they pay waste generators for their items based on market values.

Deposit / Refund Programmes: These programmes require collection of a monetary deposit purchase of a plastic container. When container is returned to an authorized redemption centre, or to the original seller, the deposit is partly or fully refunded to the redeemer.

According to the 2016 state of curbside report[12] in pilot locations of USA there was not one individual attribute that indicates curbside program success, but several that affect performance and trends became evident. The majority of the highest-performing programs collect material single-stream, collect curbside recycling automatically, use an automated cart-based system, and have public engagement

[12] https://recyclingpartnership.org/wp-content/uploads/2018/05/state-of-recycling-report-Jan2017.pdf

that influences curbside recycling to occur in their community.

Of the communities surveyed with over 400 lbs/hh/yr recovery averages, 93% provide service to their residents automatically, meaning each single-family residential unit located within a given jurisdiction is provided a collection receptacle and is included in a regularly scheduled collection route without the need for the resident to take any action.

The alternative "opt-in" style system where the resident must take action on their own to receive service can be successful with additional policy provisions, such as making recycling service mandatory when opting-into trash service, bundling garbage and recycling together with a cost structure that stays the same if recycling is refused, or changing to an "opt-out" method. Without those provisions, however, opt-in/subscriptionstyle systems can create an undue burden on the average citizen of a community.

83% of the top-performing communities collect recyclables using wheeled carts with lids with the large majority being 95 gallons. These carts do not only provide more capacity for those residents that are currently recycling to recycle more, but convenience for those that do not recycle to start participating.

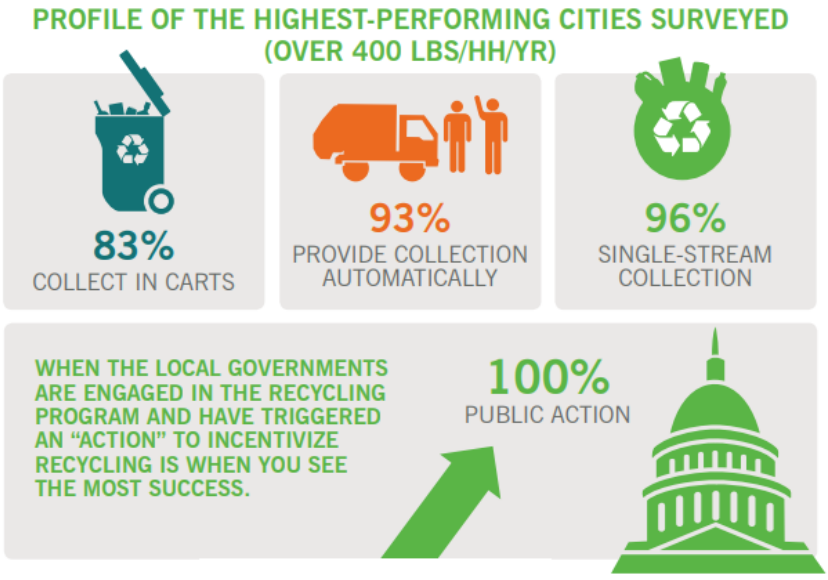


Figure 14 Profile of highest-performing cities surviyed[12]

The collection process mentioned above demand for a significant involvement of the local communities and their citizens. As the worldwide population is moving towards a more urban lifestyle, the amount of municipal household waste increases, and so does the need for citizenship involvement. This is a significant point when we analyse the world population data; ten years ago there were 2.9 billion urban residents who generated about 0.64kg of municipal waste per person per day (0.68billion tonnes per year). Nowadays it has been estimated that the amount has increased to about 3 billion residents generating 1.2 kg per person per day (1.3 billion tonnes per year). By

2025 this will likely increase to 4.3 billion urban residents generating about 1.42kg/capita/day of municipal waste[13] (2.2 billion tonnes per year). (World Bank, 2013).

It is important to note, as well, that the changing nature of rural communities, with a significant demographic, economic and social change in relation to how these rural communities were 20 years ago (new population typologies, new economic activities, residential areas, increasing growth of attraction for touristic and leisure-based activities) demand for new and innovative methods in such areas.

One of the elements that needs to be taken into consideration is the importance that overcoming anonymity can have for the development of such programmes. Currently, citizens might fell that their efforts in relation to plastic collection and recovery are not "recognised". In this regard, the PlastiCircle collection system, based on smart containers able to identify the quantity and quality of plastic packaging generated by each family/citizen, will be a step forward in overcoming such anonymity issue. For this, Containers will be provided with a user identification system based on the reading of a "citizen card" (i.e. unique and smart identification system based on RFID or QR). After reading, the container lid will be unlocked to allow the citizen to deposit the garbage bag with the packaging waste inside. Citizens will stick a label on the garbage bag before depositing it in the container, which will be provided by the container. This label, which will also be designed in the project, will identify the citizen. The system will be completed with regular assessment of the composition of bags (characterization protocol; segregation quality).

Globally, ample opportunity exists for smart waste collection solutions that can increase efficiency and improve the quality of these services. The commercialization of related technologies represents a fertile ground for existing waste haulers and new market entrants, particularly as city administrators face pressure to carry out waste collection as efficiently and effectively as possible—often on a tight budget. [14]

Within the waste and recycling industry, a few key categories have emerged where objects connected to the internet are affecting operations and efficiencies. Radio-frequency identification (RFID) technology on carts helps track those assets in the field and can be used by haulers to confirm that addresses have been serviced. [14]

The trend of putting a wider variety of devices online—the so-called Internet of Things—continues to spread. Increasingly, household devices are now internet enabled, allowing users to control them remotely or get alerts if something is amiss. Devices increasingly collect new streams of data that can be analyzed to change behaviors or purchasing decisions. The waste and recycling industry is also being

13 http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf

14 https://www.navigantresearch.com/news-and-views/the-global-smart-waste-collection-technology-market-is-expected-to-exceed-$223-million-in-2025

affected, with trucks, containers of all sizes and other pieces of equipment increasingly becoming part of this Internet of Things. [14]

The global smart waste market is forecast to grow at 16.82% CAGR over the period 2014-2019.The sensor-based container is a battery-powered wireless device that helps reduce the overall collection and logistics cost of waste collection by approximately 50 percent. The decrease in cost of solid municipal waste collection thanks to smart waste technologies is an important factor that will propel growth in the Global Smart Waste Market in the coming years. [15]

Some important companies in this sector are: Covanta Energy, Republic Services, Suez Environment, Veolia North America, Waste Management, Bigbelly, BRE SMARTWaste, Enerkem, Enevo, Harvest Power, RecycleSmart Solutions and ROS ROCA's.

According to Navigant Research, the global smart waste collection technology market is expected to grow from $57.6 million in 2016 to more than $223.6 million in 2025. [14]

Within the waste and recycling industry, a few key categories have emerged where objects connected to the internet are affecting operations and efficiencies. Radio-frequency identification (RFID) technology on carts helps track those assets in the field and can be used by haulers to confirm that addresses have been serviced. [14]

Sensors that detect fill levels of all types of containers are a second category. These hardy devices let haulers know how full carts or cans are so that pickups can be optimized. The aggregation of data on how fast certain carts fill can also be used to predict future pickup schedules and make routes more efficient. [14]

Garbage trucks themselves are increasingly wired. Dispatchers can track trucks in the field. Advanced telematics systems can let maintenance shops know about issues as they occur (or even before they become bigger problems), allowing for more predictive maintenance and less downtime. [14]

Lastly, when it comes to organics, small digesters installed in commercial operations often include sensors that can analyze what's being passed into them. Crunching the numbers can inform generators how to reduce how much food they waste. [14]

The Use of RFID[14]

RFID technology systems are being integrated into waste haulers' and municipalities' customer relationship management (CRM) and billing system to improve customer service and billing accuracy.

[15] https://www.prnewswire.com/news-releases/global-smart-waste-market-growing-at-16-cagr-to-2019-292351141.html

RFID technology uses electromagnetic fields to identify and track tags attached to objects. The tags contain electronically stored information.

Many cart manufacturers, for example, use RFID technology on assets to confirm delivery and track assets in the field.

- Rehrig Pacific Co. developed the Container Asset Recovery Tracking System (CARTS). The proprietary system enables a series of services. It allows users to conduct residential surveys to gather feedback on services, determine interest in new programs or select a container size. It allows tracking of container shipments and managing inventory levels at distribution centers. Container deliveries are recorded in real time by using handheld scanners in conjunction with CARTS. It can generate daily distribution reports that include household address, container serial number, RFID tag number, type, size, date and time of delivery.

- Cascade Cart Solutions' (CCS) offering includes the Xtreme Tag RFID tag and the CartLogic asset management software. CCS' CartLogic allows management of cart services and location information using RFID technology, GPS systems and cloud computing. Each time a delivery, swap, repair or removal is made the cart's RFID tag is scanned (or a serial number is entered) and the cart's location and type of service provided is recorded, generating a service history log for each cart, whether in the field or at the yard. This information synchronizes with CartLogic's cloud-managed platform, storing all cart inventory data online.

- Otto also offers a variety of container management solutions. It can confirm delivery for carts. Then, real-time service verification allows orders to be updated and closed—all while in the field using handheld devices.

- SSI Schaefer's waste technology division, meanwhile, developed WISTAR Technology, which includes RFID tags on carts and proprietary software with a variety of capabilities. The company's RFID-enabled waste carts provide real-time managed assembly and distribution, GPS location, revenue audits, online reports and inventory management.

- Toter has its ToterTrax system that includes the embedding of an RFID tag into the handle of each Toter cart during the manufacturing process. As each cart is delivered to a specific address, the crew scans the cart's RFID tag with the ToterTrax mobile app portion of the system to register that it's been delivered. The ToterTrax app then retrieves the RFID data, serial number, geo coordinates of location (where the cart was scanned) and time stamp (when cart was scanned) and sends this data through a Bluetooth connection to the ToterTrax web portal. This allows real-time monitoring of cart delivery and rollout.

RFID codes on carts are also used by haulers to confirm when pickups have been performed.

In typical industry applications, inexpensive RFID tags are affixed to residential carts and commercial containers, while waste and/or recycling trucks are equipped with RFID readers. When a cart or container is serviced, the RFID reader recognizes and records the RFID tag. The RFID tag and the geo-coordinates for the location of the service are then sent back to a central database.

Additionally, RFID is used to measure set-out rates by customers, and knowledge of how many carts are serviced by each truck helps improve operational efficiency by balancing the workload per truck.

Lakeshore Recycling Systems (LRS) in Morton Grove, Ill., for example, uses UHF RFID-tagged waste and recycling carts that transmit information—including the resident's address, name and date—to a reader located on the arm that lifts the carts for service. The cart's chip also distinguishes whether it's waste or recycling. When each route is closed out at the end of the day, the information is collected, disseminated and processed by LRS' software for the sake of billing.

Most municipal waste collection operations focus on emptying containers according to predefined schedules at a set frequency, creating the possibility of half-full bins being emptied, poor use of city assets, and unnecessary fuel consumption. While the smart waste collection market is still in its early phase, a wide availability of commercially viable technologies and growing interest in connectivity and city IoT networks are expected to drive growth in this market, reducing these issues.[16]

The implementation of these technologies related to intelligent collection of waste, has also led to the development of smart containers, with the intention of knowing at what moment the container is ready to be picked up during the route

One of the biggest areas of innovation is the development of devices that can measure the fullness levels of various types of carts and cans. In some cases, these are devices that can be placed into a cart, can or other receptacle and measure how full it is and notify haulers when the container needs to be serviced. In other cases, the technology is built right into the can itself.[14]

Finnish company Enevo has developed a wireless sensor that can be affixed to a full range of refuse containers carrying all types of garbage. It is designed to tolerate harsh weather and grueling conditions, track fill levels and monitor temperatures and movement to detect fire or vandalism. Pertinent information is transmitted to haulers via sonar technology so drivers can be more efficient, responsive and timely with pickups. It's mainly geared for the commercial and industrial sector. [14]

[16] https://www.navigantresearch.com/news-and-views/the-global-smart-waste-collection-technology-market-is-expected-to-exceed-$223-million-in-2025

San Francisco-based Compology has developed rugged sensors for the insides of roll-off and front-load containers to track fullness, GPS location and motion information. The sensors feed real-time data to Compology's web-based software dashboard, where haulers can make timely, data-driven decisions to improve operations and customer service. Compology has a partnership with Wastequip, which allows customers to get new roll-off containers delivered directly from the factory with the technology preinstalled. [14]

3.4 Incentive mechanisms

Also in today's world, people are often too "lazy" to walk ten extra steps to the trash can and they litter their surroundings with plastic bottles, cans and glass. An Intelligent Trash can that will actually pay people for throwing recyclable trash like glass and plastic in them.[19]

The trash can aims to achieve three fold benefits:

1. Reduce the plastic pollution in the environment.

2. Pay the people to clean up the society so they get motivated.

3. Manage the entire waste transportation smartly. The dustbins will communicate when they are about to reach their capacity, a dumper can collect the waste and deposit it to bid dumping areas. In this way the dustbins will be usable with out any garbage falling outside of them.

4. Get a trash full of JUST recyclable materials—glass bottles and plastic! Segregation of wastes into recyclable and non recyclable materials is one of the worst problems of cleaning up huge dumping grounds, and here we get people to do it themselves!.

At this point, it is important to note that technological solution might need to be supported by the implementation of incentive mechanisms. An incentive scheme is here understood as any recycling system that is based on incentive motivation through giving economic or other kind of incentives for recycling, that means, award the act of recycling to motivate the people. For the implementation of a recycling incentive plan, the laws and regulation that affect each community must be taken into account because they will limit or enhance the implementation of any programme.

Currently, the main recycling incentive alternatives being used are the following:

- **Pay as you throw (PAYT)**: is a strategy in which the consumer pays more to dispose of more waste (the less waste you generate, the less you pay). The consumers that recycle, reduce and compost save money in their bills, something that provides and

incentive to recycle and reuse. Although these systems started almost 100 years ago, the real impact of PAYT programmes began in 1990s.[17]

- **Recycle bank and point-based recycling credits**: They provide consumers with financial or other incentives for participating in recycling. Consumers receive money points based on the amount of recyclable material, and these points can be changed for discount coupons, or gift cards, or other options. This programme began with pilot projects in 2005. Consumers are encouraged to recycle because they receive money or points (and more points link to savings on retails or other types of reward).

- **Deposit and return systems (DRS)** are a combination of a product charge (the deposit) and a subsidy for recycling or proper disposal (the refund).

The implementation of an incentive recycling system requires a project planning that takes into account specific conditions in each case. Several agents need to be involved in the process and specific stages need to be foreseen, including project planning and municipal teams creation, assessment and collaboration agreements, campaigning and monitoring.

These efforts will need to be supported by a carefully planned financial and resources investment identification that includes:

- Investments to conduct
    - Container/machine implementation
    - Training Activities
    - Communication campaigns
- Operating costs
    - Staff dedicated to the scheme
    - Operational costs
    - Costs for the incentive plan
- Incomes
    - Plastic commercialisation
    - Sponsorships
    - Subsidies

[17] Reschovsky, J. D., & Stone, S. E. (1994). Market incentives to encourage household waste recycling: Paying for what you throw away. *Journal of policy analysis and management*, *13*(1), 120-139.

- Savings

    - Costs that will not occur or reduced

- Non-economic benefits

Working upon this rationale the Plasticircle project will promote the implementation of a compensation system aimed at guaranteeing the involvement and the active participation of the citizens.

3.4 Plastic transport

An improvement in plastic waste recovery and recycling demands for a more effective transport and routing of plastic waste. Different elements will need to be considered at this point in order to assess the effectiveness of the model, including the time required for plastic transport from collection point to sorting plant, the traffic existing in the community and the capacity to compress the plastic waste collected (in order to ensure a most efficient transport of material).

This effort will need to take into consideration specific traffic regulations in the local communities where the PlastiCircle project will be implemented. Specific regulations, such as traffic timings, not circulation zones, etc. will need to be considered in order to assess the market opportunities for the Plasticircle solutions.

Currently a multimodal transportation approach has proven to be a good solution for maximising accessibility and reducing the travel distance. Multimodal transportation is defined as transporting products by two or more modes of transport system. Applying a multimodal transportation system to convey wastes is an approach to increase access to different sites and reduce negative effects of an invariable transportation system.

It will be important for the PlastiCircle solution to identify the possibilities offered by a multimodal method of transportation, and the capacity of the solutions developed to be adapted to such alternative modes of transportation. This will guarantee the replicability of the transportation process and will increase the market reach of the solution in terms of implementation sectors and strategies.

The global smart transportation market size is estimated to reach USD 285.12 billion by 2024, according to a new study by Grand View Research, Inc., registering a CAGR of 22.5% during 2018 - 2024. Rising number of on-road vehicles and ineffective existing transport infrastructure are expected to propel the need for efficient management systems. Favorable government initiatives for building better infrastructure and smooth

running of existing transport systems are expected to boost industry growth.[18]

Increasing investments in smart city projects are anticipated to open up new avenues for growth in the coming years as smart transportation is an integral part of any smart city. In addition, rising government focus on reducing greenhouse gas emissions and curbing alarming levels of traffic congestion is anticipated to drive industry growth over next few years. Increasing number of government mandates, such as those by the European Union (EU) and Directive on Intelligent Transport System, are also anticipated to favor the market during the forecast period.[18]

On the flip side, need for massive capital for replacing existing infrastructure with smart technologically advanced systems is expected to hinder industry growth. Longer downtime for replacing existing systems may also pose a challenge to its growth and can affect daily commute. [18]

Some key factor are identified in the report: [18]

- Key solutions available in the market include ticketing management systems, parking management systems, integrated supervision systems, and traffic management systems
- Integrated supervision systems are used for reducing traffic blocks, minimizing accidents, and providing better safety measures. This segment holds high growth potential
- The cloud service segment is anticipated to witness a surge in demand, owing to rising need for storage of data generated through these systems
- Professional service vendors offer consulting services and may witness an increase in demand over the next few years, owing to need for services to upgrade existing infrastructure
- The North America market accounted for over 27.0% of the global revenue in 2015; Asia Pacific, on the other hand, is estimated to be the fastest-growing segment, offering lucrative growth opportunities for industry players
- Government initiatives to enhance transport infrastructure are expected to favor the Europe market for smart transportation. The MEA market is also likely to be driven by increasing government investments in transport infrastructure
- Key industry participants include Accenture PLC; Alstom, SA; Cisco System, Inc.; Cubic Corporation; General Electric Company (GE); Indra Sistema S.A.; International Business Machine (IBM) Corporation; Kapsch; LG CNS Corporation; and Xerox Corporation.

The detection, monitoring and management of waste is one of the primary problems

[18] https://www.grandviewresearch.com/press-release/global-smart-transportation-market

of the present era Manually keeping track of pickup routes and fill-levels are expensive and time-consuming procedures. IoT companies look at the waste crisis as both a challenge and as an opportunity to invent solutions that will reduce costs and increase efficiency.[19]

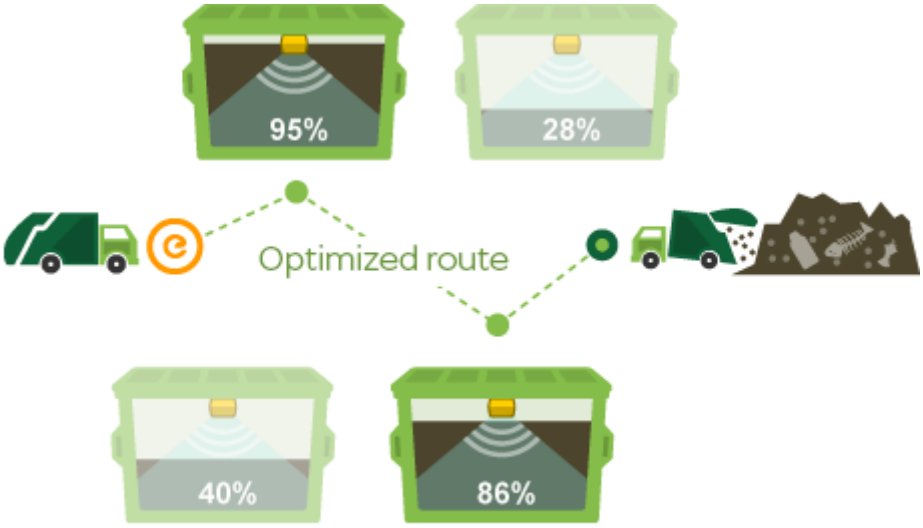


Figure 15 Smart Waste Management[19]

The ultrasonic level sensor is one type of sensor that IoT companies have put to good use. Initially designed to measure slurries and liquids, several businesses and municipalities are applying the sensor to measure solid waste as well. It is a radar system that tracks the amount of garbage in a trash can. This data could be used to reduce transportation costs involved in going to collect trash from localities that have partially filled trash cans or empty trash cans.[19]

The smart transportation market, based on service, can be classified into business, cloud, and professional services. The cloud services segment dominated the market and was valued at USD 7.56 billion in 2016. The segment is anticipated to retain its dominance over the forecast period, attributed to rising demand for storage of large amounts of data generated on a daily basis.[20]

North America accounted for over 27.0% of the global revenue in 2015. Rising government investments in transport infrastructure are expected to propel regional growth over the coming years.[20]

The Asia Pacific market is anticipated to witness the fastest growth over the forecast period, owing to several government initiatives. Growth is relatively higher in China, India, South Korea, and Japan. The Indian government's initiative to build 100 smart

[19] https://blog.boltiot.com/smart-transportation-smart-waste-management-d35f1e141629
[20] https://www.grandviewresearch.com/industry-analysis/smart-transportation-market

cities is anticipated to create new avenues for industry players. [20]

Europe is expected to present significant opportunities for industry expansion, owing to early adoption of several new technologies and rising traffic congestion in major cities. Directive 2010/40/EU was adopted in July 2010 in European Union member countries in order to accelerate deployment of innovative transport systems across Europe. Such government regulations are expected to favor industry growth over the next few years. [20]

Key smart Transportation industry participants include Accenture PLC; International Business Machine (IBM) Corporation; Kapsch; Alstom, SA; Cisco System, Inc.; and General Electric Company (GE). Other prominent vendors include Indra Sistema S.A., LG CNS Corporation, Cubic Corporation, and Xerox Corporation. Alstom offers solutions that cater to transport ranging from high-speed trains to metros and tramways. It also offers associated modernization, maintenance, infrastructure, and signaling solutions. [20]

3.5 Plastic waste sorting

Sorting, the first step in recycling plastic waste after collection, separates, cleans and prepares materials intended for recycling. Depending on its nature, sorted plastic waste will be processed directly on the site of the recycling company responsible for receiving it or be taken to a specialist recycling centre. Since there are many categories of materials and many processes, varying according to the type of product,[21]

Many waste plastics are not currently sorted, and are instead sent to landfill because of the cost and difficulty of separating the different types of plastics into separate streams. A recent report from WRAP identified this as a major problem facing the waste plastic sorting industry, and Impact Solutions is committed to help alleviate some of the problems faced.[22]

Assorted waste plastics can be separated currently using expensive technology. Impact Solutions is looking to develop a waste plastic sorting technology which will have a low capital investment and a low on going maintenance.[22]

Plastic waste, whether separately or co-mingled collected will have to undergo a sorting and upgrading process in order to produce new feedstock for recycling. The basic principles in sorting plastic waste and the technologies applied are analysed as follows.

Currently, the sorting process comprises several sorting steps with different types of

[21] https://www.paprec.com/en/understanding-recycling/recycling-plastic/sorting-plastic-waste
[22] http://www.impact-solutions.co.uk/impact/waste-plastic-sorting-technology-market-need/

processes and materials removed from the primary stream. The most commonly agreed sorting process includes the following steps:

Initial material sorting:

- Manual sorting – removal of films, cardboard and bulky items
- Size reduction – shredding and cutting
- Screens, air classifiers and ballistic separators – removal of small, light pieces such as film and paper ad removal of heavy pieces such as glass and stones.
- Overband magnet – removal of ferrous metals
- Eddy current separator – removal of aluminium
- Optical sorting of materials – two-dimensional items like paper and cardboard are removed from three-dimensional containers

Polymer sorting:

- Size reduction – flaked
- Cleaning of plastic – washing and drying
- Optical sorting of polymers – polymer type and colour
- Density separation of polymers – polymer type

Post-sorting

- Purification – food grade plastic
- Extrusion - Production of pellets
- Quality control – lab testing
- Packaging – bulked or baled

In this respect, the PlastiCircle sorting solution is based on Near-Infra-Red-Hyperspectral-Imaging (NIR-HSI). Moreover, advanced optical detection technologies will be integrated: THz imaging and hyperspectral snap shooting. Tests will be done by changing the hyperspectral camera RED-EYE 2.2 by a THz Camera and a snap shooter. The project will develop classification trees and algorithms for spectral fingerprints of PVC and conventional bioplastics. They will be for the NIR wavelength range from 1.2 to 2.2 µm. Methods considered will be PLS-DA (Partial Least Squares Discriminant Analysis), ANN (Artificial Neural Networks) and SVM (Support Vector Machines). A new sorting design free of conveyor belts will be designed. It will be based on air flows. The optimal conditions for the ejection system to achieve medium air pressure and decrease negative turbulence effects. Finally, Ad-hoc pre-treatment processes will be designed in order to increase the subsequent sorting efficiency. This will be done in a four-step procedure for the separation of: (1) organics and glass (trommel); (2) light plastic (i.e. films and shopping bags); (3) metals (i.e. metal separator, eddy current); (4) paper (i.e. optical).

Recycling of plastic majorly depends on the type of plastic. Collection of waste does not ensure the type of plastic. Before recycling compatibility issue has to be resolved. In a collection there may be number of plastics. Segregation of plastic has to be done

to sort out various materials and it depends only on the sorting personal's experience. Introduction of one polymer into another may lead to reduction in properties of recycled material because of the different melting points.[23] For these reason some of the techniques for segregation and identification of different plastic materials have been developmented.

Potential suppliers of recycled plastics do not invest sufficiently in sorting and recycling capacity because the profitability of these operations is limited. Potential buyers (i.e. manufacturing firms) have limited incentives to use recycled plastics as inputs because of uncertainty about their availability and quality. Market outcomes could improve significantly if these issues were addressed.[24]

Over the years, there have been significant advancements in spectrographs and detector designs, which have resulted in decreased costs and improved instrumentation capabilities. As a result, hyperspectral imaging is increasingly being used in various application areas. Unlike conventional cameras, hyperspectral cameras acquire a 3D image cube and spectral information, which is appropriate for any situation where images have to encompass a large area and encode a great deal of information within a single view. [25]

The global hyperspectral imaging systems market is projected to reach USD 21.33 billion by 2023 from USD 8.14 billion in 2017, at a CAGR of 17.5%. The hyperspectral imaging systems market comprises several large as well as small players. The key growth strategies adopted by the players in the market include acquisitions, agreements and partnerships, expansions, and product launches & approvals. The prominent players in this market include Headwall Photonics (US), Corning Incorporated (US), SPECIM (Finland), Resonon (US), Telops (Canada), Norsk Elektro Optikk (Norway), Applied Spectral Imaging (US), BaySpec (US), Surface Optics Corporation (US), and ChemImage Corporation (US).[25]

3.6 Plastic waste recycling

One of our society's main challenges is to guarantee that recovered plastic waste can be considered a resource rather than just waste. The term plastic valorisation comes here to importance, referring to any industrial processing activity aimed at reusing, recycling or composting from a waste source, useful products or sources of energy. It usually takes the form of one of the following activities: processing of residue or by-products into raw materials, use of discarded finished or semi-finished products as raw materials or energy sources, use of waste materials in manufacturing process stages, and addition of waste materials to finished products.

As it has been seen above, recycling is just one type of valorisation process. Plastic

[23] http://www.fernandofraternaliresearch.com/publications/JCOMB_Recycling_Review_2016_Online_First.pdf
[24] https://www.oecd.org/environment/waste/Policy-Highlights-Improving-Markets-for-Recycled-Plactics.pdf
[25] https://www.marketsandmarkets.com/Market-Reports/hyperspectral-imaging-market-246979343.html

materials can be recycled in significant variety of ways and the ease of recycling varies among polymer type, package design and product type. For example, rigid containers consisting of a single polymer are simpler and more economic to recycle than multi-layer and multi-component packages, something that has a significant impact upon the sorting and manufacturing process.

For 2020, the 45% output recycling target is set for plastic packaging waste (see COM (2014) 397 final). The target for recycling of plastic packaging waste rises to 55% (COMV(2014) 397 final) in 2030.

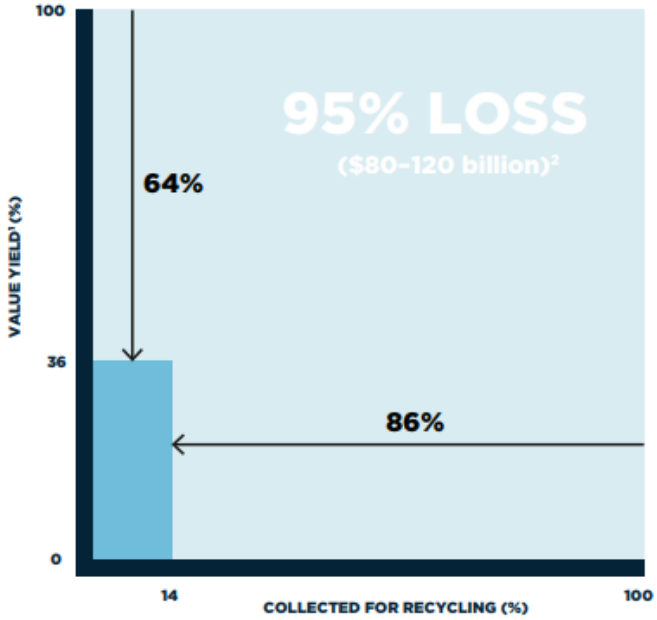


Figure 8. Source: http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf

Thermoplastics, including PET, PE and PP all have high potential to be mechanically recycled. Thermosetting polymers such as unsaturated polyester or epoxy resin cannot be mechanically recycled, except to be potentially re-used as filler materials once they have been size-reduced or pulverized to fine particles or powders (Rebeiz & Craft 1995). This is because thermoset plastics are permanently cross-linked in manufacture, and therefore cannot be re-melted and re-formed. Recycling of cross-linked rubber from car tyres back to rubber crumb for re-manufacture into other products does occur and this is expected to grow owing to the EU Directive on Landfill of Waste (1999/31/EC), which bans the landfill of tyres and tyre waste.

A major challenge for producing recycled resins from plastic waste fractions is that most different plastic types are not compatible with each other because of inherent immiscibility at the molecular level, and differences in processing requirements at a macro-scale. For example, a small amount of PVC contaminant present in a PET recycle stream will degrade the recycled PET resin owing to evolution of hydrochloric acid gas from the PVC at a higher temperature required to melt and reprocess PET. Conversely, PET in a PVC recycle stream will form solid lumps of undispersed crystalline

PET, which significantly reduces the value of the recycled material. However, the industry is innovating in the development of compatibilizers to increase compatibility among certain polymers.

Hence, it is often not technically feasible (depending on the recyclable percentage) to add recovered plastic to virgin polymer without decreasing at least some quality attributes of the virgin plastic such as colour, clarity or mechanical properties such as impact strength. Most uses of recycled resin either blend the recycled resin with virgin resin—often done with polyolefin films for non-critical applications such as refuse bags, and non-pressure-rated irrigation or drainage pipes, or for use in multi-layer applications, where the recycled resin is sandwiched between surface layers of virgin resin. The ability to substitute recycled plastic for virgin polymer generally depends on the purity of the recovered plastic feed and the property requirements of the plastic product to be made. This has led to current recycling schemes for post-consumer waste that concentrate on the most easily separated packages, such as PET soft-drink and water bottles and HDPE milk bottles, which can be positively identified and sorted out of a co-mingled waste stream. Conversely, there is limited recycling of multi-layer/multi-component articles because these result in contamination between polymer types. Post-consumer recycling therefore comprises of several key steps: collection, sorting, cleaning, size reduction and separation, and/or compatibilisation to reduce contamination by incompatible polymers.

Plastic waste is typically sorted two or three times, often at different locations, before it is pure enough to be used as feedstock in new production. The route of the plastic waste from disposal to recycling is not always easy. It is a challenge to identify where and how the plastic waste is being utilized, because it might be traded and upgraded several times. It is sometimes difficult to find local plants within the region capable of sorting new plastic fractions.

It is also difficult to track the destination of plastic and ensure that the plastic became recycled as intended. One risk is that only high-value materials are recovered. Another risk is that the quality of the reprocessed material gets deteriorated because of the poor quality input or insufficient upgrading. It is always a challenge to produce a consistent output when the input materials come from a variety of sources with varying quality.

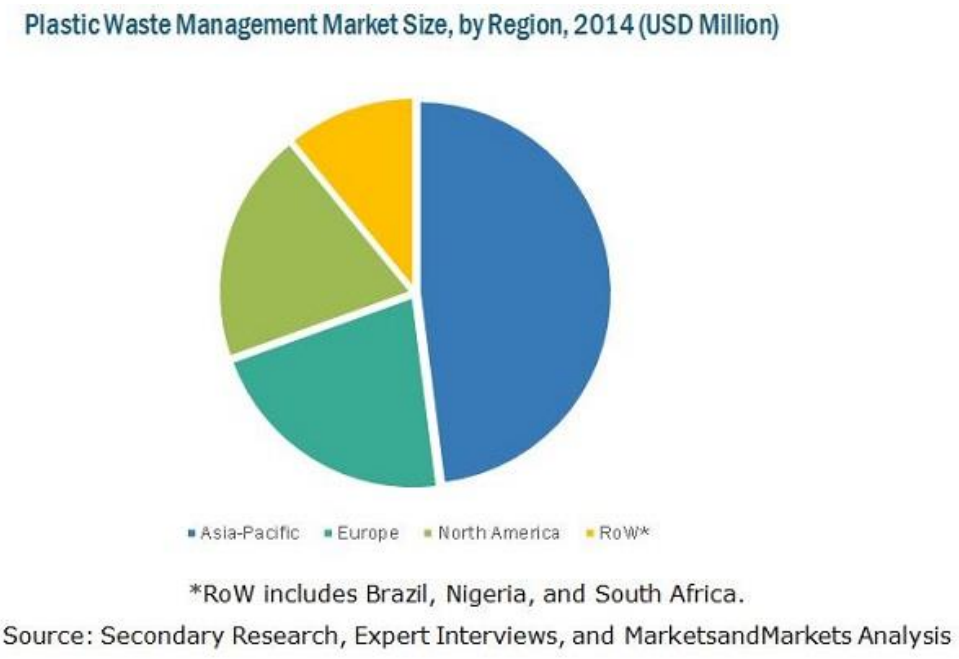
Export to Asia for low quality materials due to its lower quality standards, can be seen as a solution but it is a missed opportunity for developing domestic workplaces. The high rates of contaminants in mixed plastic fractions are a hindrance for cost-efficient reprocessing of plastics. The share of contaminants, non-target materials and lost material was as high as 50% in many cases. Moreover, certain limitations might be mentioned here, as customs control and new legislation.

4. Benchmarking analysis. Similar

initiatives and projects

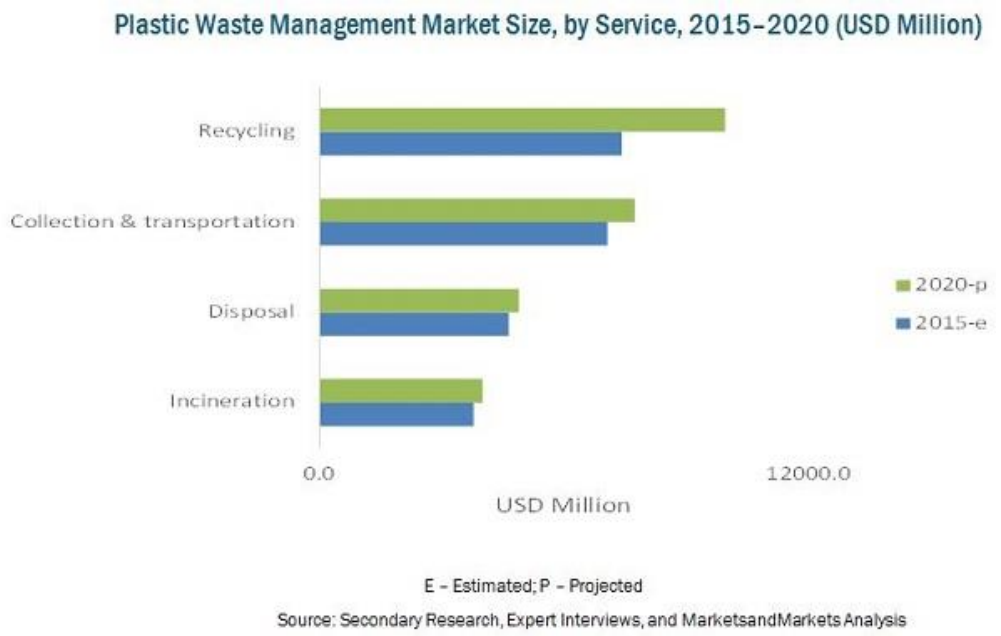
The global plastic waste management market is projected to be valued at around USD 26,573.3 Million by 2020, growing at a CAGR of 3.02% from 2015 to 2020. Factors such as increasing urban population, industrialization, and growing consumer awareness have propelled the growth of the global plastic waste management market. Concerns about the environment and well-being of mankind and other habitants on the earth have resulted in governments imposing stringent regulations to minimize the impact of waste and its harmful byproducts on the environment. Strict laws have been enforced by the governments for the management of plastic waste in order to reduce solid waste accumulating in landfills. Increasing disposable incomes of people in developing countries and changing preferences of manufacturers for cost-efficient packaging are some of the factors that are driving the plastic waste management market. Certain factors such as the lack proper infrastructure and low participation of waste generators in waste management hinder the growth of this industry. [26]

The plastic waste management market is dominated by firms such as Veolia Environnement S.A. (France), SUEZ Environnement Company (France), Waste Management Inc. (U.S.), Republic Services Inc. (U.S.), and Stericycle Inc. (U.S.). The other notable players in the market are Clean Harbors Inc. (U.S.), Progressive Waste Solution Ltd (Canada), ADS Waste Holdings, Inc. (U.S.), Covanta Holding Corporation (U.S.), and Remondis SE & Co. KG (Germany). By gaining considerable expertise and experience over the years, they have optimized their services and practices to become more efficient.



[26] https://www.marketsandmarkets.com/Market-Reports/plastic-waste-management-market-80259244.html

- The types of plastic waste generated include polymers such as polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), polyurethane (PUR), polystyrene (PS), and polyethylene terephthalate (PET).
- The segmentation based on services offered under plastic waste management are divided into collection & transportation of plastic waste, recycling, incineration, and disposal.
- The sources of plastic waste are residential, commercial & institutional, and industrial.
- The recycled plastics market is divided according to its end-use sector into, packaging, building & construction, textile & clothing, automotive, and furniture.
- The final segment, region, comprises the four main regions, namely, North America, Europe, Asia-Pacific, and Rest of the World (RoW).



The recycling market is driven by regulations which state that plastic waste collected should be sorted and the material that can be recovered should be recycled, laws & regulations pertaining to this market are in favor of minimum disposal of waste. The second-fastest-growing market would be the collection & transportation market; collection of waste is very crucial in the plastic waste management market. Other markets such as recycling and incineration depend on the waste collected & transported to facilities.

The interest and the need to improve waste management and generate more efficient and integrated solutions have resulted in the development of significant initiatives that can contribute to setting the way for a better recycling and plastic waste management market. These initiatives do take place in diverse environments and shapes, from institutional initiatives, collaborative funded and research projects or private initiatives.

Following there is a description of similar initiatives and solutions that will need to be taken into consideration when implementing the PlastiCircle project in order to assess the project competitiveness and complementarities.

4.1 Collaborative projects

Below it can be found a preliminary selection of those initiatives similar to the PlastiCircle and for which it would be interesting to identify possible collaboration activities and synergies.

PLASTIC ZERO

http://www.plastic-zero.com/

The overall objective of the Plastic Zero project was to reduce wasteful use of plastic made from fossil-based oil, save non-renewable resources and enable carbon neutral energy production from waste. Involving the partner European cities of Copenhagen, Hamburg, Malmö and Riga, three waste management companies and a university, this project would investigate how to prevent waste plastics and increase recycling rates. Information would be gathered from interviews with stakeholders and site visits, plus a review of literature in the field.

Specific objectives included:

- The establishment of a road map for reducing plastic in waste streams with a view to providing inspiration on possible measures to tackle the issue;
- The demonstration and documentation of selected measures for the prevention of plastic waste;
- The demonstration and documentation of selected technologies and methods for sorting and recycling plastic waste;
- The development of initiatives to create new green businesses and growth within the recycling sector; and
- The dissemination of knowledge, good practices, technologies and systems to other European cities.

eucertplast

http://www.eucertplast.eu

EuCertPlast is an EU-wide certification aimed at post-consumer plastics recyclers. It was developed via a three-year project co-financed by the European Commission under the Eco-Innovation Programme. The certification works according to the European Standard EN 15343:2007 which specifies the procedures needed for the traceability of recycled plastics. EuCertPlast aims at encouraging an environmentally friendly recycling of plastics, particularly by focusing on the process of traceability and assessment of conformity and content of recycled plastics. The overall objective of this certification is to establish a wide certification scheme for post-consumer plastics recycling.

SMART WASTE

http://www.lifesmartwaste.com/

The H2020 project coordinated by ENEVO OY in Finland, SMART WASTE is addressing two significant EU-wide challenges:

- Optimising transport operations and tackling the environmental and logistical challenges that the European transport sector is facing
- Waste management in the circular economy context. The objective of SmartWASTE proposal is to scale-up and expand the service into new European regions by piloting the solution with potential customers in 10 large scale pilots. Through piloting, Enevo gains important feedback that is provided back to product development to improve Enevo's offering and operations to be better suited for large scale regional expansion. Coordinator ENEVO OY.

FUTURE-PACK

https://www.zero.no/wp-content/uploads/2017/04/Futurepack-Zero-April-2017-min.pdf

The Nowegian project FuturePack project will develop a comprehensive knowledge platform for the Norwegian production of sustainable packaging materials from Norwegian biomass and polymer waste resources, in accordance with the principles of circular economy.

The objectives of the project are:

- Evaluate the fit of Norwegian biomass and plastics waste resources for polymer production Develop technology for cost-efficient conversion of biomass and plastics waste into building blocks for polymers
- Demonstrate sustainable polymer production from biomass and recycled plastics
- Develop smart and sustainable packaging design for improved material recycling

- Develop sustainability assessments for bioplastic packaging concepts SO6: Provide a knowledge platform with communication and networking tools

http://cordis.europa.eu/project/rcn/210520_es.html

The H2020 project CIRC-PACK project aims at more sustainable, efficient, and competitive, less fossil fuel dependence, integrated and interconnected plastic packaging value chain. To this end, three case studies will work in developing, testing and validating better system-wide economic and environmental outcomes by i) decoupling the chain from fossil feedstocks, (ii) reducing the negative environmental impact of plastic packaging; and (iii) creating an effective after-use plastics economy. All in all, the work will be supported by non-technological analysis and advanced methodological analysis (including circular economy and industrial symbiosis principles) which will trigger a broadly deployment of the tested solutions. CIRC-PACK project will provide breakthrough biodegradable plastics using alternative biobased raw materials, which will have an instrumental role to play in the subsequence steps of the plastic value chain. In addition, eco-design packaging for improving and end-of-like multilayer and multicomponent packaging will be technologically advanced and adapted also to the new materials produced. Thus these developments will also contribute with a great impact in the packaging footprint, and increasing the biobased content and using compostable materials. Lastly, a multi-sectorial cascaded approach along plastic packaging value chain will be applied with critical impacts in other value chains beyond the targeted plastic packaging value chain. The overall outcome of the project will facilitate the transition from the current linear plastic packaging value chain to circular economy principles.

http://cordis.europa.eu/project/rcn/210516_es.html

The H2020 funded project PolyCE will demonstrate the feasibility of circular plastics supply and value chain. In particular, PolyCE will elaborate harmonized set of technical requirements addressing the entire value chain and develop grade system for recycled plastics according to their material properties and final application suitability. Accordingly, PolyCE will strengthen the market for recycled plastics through an online platform integrating the different plastic grades. In parallel, the technical and economic feasibility as well as environmental benefits of using recycled plastics will be validated in several electronics demonstrators. In addition, PolyCE will provide Guidelines for designing new electronics products with recycled plastics. The project's impact will be scaled up by involving target cities and their green public procurement initiatives; by EU-wide information and awareness raising campaigns. PolyCE will establish a feedback loop from the research activities, provide policy input regarding technical feasibilities and policy conflicts from technical perspective.

4.2 Private initiatives

Similarly private initiatives have been developed addressing similar objectives.

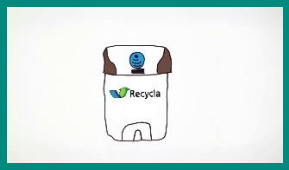
http://www.epbp.org/

The European PET Bottle Platform is a voluntary industry initiative that provides PET bottle design guidelines for recycling, evaluates PET bottle packaging solutions and technologies and facilitates understanding of the effects of new PET bottle innovations on recycling processes. This initiative fully supports the economic and environmental sustainability of the European PET value chain. EPBP assessments are performed ensuring strict business confidential information protection and the opinions are fully recognized by decision makers that source PET bottle packaging solutions. The European PET Bottle Platform (EPBP) is a voluntary initiative supported by the European Federation of Bottled Waters (EFBW), the European Association of Plastic Recycling and Recovery Organizations (EPRO), Petcore Europe, Plastics Recyclers Europe (PRE) and the European non-alcoholic beverages association (UNESDA). The Platform consists of technical experts in the field of PET production, design and recycling, whose only objective is the evaluation of new technologies and providing an independent and confidential assessment of their impact on the PET recycling processes across Europe. EPBP has established several test procedures in order to assess the impact on recycling of new packaging technologies. Products that pass the tests should not cause any problems during recycling.

http://recyclass.eu/

Plastics Recyclers Europe, based in Brussels, represents over 100 plastic recyclers in Europe. The quantity of plastic waste which PRE member companies recycle is growing every year – currently this is already more than 2.4 million tonnes a year. Plastic Recyclers Europe have developed the Recyclass initiative, based upon the idea that design determines whether packaging can be recycled. If you want to design environmentally-friendly packaging, here you can learn what is important. In just a few steps you can check the level of recyclability of your package by using "RecyClass". There is also advice on improving your package's design. Finally, you can have your package certified by an expert in case you want to use our label in your marketing. Recycling entails the reuse of spent packaging in a new plastic product. Far too much plastic packing is not fit for this purpose and hence destined for energy recovery only. The recyclability of packaging can be improved when a few criteria are closely followed. This is not possible with all packaging because other functions (e.g. convenience, shelf life, transport safety) take

precedence.



Recycla is a system that places citizens at the centre of the Project, taking into account their recycling habits and once this is established, these customs are analysed using the elements in the system described below:

A smart process
Voluntary registration of cards and labels
Smart container / access card / bar code
Bags with individual labels
Data taking
Waste inspection
Sending data
Container / website information access data

When the system is operating, the data received is analysed and any recycling black spots are detected, with a view to enabling suitable awareness campaigns to be devised and put into operation to remove them.

SUEZ environnement

https://www.suez.com

SUEZ Environnement and RUBICON has announced a strategic partnership to advance the digitalisation of its recycling and recovery activities on mainland Europe. In 50 years, the use of plastic has increased twenty-fold, and certain consumer products contain more than 50 different plastic resins. So recycling them poses a technical challenge. As a key player in plastics recycling, SUEZ is an expert in all plastic recycling techniques for bottles, containers, plastic films, technical industrial plastics etc., even the most complex techniques need to recycle food-grade plastics.

4.3 Institutional programmes

Institutional programmes do play a significant role in the development of effective and impactful collection and recycling initiatives. In this sense public authorities (mainly local, municipal and regional bodies) are responsible for setting up the infrastructure

for segregation, collection, storage, transportation, processing and disposal of plastic waste. The responsibilities that need to be assumed by these bodies and that will need to be taken into consideration during the operational phases of the Plasticircle are:

- Ensuring segregation, collection, storage, transportation, processing and disposal of plastic waste.
- Ensuring that no damage is caused to the environment during this process
- Ensuring channelization of recyclable plastic waste fraction to recyclers
- Ensuring processing and disposal of non-recyclable fraction of plastic waste
- Creating awareness among all stakeholders about their responsibilities.
- Ensuring that open burning of plastic waste does not take place.

Some institutional initiatives have been already identified:

R4R REGIONS FOR RECYCLING http://www.regions4recycling.eu
Regions for Recycling (R4R) was a 3-year European project (2012-2014) aiming to enable its partners to improve their recycling performance through consistent comparisons and an exchange of good practices. The R4R project brings together 13 partners wishing to share and discuss their experience about municipal waste recycling. European local and regional territories share the same framework and objectives, yet they have designed different waste management systems leading to different performances, which makes comparisons very useful.

CADAQUES MUNICIPALITY http://www.cadaques.cat/
Between 15 April and 30 June, the Catalan town will be using a Deposit and Return System (DRS) pilot project for beverage containers. Cans and plastic bottles of less than three litres of soda, water, juice and beer will have a five-cent deposit which will be refunded when the package is returned at any of the 10 partner establishments. The pilot project opens a way to prevent the elimination in landfill, incineration or littering of 5.5 million beverage containers, out of the 9 million which are consumed every day in the Spanish region of Catalonia. The aim of the project is demonstrating the feasibility of a recycling option that already works successfully in more than 40 countries and regions worldwide and will coexist with the current system of roadside containers which has shown its clear limitations to recycle packaging

5. PlastiCircle EU legislation and the circular economy

5.1 Background

5.1.1 The rationale for policy action[27]

There is a co-ordination failure at the heart of poorly functioning markets for recycled plastics. Potential suppliers of recycled plastics do not invest sufficiently in sorting and recycling capacity because the profitability of these operations is limited. Potential buyers (i.e. manufacturing firms) have limited incentives to use recycled plastics as inputs because of uncertainty about their availability and quality. Market outcomes could improve significantly if these issues were addressed.

Suppliers and buyers of recycled plastics would both benefit from larger and more liquid markets for recycled plastics, but neither party has strong incentives to act alone. In turn, improved market outcomes could, to some extent, become selffulfilling as scale efficiencies are captured and a more widespread consumer acceptance develops.

These factors provide a clear rationale for policy intervention, as well as potential insights into how to do it effectively. In particular, policies are likely to be more effective if they jointly address the challenges – market failures, policy misalignments, and status quo biases – on both the supply and demand sides of recycled plastics markets. Put differently, an effective policy framework would address challenges across the entire plastics life cycle, from plastics and product design through to end-of-life management and recycled plastic production.

If recycling is to become the dominant management route for waste plastics and plastics continue to be widely used, strong and stable markets for these materials will be essential. However, these markets currently face some significant challenges, including:[28]

- Economical challenges associated with vulnerable markets for recycled plastics and the cost of supplying resin sourced from waste plastics;
- Technical challengues associated with the widw variety of polymers and additives used, the significant levels of contamination in post-consumer waste plastics, and the practical challengues associated

27 http://www.oecd.org/environment/waste/Policy-Highlights-Improving-Markets-for-Recycled-Plactics.pdf

28 https://read.oecd-ilibrary.org/environment/improving-markets-for-recycled-plastics_9789264301016-en#page111

with collecting waste plastics;
- Enviromental challegues due to the presence of hazardous additives in some waste plastics; and
- Regulatory challengues, principally associated with illegal waste trade but also due to constraints posed by existing regulation and, in low context, uncontrolled dumping and burning of wastes.

The following table analyses the main barriers identified in the plastics recycling sector and the actions that could be taken to overcome them: [28]

Table 4 Barriers and potentials interventions for recycled plastics

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
Economic barriers						
1	**Costs of collecting, sorting and processing waste plastics.**	Drive supply of recycled material to increase economies of scale and reduce costs by: • Setting targets for recycling. • Banning plastics from landfill. • Implementing extended producer responsibility regulation. • Standardising waste collection systems.	• Invest in collection infrastructure to reduce operating costs (e.g. collection vehicles, shredders and balers to reduce recycling transport costs). • Charge waste producers for collection and disposal of non-recyclable waste.	• Support development of more cost-effective technologies for sorting waste plastics. • Develop alternative technologies that enable recyclers to process poor quality material (e.g. low value and contaminated materials).	• Raise public awareness to create demand for plastics recycling, reduce contamination, and to reduce littering and dumping. • Share best practice on all aspects of the collection, sorting and reprocessing supply chain.	• Create voluntary standards for collection, sorting and reprocessing.

Table 5 Barriers and potentials interventions for recycled plastics *(continued)*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
2	**Limited resilience of the sector to market shocks.**	Drive supply to increase economies of scale and resilience by: • Setting targets for recycling • Banning plastics from landfill • Implementing extended producer responsibility regulation • Standardising waste collection systems.	• Use financial market mechanisms to increase the resilience of the market to fluctuations in prices (e.g. futures markets or centrally managed risk funds).		• Improve access to data on quality, price and quantity of materials available to reduce uncertainty for investors and potential market entrants.	
3	**Global markets concentrated in a small number of countries**	• Implement quality standards in order to re-open trade.	• Support development of domestic reprocessing capacity to reduce reliance on global markets.		• Develop and share market information to allow actors to expand into new markets. A more globalised market will reduce reliance on a single actor.	

Table 6 Barriers and potentials interventions for recycled plastics *(continued)*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
4	**Lack of differentiated demand for recycled plastics.**	• Mandate requirement for recycled content to create demand • Use public procurement policies to create demand for recycled content. • Obligate monomer manufacturers to buy back recycled plastics.	• Use taxes or trading mechanisms to internalise the externalities associated with primary plastics. This will support the price of recycled plastics. • Introduce tax incentives to encourage use of recycled plastics.		• Provide information and training to designers and manufacturers to encourage use of recycled content. • Provide information to consumers to encourage purchase of products using recycled content and drive demand.	• Work with supply chain to encourage use of recycled content.
5	**Poor data on the plastics recycling industry.**	• Introduce mandatory data reporting mechanisms for plastics recycling.			• Develop and share appropriate data sources to stimulate the market and encourage new entrants, including standardising terminology and developing market-enabling tools and services.	

Table 7 Barriers and potentials interventions for recycled plastics *(continued)*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
Technical barriers						
1	**Collection systems for wastes not available for a substantial proportion of the global population.**		• Mobilise investment for developing collection systems in low income contexts and incorporate plastics. Note: in these contexts, working with the informal sector will be essential.	• Development of appropriate low-tech plastics reprocessing technology that is suitable for use in low-income economies.	• Share best practice on all aspects of waste collection, sorting and recycling. • Raise consumer awareness to create demand for plastics recycling, reduce contamination, and to reduce littering and dumping.	
2	**Plastics contaminated and mixed with other materials**	• Standardise recycling collection schemes to create economies of scale and improve recyclate quality.		• Support technology innovation for sorting plastics and removing contamination or handling contaminated plastics. • Support the development and demonstration of alternative technologies for mixed and/or low value plastics.	• Share best practice on recycling collection schemes, sorting processes and recycling technologies. • Raise consumer awareness to create demand for plastics recycling, reduce contamination, and to reduce littering and dumping.	• Industry-led initiative to standardise polymers and additives.

Table 8 Barriers and potentials interventions for recycled plastics (*continued*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
3	**Problematic additives.**	• Ban or reduce these additives in primary plastics.	• Tax additives that cause detrimental effects on recycled plastics. • Tax degradability enhancers to disincentives their use.	• Develop alternatives to problematic additives. • Develop technologies that can identify these additives so that they can be eliminated from recycled plastics. • Develop purifying and stabilising technologies that can overcome the physical effects of these additives in recycled plastics.	• Enhance supply chain awareness of problematic additives so that the impact on markets for recycled plastics is understood.	• Industry-led phase out of problematic additives from primary plastics. • Standardise the use of additives and improve the information provided.

Table 9 Barriers and potentials interventions for recycled plastics *(continued)*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
4	**Biodegradable plastics mixing with other plastics.**	• Mandate labelling for biodegradable plastics and improve associated standards		• Develop technologies for identifying biodegradable plastics. • Develop purifying and stabilising technologies that can overcome the physical effects of biodegradable plastics in waste plastics streams.	• Provide clear labelling and information for biodegradable plastics to encourage appropriate management by consumers.	
5	**Limited collection schemes and treatment technologies for thermosets.**	• Set targets (including using EPR) for recycling thermosets to drive supply.		• Develop and demonstrate effective collection and recycling systems for thermosets.	• Raise consumer awareness to create demand for recycling schemes for thermosets.	

Table 10 Barriers and potentials interventions for recycled plastics *(continued)*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
Environmental barriers						
1	**Hazardous additives.**	• Ban or reduce hazardous additives from primary plastics.		• Develop alternatives to hazardous additives. • Develop technologies for identifying or tracking hazardous additives so that they can be eliminated from recycled plastics.	• Reduce uncertainty over the health effects of hazardous additives.	• Industry-led phase out of hazardous additives from primary plastics.
2	**Competition between recycling and energy from waste.**	• Ban plastics from energy from waste.	• Incentivise recycling over energy from waste by introducing a tax to reflect the relative environmental burden/benefit of energy from waste and recycling (and landfill).			

Table 11 Barriers and potentials interventions for recycled plastics *(continued)*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
3	**Concerns over environmental standards for recycling in emerging markets.**	• Regulation and enforcement to ensure consistent environmental standards. • Mandate sellers to establish and audit end-destinations for environmental standards.			• Encourage openness about standards and provide information on end-destinations.	• Industry-led initiative to ensure consistent environmental standards in global markets.
Regulatory barriers						
1	**Regulatory burden of materials classified as waste.**	• Ensure regulation is proportionate and clarify end-of-waste standards.				• Develop effective voluntary standards for recycling sector to limit need for regulation.

Table 12 Barriers and potentials interventions for recycled plastics *(continued)*

No.	Barrier	Intervention				
		Regulatory	Economic instrument	Technology	Data and information	Voluntary
2	**Uncontrolled dumping and burning of municipal wastes.**	• Enforcement action to reduce illegal dumping, particularly in low and middle income countries where uncontrolled dumping is still widespread.			• Raise public awareness to create demand for plastics recycling, reduce contamination, and to reduce littering and dumping.	
3	**Illegal trafficking in waste plastics.**	• Enforcement action.				• Industry-led initiatives to crack down on waste crime.

5.1.2 Assessment of potential interventions

An initial assessment of the intervention identified in table 1 has been undertaken to consider their potential to improve markets for recycled plastics. This assessment is intended to provide a basis for understanding the types of interventions that have been or could be applied to support these markets.

Each intervention have been qualitatively assessed in terms of three factors:

- **Instrument maturity:** the extent to which the proposed intervention has been applied in the context of recycled plastics, or in similar recycled materials markets.
- **Instrument feasibility:** the feasibility of implementing the proposed intervention, particularly in terms of the extent to which different stakeholders would need to work together
- **Instrument impact:** the potential impact of each intervention in terms of the number and significance of barriers that could potentially address.

In the following tables we could find tehe result of evaluation carried out with interviews with experts:

Table 13 Summary of intervention assessment

No.	Intervention	Barriers that could be addressed	Maturity	Feasibility	Impact
	Regulatory				
1	Set statutory targets for recycling to drive supply of material, increase economies of scale, reduce costs and increase resilience.	• Costs of collecting, sorting and processing waste plastics. • Limited resilience of the sector to market shocks.	H	H	H
2	Ban plastics from landfill to drive supply of material and increase economies of scale, reduce costs and increase resilience.	• Costs of collecting, sorting and processing waste plastics. • Limited resilience of the sector to market shocks.	H	M	M
3	Use Extended Producer Responsibility (EPR) regulation to drive supply of material and increase economies of scale, reduce costs and increase resilience.	• Costs of collecting, sorting and processing waste plastics. • Limited resilience of the sector to market shocks.	H	M	H
4	Standardise waste collection systems to increase economies of scale and reduce costs.	• Costs of collecting, sorting and processing waste plastics. • Plastics contaminated and mixed with other materials.	M	M	M
5	Mandate requirement for recycled content to create demand.	• Lack of differentiated demand for recycled plastics.	L	M	H
6	Use public sector procurement policies to create demand for recycled content.	• Lack of differentiated demand for recycled plastics.	M	H	M/H
7	Introduce mandatory data reporting mechanisms for plastics recycling.	• Poor data on the plastics recycling industry.	M	H	M
8	Ban or reduce problematic additives in primary plastics.	• Problematic additives.	L	M	M
9	Mandate labelling for biodegradable plastics and improve associated standards.	• Bio-degradable plastics mixing with other plastics.	L	M	M
10	Set targets (including using EPR) for recycling thermosets to drive supply.	• Limited collection schemes and treatment technologies for thermosets.	L	M	M
11	Ban or reduce hazardous additives from primary plastics.	• Hazardous additives.	M	M	M
12	Ban plastics from energy from waste.	• Competition between recycling and energy from waste.	L	L/M	M
13	Ensure regulation is proportionate and clarify end-of-waste requirements.	• Regulatory burdens of materials classified as waste.	M	M	M
14	Enforcement action to reduce illegal dumping, particularly in low and middle income countries where dumping is common place.	• Uncontrolled dumping and burning of municipal wastes.	M	M	H
15	Enforcement action to reduce illegal waste trafficking.	• Illegal trafficking in waste plastics.	M	M	H
16	Regulation and enforcement to ensure consistent environmental standards in global markets.	• Concerns over environmental standards for recycling in emerging markets.	M	M	M
17	Mandate sellers to establish and audit end-destinations for environmental standards.	• Concerns over environmental standards for recycling in emerging markets.	L	L	M
18	Obligate monomer manufacturers to buy back recycled plastics	• Lack of differentiated demand for recycled plastics	L	L	M/H

	Economic instruments				
19	Mobilise investment for developing collection, sorting and processing systems, particularly in low income contexts.	• Costs of collecting, sorting and processing waste plastics. • Collection systems for wastes not available for a substantial proportion of the global population.	M	M	H
20	Use financial market mechanisms to increase the resilience of the market to fluctuations in prices (e.g. futures markets).	• Limited resilience of the sector to market shocks.	L	M	H
21	Support development of domestic reprocessing capacity to reduce reliance on global markets.	• Global markets concentrated in a small number of countries	M	M/H	M/H
22	Use taxes or trading mechanisms to internalise the externalities associated with primary plastics. This will support the price of recycled plastics.	• Lack of differentiated demand for recycled plastics.	L	L/M	H
23	Direct or indirect government support for recycled plastics, e.g. through lower VAT rate	• Lack of differentiated demand for recycled plastics	L	L/M	H
24	Tax additives that cause detrimental effects on recycled plastics (including degradability enhancers).	• Problematic additives.	L	L	M
25	Incentivise recycling over energy from waste by introducing a tax to reflect the relative environmental burden/benefit.	• Competition between recycling and energy from waste.	L	M	L/M
26	Introduce tax incentives to encourage use of recycled plastics (e.g. VAT exemptions).	• Lack of differentiated demand for recycled plastics.	L	L/M	M
27	Charge waste producers for collection and disposal of non-recyclable waste.	• Costs of collecting, sorting and processing waste plastics.	M	M	M
	Technology				
28	Support development of better and more cost-effective technologies for collecting, transporting and sorting waste plastics.	• Costs of collecting, sorting and processing waste plastics.	M	M	H
29	Support the development and demonstration of commercially viable technologies for mixed and/or low value plastics.	• Plastics contaminated and mixed with other materials.	L	M	H
30	Develop alternatives to problematic and hazardous additives.	• Problematic additives.	L	M	M
31	Develop technologies that can identify or track problematic and hazardous additives so that they can be eliminated from recycled plastics.	• Problematic additives.	L	M	M

No.	Intervention	Barriers that could be addressed	Maturity	Feasibility	Impact
32	Develop purifying and stabilising technologies that can overcome the physical effects of problematic additives in recycled plastics.	• Problematic additives.	L	M	M
33	Develop technologies for identifying biodegradable plastics	• Biodegradable plastics mixing with other plastics.	L/M	M	M
34	Develop purifying and stabilising technologies that can overcome the physical effects of biodegradable plastics in waste plastics streams.	• Biodegradable plastics mixing with other plastics.	L	L	L/M
35	Develop and demonstrate effective systems for collecting and recycling thermosets.	• Limited collection schemes and treatment technologies for thermosets.	L/M	M	M
	Data and information				
36	Raise public awareness in order to create demand for plastics recycling, reduce contamination, and to reduce littering and dumping.	• Costs of collecting, sorting and processing waste plastics. • Collection systems for wastes not available for a substantial proportion of the global population. • Plastics contaminated and mixed with other materials. • Limited collection schemes and treatment technologies for thermosets. Uncontrolled dumping and burning of municipal wastes.	M/H	H	H
37	Share best practice on all aspects of the collection, sorting and reprocessing supply chain.	• Costs of collecting, sorting and processing waste plastics. • Collection systems for wastes not available for a substantial proportion of the global population. • Plastics contaminated and mixed with other materials.	M	H	H
38	Develop and share market information to allow actors to expand into new markets. A more globalised market will reduce reliance on a single actor.	• Poor data on the plastics recycling industry. • Global markets concentrated in a small number of countries • Limited resilience of the sector to market shocks.	L	H	M/H
39	Enhance supply chain awareness of problematic additives so that the impact on markets for recycled plastics is understood.	• Problematic additives.	L/M	M	M
40	Provide information and training to designers and manufacturers to encourage use of recycled content.	• Lack of differentiated demand for recycled plastics.	M	H	H
41	Provide information to consumers to encourage purchase of products using recycled content and drive demand.	• Lack of differentiated demand for recycled plastics.	M	H	M/H
42	Provide clear labelling and information for biodegradable plastics to encourage appropriate management by consumers.	• Biodegradable plastics mixing with other plastics.	M	H	M
43	Reduce uncertainty over the health effects of hazardous additives.	• Hazardous additives.	M	M	M
44	Encourage openness about standards and provide information on end-destinations.	• Concerns over environmental standards for recycling in emerging markets.	L/M	M	M
	Voluntary				
45	Create voluntary standards for collection, sorting and reprocessing.	• Costs of collecting, sorting and processing waste plastics.	M	M	M
46	Work with supply chain to encourage use of recycled content.	• Lack of differentiated demand for recycled plastics.	M	H	H
47	Industry-led initiative to standardise polymers and additives, and improve information on additives.	• Separating polymers from other materials, other polymers and contamination.	M	M	M/H
48	Industry-led phase out of problematic and hazardous additives from primary plastics.	• Problematic additives.	M	M	M
49	Develop effective voluntary standards for recycling sector to limit need for regulation.	• Regulatory burdens of materials classified as waste.	L	M	M
50	Industry-led initiatives to crack down on waste crime.	• Illegal trafficking in waste plastics.	L/M	M	H
51	Industry-led initiative to ensure consistent environmental standards in global markets.	• Concerns over environmental standards for recycling in emerging markets.	L	L	M

Key: H: High M: Medium L: Low

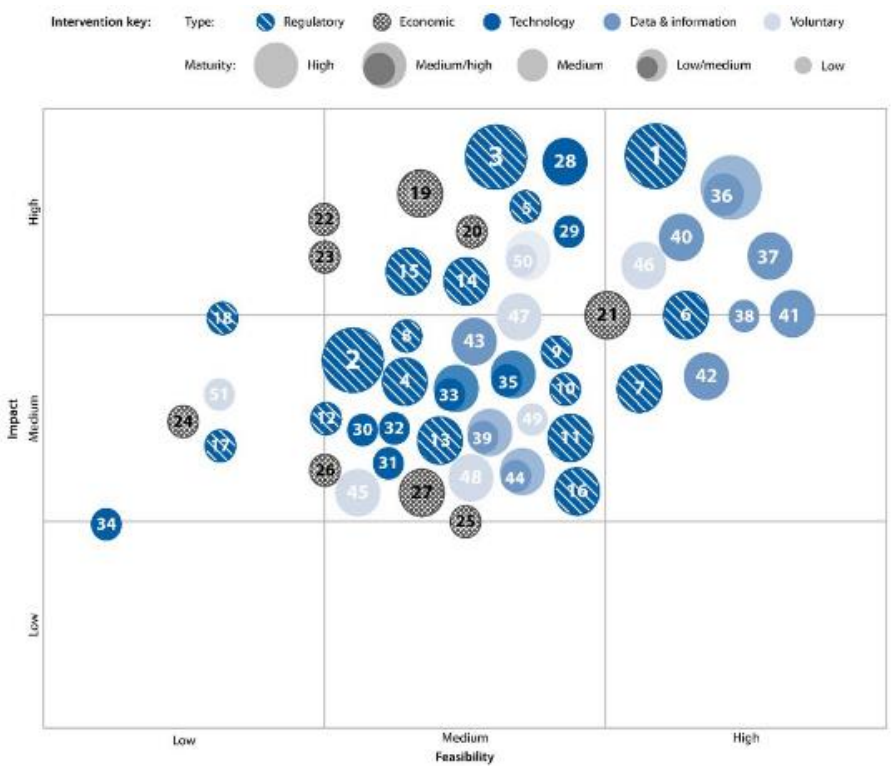


Figure 16 Intervention mapping

5.2 EU policy

Several pieces of EU legislation apply to plastics and plastic waste, including the following:

Waste Framework Directive: The Directive 2008/98/CE defines the concepts relevant to the management of plastic waste, such as the waste hierarchy (an ordered priority list of waste prevention and management options: 1) prevention, 2) preparation for re-use, 3) recycling, 4) energy recovery, and 5) disposal and "extended user responsibility).

Directive on packaging and packaging waste: The 1994 directive sets targets for recycling of packaging waste, including plastic packaging (22.5% of plastic packaging to be recycled back into plastics by 2008, except for member states with derogation). The directive was amended in 2015 to require member states to make sure that the annual per capita consumption of lightweight plastic carrier bags was reduced to 40 by 2025 and / or that consumers were not provided with these bags for free of charge after December 2008.

Regulation on classification, labelling and packaging (CLP Regulation): This 2008 regulation aims to ensure that the hazards posed by chemical substances are clearly

identified and communicated.

Regulation on the registration, evaluation, authorisation and restriction of chemicals (REACH Regulation): This 2006 regulation lays down the general framework on chemical and contains general provisions on authorisation and restriction as well as specific provisions intended to facilitate the placing in the market of recycled materials. Although polymers are excluded from its scope, it covers additives used in plastics.

Closing the loop –An EU action plan for the circular economy: The EC adopted (2nd, December 2015) a proposal "which includes legislative proposals to amend current EU waste legislation, including the Waste Framework Directive, the Landfill Directive and the Directives on packaging and packaging waste and electrical and electronic waste (EC, 2016a). The objective is to stimulate a transition towards a circular economy which can contribute to improving global competitiveness, fostering sustainable economic growth and generating new jobs. Currently, modifications to the Directive are being held by EU authorities and expected to be accepted by the end of 2017.

The revised legislative proposals on waste set clear targets (currently under discussion) for the reduction of waste and establish an ambitious and credible long-term path for waste management and recycling. To ensure effective implementation, the waste reduction targets in the new proposal are accompanied by concrete measures to address obstacles on the ground and the different situations across Member States. Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to a maximum of 10% of all waste by 2030;
- A ban on land filling of separately collected waste;
- Promotion of economic instruments to discourage land filling;
- Simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU;
- Concrete measures to promote re-use and stimulate "industrial symbiosis", thereby turning one industry's by-product or unwanted output into another industry's material input;
- Economic incentives for producers to put greener products on the market and support
- Recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

5.3 Circular economy framework

In 2015, the European Commission identified plastics as one of the priority areas of the circular economy action plan, proposed new reuse and recycling targets for plastic packaging waste and pledged to adopt a strategy on plastics in the circular

economy by the end of 2017. A circular economy implies reducing waste to a minimum. Moving the plastics value chain in this direction would mean improving recycling, promoting reuse, and redesigning products, while taking into account the whole life-cycle of products. Although this could deliver opportunities (in particular enhanced security of supply, economic benefits and reduced pressure on the environment) there are also challenges (in particular weak economic incentives, technical issues and finance). The European Parliament recognises the need to introduce specific measures on plastic waste in EU legislation and to value plastics as a resource.

Finite raw materials will increasingly drive companies and society towards the efficient use of resources. In Europe, it is estimated that the financial opportunities could amount to EUR 1.8 billion by 2030. At the same time, the OECD estimates that 3 billion people will enter the middle class as standards of living improve, increasing the size of the middle class to 4.9 billion people. The need for raw materials is expected to double, as people will be consuming more than ever before.

A 2016 study for the European Commission on regulatory barriers to the circular economy identified poor implementation of the waste hierarchy (leading to relatively high landfill and incineration rates) as the main regulatory barrier to the recycling of packaging plastics. In a roadmap outlining the contents of the strategy on plastics in a circular economy, the Commission indicated it would be aimed at '(1) decoupling plastics production from virgin fossil feedstock and reducing its life-cycle greenhouse gas impacts, (2) improving the economics, quality and uptake of plastics recycling and reuse, and (3) reducing plastic leakage into the environment.

6. Market development

6.1 Understanding the market

As is said by RECOUP, global demand significantly outweighs supply.[29] Collected plastic waste can either be sold once sorted by polymer type (which commands the highest value) or can simply be marketed as a mix of all types material. The key factors for maximising income are: quantity of non-plastic contamination, tonnage commitment and tonnage shipped per load (a function of bale density and loading arrangements).

[29] http://www.recoup.org/p/51/understanding-the-market

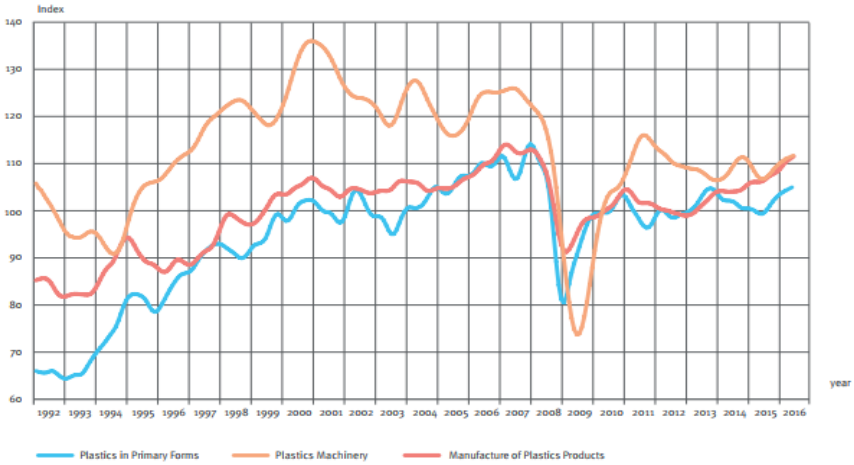


Figure 10. Plastics industry production in EU-28 index (2010=100, trend cycle & seasonally adjusted data).

Source: PlasticsEurope[30]

According to the data provided by EUROSTAT the traded volume of secondary plastic tripled over the period from the year 2002 to 2012 from approximately 180 000 tonnes/month to around 650 000 tonnes/month. 2013 was the first year since 2002 in which the annual trade volume did not grow and the trade volume 2013 was lower than the year before. Within a year the observed volatility is also significant. For 2015 the monthly average for the whole year is approximately 680 000 tonnes. A spike can be observed in June 2015 of approximately 770 000 tonnes and the lowest volume with 542 000 tonnes in January 2015.[31]

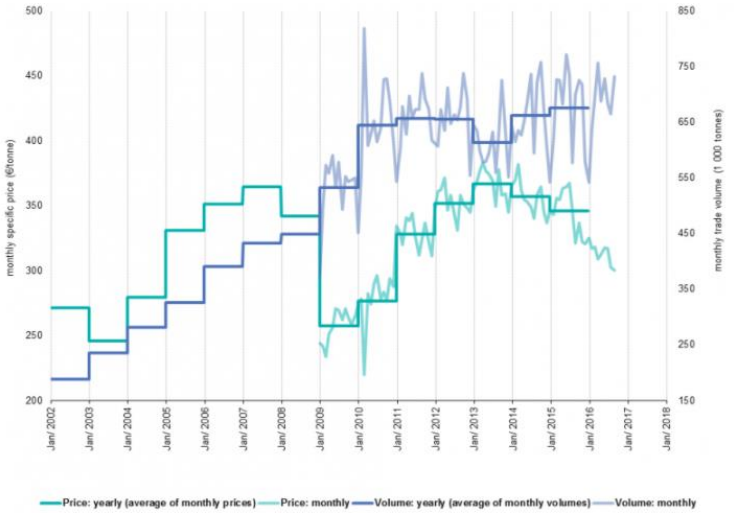
Figure 11. Production of plastics in primary forms, EU28.

[30]http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf
[31] http://ec.europa.eu/eurostat/statistics-xplained/index.php/Recycling_%E2%80%93_secondary_material_price_indicator#Plastic

Source: PlasticsEurope

The price of plastic waste depends on one hand on the supply and demand of plastic waste material, and on the other hand on the crude oil price, which strongly influences the price of the virgin (primary) material. Since 2003 the price has increased to levels above 350 €/tonne. Afterwards the price recovered with the exception of March 2010 when the lowest price in the decade with 220 €/tonne is shown (monthly data in transparent turquoise line). By 2013 the price recovered to the price level of 2007 with around 370 €/tonne, since then the price is again continuously decreasing to a level of 301 €/tonne in September 2016.[32]

Recycling is expected to become an important sector of the European economy as direct revenues from recycling constitute considerable and constantly growing contributions. An increase of the recycling rates targets is a prerequisite in order to have an impact not only on the environment but also on the economy and the job market in particular. It was estimated that by enforcing higher recycling rates across the member states up to 50.000 new jobs could be created by 2020 for in the recycling value chain including the recycling process itself and waste management



Such increase would have an effect on down and upstream sectors as well as on the wider economy, resulting in the creation of an additional 75.000 of indirect jobs concerning construction of new recycling facilities, manufacturing equipment for recycling, maintenance of recycling facilities and equipment, research and innovation, as well as jobs related to administration and management. This number could grow to 80 000 in direct jobs and 120 000 in indirect jobs by 2025. Regarding the direct job creation, the most significant increase would occur at sorting and separation of material as well as at collection and recycling. It is worth noting as well that direct jobs are mainly related to low-skilled workers and thus have an implication on social inclusion and poverty alleviation for a number of people with fewer possibilities of employment. Energy recovery on the other hand is very low job-intensive

[32] Idem

and does not have an impact on job creation. More with less is possible: creating more jobs and having less waste and in effect less pollution.

6.2 Market access and generation

According to the report published by PlasticsEurope and including data for 2016 the plastic industry includes more than 60.000 companies, with a turnover of more than 340 billion euros in 2015[33].

Market development will always face questions like the market uncertain demand, the product mispricing or the lack of information from the final consumers. Ensuring that these questions are correctly addressed will demand for the interaction of endogenous and exogenous of the plastic packaging waste management and recycling sector and the active involvement of all the competent agents.

The following is a set of elements that will need to be taken into consideration to help fostering the market potentialities for recycled plastic packaging waste products:

- Creating strategic agreements with different retail sectors will improve the market accessibility of the recycled products. Although clothing and construction sectors have proved strong users of recycled materials (see table below) new market opportunities such as the home ware sector (where important strategic alliances could be analysed) or outdoors equipment can strongly benefit from the use of recycled plastic packaging waste.

- Working in close collaboration with public agencies and local government in the identification of potential procurement contracts. The public sector must be an important user of plastic packaging waste recycled materials, for instance in using recycled materials as equipment for public transport vehicles (trains, buses, etc) or facilities (playgrounds, public facilities, etc.). The growing concern of local administration in ensuring greener municipal strategies will act as a potential generator of market opportunities for recycled materials.

- Integrating plastic packaging waste recycling programmes into the competent environmental strategies can foster the demand for plastic waste recycling initiatives and programmes.

- Existing regulatory activity and public initiatives do currently put more focus more on the recovery of plastic waste than on the use of recycled materials. Regulations should also be directed at boosting the demand for recycled plastic packaging waste products.

33 http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf

- Product labelling standards and certificates need to be developed to boost the market development. Additional incentives could be the requirements to use significant percentages of recycled materials for the production of certain goods (such as the already mentioned case of the automotive industry).

- Recycled products markets are more successful in countries or regions which benefit from a higher level of consumer awareness of environmentally preferable products and therefore a consumer demand for environmentally friendly products. Strategic collaborations with public administration departments, NGO's and consumer groups will contribute to increase consumer awareness on these products.

6.3 Inter-sector strategic collaborations

Multi-stakeholder partnerships, large and small, and inter sector collaboration is fundamental in order to increase awareness both within and without the sector, reinforce stakeholders involvement, foster research and development initiatives and guarantee the development and enforcement of waste prevention and management regulations.

The main objectives of inter-sector initiatives towards a more active market development should be:

- Make choices on how to improve plastic packaging waste management mechanisms and channels.

- Encourage citizens, industry and governments to take responsibility for their contribution in the waste management process.

- Facilitate all those initiatives and commercial actions aimed at turning waste into a resource in an environmentally sustainable manner.

- Develop global, regional, national and local targets to enforce the development of plastic packaging recycling initiatives.

- Improve knowledge, understanding among other sectors representatives of the need and benefits of developing recycling initiatives.

- Encourage financial support for plastic packaging waste recycling commercial actions.

- Involve local communities in the development of plastic packaging waste recycling initiatives.

Securing financial provisions for the development of recycling initiatives is fundamental

to ensure the stability and the success of the sector. It is thus important to establish contacts with representatives of the local entrepreneurial and financial environment.

Local Communities and competent authorities should also be engaged in the development of the recycling activities, to identify possible co-operators, operators and contracts, and to secure the involvement of local agencies and the public administration bodies.

6.4 Market development Support Policies

As it has been stated above institutional involvement is indispensable for the successful development of integrated plastic packaging waste recycling initiatives and policy measures need to act as the pillars upon which such initiatives can grow and expand.

Among the most important measures of policy support identified so far are:

Setting up an appropriate legal framework: Endorsing a set of guidelines and recommendations establishing the operational framework for plastic packaging waste management and recycling process.
Local and regional plans integration: Plastic packaging waste and recycling initiatives should be incorporated into local, regional authorities' waste management plans. The involvement of local and municipal authorities is paramount for the effective and informed integration of these strategies.
Development and agreement on a set of common standards and harmonisation processes that will help consolidating the local and European market.
Exchange practices on incentive processes and initiatives will raise awareness on the impact of such measures in increasing market share for recyclable materials and recycled products.
Development of public-private initiatives for the development of market support initiatives.
Foster inter-sector dialogue: Public administration will play a key role in fostering the dialogue among the different agents of the sector in order to identify common objectives.
Supporting technological innovation requirements (i.e. smart sensors, mart routes, etc.) in tendering requirements of local and municipal tendering processes.
Creation and facilitation of a market for secondary raw materials removing most obstacles for its development.
Streamlining the recycling chain: For the successful development of the recycling system it is important that public bodies work together with the plastic sector representatives towards the definition of a clearly defined recycling chain including a legally binding system of waste management and waste valorisation. Moreover, public administrations must promote cooperation between different authorities and sector-related agents.
Implementing indicators: Implementing indicators to evaluate the logistic requirements to ensure an efficient collaboration between the agents involved in the recycling process.

Increase demand for recycled plastics by introducing a minimum recycled content in the new products.
Creating new market consumption paradigms: Institutional agents can contribute to the sector development by promoting new consumption attitudes.
Education is a powerful tool to develop the next generation of entrepreneurs, engineers and policy makers who will be much more aware of and sensitive about decoupling growth from the exploitation of natural resource.
Reduce plastic waste exports that due to lower quality standards hamper the expansion of the EU market's recycling capacity.
Strengthen public awareness: Public administration need to play an important role in implementing raising awareness initiatives and public education programmes on the opportunities and benefits generated by plastic packaging waste recycling initiatives.
Reinforce investments in the sector will be fundamental for the uptake of the market

Table 5. Market Support Recommendations

6.5 Market applications

Several market applications have been identified throughout this initial phase that can guide the identification of future opportunities for commercialisation.

Identified commercial applications for recycled plastics	Use
F-Boards	Building and Construction
Ground Protection Materials	Building and Construction
Stilt	Building and Construction
Cable covers	Building and Construction
Doors and Window Frames	Building and Construction
Shop Fittings	Building and Construction
Precast Concrete	Building and Construction
Beam and Insulated Floors	Building and Construction
Landfill Lining	Building and Construction
Chairs and table sets	Garden Furniture

Benches and exterior furniture	Garden Furniture
Picnic sets	Garden Furniture
Plastic-Decking	Landscaping
Planters and Raised beds	Landscaping
Plastic Wood and fences	Landscaping
Interior sets and decoration	Houseware
Duvets	Houseware
Interior furniture	Houseware
Kitchenware	Houseware
Refuse sacks	Houseware
Eco-products	Houseware
Picture Frames	Houseware
Plastic Lumber	Warehouse
Mailing bags	Warehouse
Toys	Leisure
Fishing Pegs	Leisure
Headphones and audio sets	Leisure
Garden leisure kits	Leisure
Dog Cubes	Leisure
Water tables	Leisure
Walls	Leisure
Floating Docks and Bridges	Leisure
Scenic Foodtrails	Leisure

Ball Points and pens	Office Supply
Office Furniture	Office Supply
Mailing Bags	Office Supply
Hallstands	Office Supply
Recycling Units	Collection Units and bins
Bins	Collection Units and bins
Caddies	Collection Units and bins
Plastic Sign Posts	Roads
Bollards	Roads
Bags	Packaging Products
Hidrozorb	Packaging Products
Skin Pack Trays	Packaging Products
ABS Filament	3D Printing
Shoes	Clothing
Baselayers	Clothing
Bags	Clothing
Sportswear	Clothing
Engine plastic covers	Automotive
Fishing Nets	Other
Mussel Cultivation Ropes	Other
Art labs material	Other

Table 6. Market applications

6.6 Active Companies

A growing number of companies active in the field of activity of the project will be

analysed in the course of the project in order to identify opportunities and complementarities. An incomplete list of these companies (to be regularly updated includes):

OPTICAL SORTING SOLUTIONS	
Pellenc ST	Pellenc ST develops optical sorting machines for household and industrial wastes. The technologies used to sort these materials are near infrared (NIR), middle infrared, vision & induction technologies.
TOMRA Sorting	Norwegian firm, which manufactures sensor based sorting equipment for the recycling industry, has launched its next generation AUTOSORT FLAKE for sorting plastic flakes by both polymer and colour
Krause Manufacturing	Krause Manufacturing is a division of the CP Group of Companies, which combines the experience, expertise and capabilities of over 150 years in the industry to provide turnkey Material Recovery Facilities and components for virtually every type of waste and recycling operation
Meyer	Meyer Recycling Technology Limited focus on the sorting technology in waste plastic recycling and mining recycling industry, we developed the technology for these industry as below: NIR Sorting equipment for PET and PVC flake separation, Optical Sorting equipment for waste plastic recycling, mining industry, X-ray Sorting equipment for PET bottle separation, separate the PVC and other bottle from PET bottle
MSS Optical	MSS optical sorting technology is designed to handle the real-world challenges of an ever-changing waste stream. For over 40 years, MSS optical sorting systems have increased system efficiency, recovered the highest quality products, and cut manual labour costs while increasing worker safety
RTT Steinert	In 2009, STEINERT Elektromagnetbau GmbH extended its product portfolio to include optical sorting systems based on colour and NIR by taking a stake in RTT Systemtechnik in Zittau. The newly established company was incorporated under the name RTT STEINERT GmbH.Since then, both companies have grown together on the various structural and organizational levels, so that STEINERT is rightly present in the market as a full-range supplier—a fact which is underlined by the familiar high-level customer service in the areas of sales, commissioning and service. The customers have accepted this benefit with great enthusiasm, and have made extensive use of it

Table 7. Preliminary list of companies

SMART CONTAINERS SOLUTIONS	
Plastics Ominum	Integrated hardware and software solution. The smart application is the complete IT solution in the truck. The system comprises a weighing and identification system,

	depending on operator requirements and is the basis for transparent calculation. We also offer applications for fleet management which enable monitoring and real-time management thus supplying data to handle more cost-effectively and reducing costs for route planning.

Table 8. Preliminary list of solutions

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant Agreement No. 730292.