REPORT

7.3.2. EPS/XPS fish-boxes waste cycle through the European market

OCEAN WISE

Reducing
EPS marine litter
in the North East
Atlantic

Interreg
Atlantic Area
European Regional Development Fund

EUROPEAN UNION

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Glossary

- **BIOEPS:** Not standardized word made up for this document. It is referred to any box/product similar to EPS box made of biodegradable plastic.
- **Briquetting machines:** EPS screw compactor. The EPS is pre-crushed in a hopper, then the screw and the automatic hydraulic jaws compact the EPS to solid and uniform blocks reducing its volume at a ratio of up to 50:1.
- **Central markets of big cities – MERCAS**: Big infrastructures that receive fresh fish and other products, located in the big cities and suppliers for population needs. It is where wholesalers and many retailers are located.
- **Commercial packaging:** Packaging for goods distribution through the commercialization channel but not intended to reach the final consumer.
- **Composting:** Biological process on which microorganisms decompose organic matter obtaining compost: high quality manure for agricultural use.
- **Door-to-door collection system**: Waste collection system in which citizens deposit their waste in bags or small containers placed in front of the door of the household or commerce, and is collected depending on fractions according to a calendar and schedule.
- **Drop-off points/civic amenity sites**: Centres for segregation and storage of waste that are not subject to household collection, in order to facilitate the proper management of non-ordinary fractions.
- **EPS sweeps**: Small and dirty EPS waste from the fish-boxes manufacturing process that is not recoverable.
- **EPS**: Expanded Polystyrene.
- **Extended Producer Responsibility (EPR):** Environmental protection strategy to reach an environmental objective of a decreased total environmental impact of a product, by making the manufacturer of the product responsible for the entire life-cycle of the product and especially for the take-back, recycling and final disposal. It is covered by the European "Packaging and Packaging Waste Directive - 94/62/EC"
- **Extended Producer Responsibility Scheme (EPR Scheme):** System or scheme set up by one or several producers to implement the EPR principle. Through this document, the most noticed EPR scheme is the "light plastic packaging from households" (household packaging fraction).
- **HORECA:** Hotels, Restaurants and Coffee shops.
- **Household packaging:** Packaging for goods distribution that reach the final consumer/citizens.
- **Household packaging fraction**: Waste fraction composed by packaging made of plastic, cardboard for liquids or metal collected by some Municipal Waste Management Systems managed by the EPR Scheme.
- **Kerbside collection**: Service provided to households, typically in urban and suburban areas, of collecting and disposing of household waste and recyclables through containers. These containers are usually collected using special vehicles to pick up the containers on the kerb.
- **Logistic platforms for distribution**: Logistic platforms for modern supply chains (Big supermarkets) which purpose is to receive merchandise and regroup them to serve their point of sale units. In the case of fresh fish products, there are specific platforms that do not receive any other product.

- **Material Recovery Facility (MRF)**: a specialized plant that receives, separates and prepares recyclable materials for marketing to end-user manufacturers.
- **Mixed plastic fraction:** Fraction resulting from the non-recyclable plastics of Material Recovery Facilities (MRF), including plastics not selected due to their difficulty in sorting and recycling or because the lack of a sustainable recycling process.
- **Modern supply chains (Big supermarkets)**: Big chain supermarkets where all kind of products/goods are sold. They stock up from the *Logistic platforms for distribution*.
- **Municipal Solid Waste (MSW)**: A mixture of not separated at source waste that is mainly managed through landfilling and/or incineration. It contains a high percentage of organic matter and plastics not currently valorised.
- **Non-hazardous waste**: Waste that do not have the characteristics of danger to health or the environment described in Regulation 1357/2014 of the European Commission.
- **Organic fraction**: Waste composed by biodegradable garden and park residues, food and kitchen residues from households, restaurants, caterers and retail premises and comparable residues from food processing plants.
- **Oxodegradable:** Plastics with specific additives for increasing decomposition into small pieces but not biodegradation.
- **Processing Companies**: Companies specialised in processing and commercialization of raw materials (fresh or frozen) in derived products like fillets, slices, rings, etc. destined to final consumer.
- **Refuse-Derived Fuel (RDF)**: Refuse-Derived Fuel produced from the reject fraction of the waste sorting facilities.
- **Reject Fraction:** Waste fraction that does not fit into any of the recoverable fractions for recycling after segregation in waste Material Recovery Facilities (MRF).
- **Rest Fraction:** A mixture of not separated at source waste that is mainly managed through landfilling and/or incineration. It contains a high percentage of organic matter and plastics not currently valorised.
- **Retailers**: Companies that sale to consumers directly, and / or supply the HORECA market. They use to be located in the Central markets of big cities - MERCAS or in other parts of the cities.
- **Reverse Logistics System (RLS):** Reverse logistics stands for all operations related to the reuse of products and materials. It is responsible for the recovery and recycling of packaging, packaging and hazardous waste; as well as the processes of return of excess inventory, customer returns, obsolete products and seasonal inventories.
- **Waste management**: collection, transport, recovery and disposal of waste, including the supervision of such operations and the valorisation of disposal sites, and including actions taken as a dealer or broker.
- **Waste manager:** Person, or entity (public or private) properly authorized and registered to perform any of the operations involved in the integral waste management.
- **Waste-to-energy (WtE)**: Process of generating energy in the form of electricity and/or heat from the primary treatment of waste through combustion, or the processing of waste into a fuel source (RDF).
- **Wholesalers:** Big intermediaries of raw materials. They buy large quantities of goods and sell them in smaller amounts (both fresh or frozen). They can be located both in auction ports and Central Markets of cities.
- **XPS:** Expanded Polystyrene.

Essay on the commercialization chain for refrigerated fisheries products packed in EPS/XPS, as well as its management cycle, processing and recovery of the waste within the European countries in the Atlantic Area.

Assessment on usage of bioplastics as materials alternative to EPS.

Expanded Polystyrene (EPS) is a fossil based plastic material, usually white and made of pre-expanded polystyrene beads. EPS is used for food packaging, moulded sheets for building insulation, packing material, agriculture, etc. Waste mismanagement may end up with these products being part of marine litter, meaning a negative global impact.

Even though numbers are variable, high amount of EPS that are put in the market escape management and valorisation cycles. Although not all EPS that escape the management and valorisation cycles end up as marine litter, the more the amount, the more the possibility that it reaches the ocean. There are many ways to reduce marine litter and improving the management and valorisation cycles are very important measures to tackle.

Every material has its own value chain and characteristics. It is by analysing these procedures and uses when it is possible to identify leaks in the process.

The EPS fish-box for commercialization of fresh fish products (refrigerated) is one of the most used EPS products. The number of EPS boxes in the market and the number of EPS boxes becoming waste is huge and this is why the "fish-box" has been chose as this assay's objective.

This document is divided in three different but related chapters. Titles and contents are as follow:

1. *EPS/XPS packaging uses through the fresh fishery and aquaculture market in Europe*. In order to identify leaks since when the EPS fish-box becomes waste. It is necessary to know in detail the multiple possibilities in the market for fresh fish products within the European context of the countries of the Atlantic Area. Depending on the country, some stakeholders and certain flows are more relevant than others. In any case, the description and diagrams that this chapter provides cover practically any eventuality and is representative of the sector. To simplify, what this chapter offers is a comprehensive idea of how goods travel (trade) in their EPS/XPS boxes, and who uses them and how.
2. *EPS fish-boxes waste cycle through the European market*. When used EPS boxes become waste, they follow different paths. This chapter describes where EPS waste is generated, who and how EPS waste from fish-boxes is managed and also problems and limitations of valorisation that have been identified. Also, there are some recommendations and improvements for implementation through the whole cycle to avoid leaks of EPS and to increase valorisation.
3. *Alternative to EPS fish-boxes materials waste cycle (biodegradable bioplastics) in the European market.* Looking for solutions to reduce EPS in marine litter, contemplates the usage of biodegradable bioplastics as an alternative to EPS boxes. Through this chapter, different management potential options are analysed in order to identify limitations and problems derived from mismanagement and misuse of these new materials.

This document is based on real interviews, meetings and conversations with many stakeholders within the fresh-fish value chain, EPS value chain and also waste management cycle. It may be considered as a fieldwork and that is why there is no bibliography epigraph.
Some important terms are defined in the glossary and each chapter has its own introduction epigraph. Furthermore, the second chapter has an epigraph at the end, “Critical points and recommendations”, focusing on improvements and recommended measures to tackle the most noted issues in the cycle. Also, at the end of each chapter, there are conclusions summarizing what it has been exposed before.

CHAPTER 1.
EPS/XPS packaging uses through the fresh fishery and aquaculture market in Europe.

1. Introduction

This report aims to follow the EPX/XPS packaging uses through the supply-commercialization channels for fisheries and aquaculture products in Spain.

This outline just includes fresh products from fisheries which are refrigerated for preservation and commercialization. Frozen products from fisheries don't use neither EPS nor XPS, so specific distribution channels focused on frozen products (i.e. Home service, etc.) are not included in this report.

Differences between raw materials and processed products must be clear from the beginning. It must be clearly differentiated from the beginning the definition of raw material and processed products. Raw materials refer to different wild species from extractive fishing as well as from aquaculture (fishes and bivalve mollusc) and crustaceans. The commercial exchange of raw material is made in EPS boxes except for crustaceans and certain molluscs (Figure 1).

Any product coming from the handling or processing of raw material (fillets, rings, slices etc.) is considered a processed product. These are usually packed in XPS / PET trays using vacuum skin pack technology designed to extend shelf life

Another important aspect to consider is the high vertical integration in the fishery sector. With the aim to diversify their interests many companies conduct different activities at the same time adding complexity to the sector's commercial network. For instance, ship owners may also be processors and some processing companies have their own distribution network. Furthermore, although distributors are usually hierarchized into three levels according to their position between suppliers and final consumers, some stakeholders interact at different levels (Figure 1) increasing the complexity of the distribution system.

Despite of the mentioned variability on the number and type of potential stakeholders involved, we are going to focus on the most typical commercial flow, from **suppliers** to **processors** and **distributors** till the **final consumer**, explaining the different packaging materials used at each step, as summarized in Figure 1.

This exercise will help to identify the most sensible steps of the commercialization process on the generation of EPS/XPS waste. The identification of these "critical points" for the EPS/XPS waste generation is the initial step towards the classification of the different strategies for waste management in place along the supply-distribution channel.

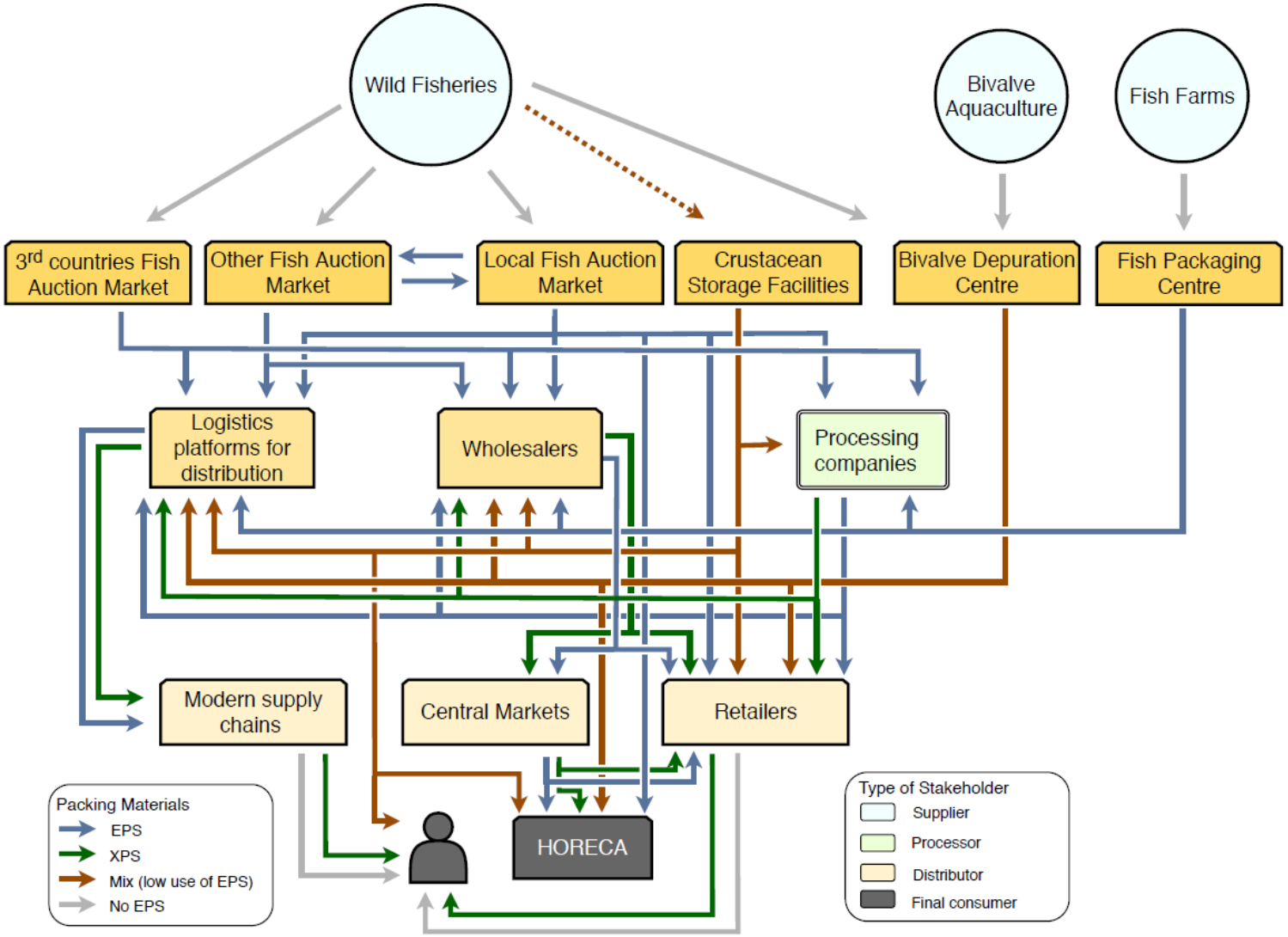


Figure 1. Summary of the packing materials employed along the supply-commercialization chain of fresh fisheries and aquaculture products in Spain.

FLOWCHART 1 DESCRIPTION

- **Blue**: EPS boxes flow
- **Green**: XPS boxes flow
- **Brown**: mix of EPS/XPS
- **Grey**: other materials

1. EPS is used through the whole fresh-fish value chain, but it does not reach final consumer.
2. XPS is used through the commercialization channel. Final consumer purchase fish in XPS or PET trays.
3. EPS waste stays within the distribution and commercialization chain and XPS waste is found mostly in households and HORECA.

2. Raw materials sources (Suppliers):

2.1. Fresh Fish

Sources of supply of raw material from **extractive fishing**:

- Catches from deep-sea vessels (Great Sole grounds) which land their goods in fish auction markets. They don't use EPS boxes on board, but rigid plastic boxes made from high density polyethylene (HDPE) filled with flake ice to keep the right temperature. Goods are auctioned inside these boxes.
- Catches from coastal trawlers and artisanal boats which land their goods in local auction markets. Like deep-sea vessels, they do not use EPS boxes on board but rigid plastic boxes made from high density polyethylene. Goods reach the market into these boxes. Flake ice is added to fish to keep the right temperature.
- Catches from other countries (Portugal, Argentina, South Africa, etc.,) transported to Europe by plane in EPS boxes. In this case, flake ice is not added due to security reasons; they use coolers instead. These goods go through the PIF (Border Inspection Post) located in airports and then go to wholesalers and large-scale distributors, avoiding fish auction markets.
- Catches arriving to fish auction markets in distant ports (national or international) and then taken to local markets by road to be auctioned again. That's called second sale. In this case, fish comes in EPS boxes with flake ice.

Sources of supply in aquaculture (fish farms):

- Fish farms producing seawater (mainly seabass, turbot and seabream) or freshwater fish (mainly trout) sell their products classified by size and sell them to wholesalers, retailers and logistic platforms for distribution avoiding the auction in fish markets. From the beginning, goods are carried in EPS boxes with flake ice.
- In order to achieve a higher added value for some species, a certain number of tons is processed (fillets) in origin, frozen and packaged (no EPS) by the same companies that grow the species. Then it's sent to wholesalers, retailers and Logistic platforms for distribution
- Salmon coming from Norway or Chile, by road/plane, is sold in EPS boxes straight to wholesalers, big supermarkets and especially, to processing companies (for smoking, cutting in fillets and loins, etc.).

2.2. Bivalve Molluscs

- Bivalve molluscs either coming from wild fishing grounds or aquaculture facilities, such as mussels or clams, go first through a depuration stage in depuration centres. Goods arrive in different types of packaging and bags but they never use EPS or XPS.
- Once depurated, these companies commercialize the product satisfying a very specific and never high demand. Their natural market are big-scale distributors, wholesalers, retailers and HORECA (HOtels, REstaurants and CAtering) channel.
- Bivalves are usually distributed using wooden/cardboard boxes or net bags, although EPS or XPS might be used in specific cases.

2.3. Crustaceans

- ✓ Different species of lobsters, sea crabs and shrimps are sold alive from their natural habitats in Ireland, Scotland, France or Canada. They are transported in trucks with special storage systems to keep them alive until destination. Lobster transported by plane from Canada come in EPS boxes with a special system to keep them alive.
- ✓ All these goods go to crustacean storage facilities equipped with pools to preserve them until commercialization.
- ✓ From the storage facilities, the different species are commercialized either alive or cooked using different packaging materials which also include EPS boxes. They are commercialized to logistic platforms for distribution, wholesalers, retailers, HORECA or directly to private consumers.

3. Commercialization and Distribution Channels

There are a number of options for commercialization and only the most important are going to be described here. That doesn't mean that many others are not possible, but to simplify we are going to identify the most common stakeholders who receive any of the goods and describe their use and destination.

The nature and features of the stakeholders involved in distribution and commercialization are extensive; likewise, the exchange flows potentially established among them are also large. Each stakeholder is specialized in a market niche and demands mainly a particular product, which multiplies the singularity and variability concerning the products' features. However, some of them certainly gain a major significance due to the market volume they bring together, such as big-scale distributors, wholesalers and HORECA.

3.1. Processing Companies

They use fresh fish as raw material and mostly frozen fish. Legislation allows defrosting the fish to be processed and freeze it again or sell it thawed as long it's mentioned on the label. The main frozen species used are halibut, and squid (*Illex* sp. and *Loligo* sp).

Info box 1. EPS and XPS boxes flow.

- ✓ Fresh fish arrives to the processing companies in EPS boxes. The rest of raw materials do not usually use EPS or XPS packaging.
- ✓ After processing, products are prepared in **XPS** and **PET** trays for commercialization.
- ✓ Thawed products can be also packed in **EPS** boxes when they are prepared to be sold in bulk.

3.2. Logistic platforms for distribution

Logistic platforms for distribution bring together the storage of goods coming from different locations and customers. Those facilities allow the grouping of goods in secondary loads with a single destination.

Modern supply chains – Big supermarkets (CARREFOUR, ALCAMPO, MERCADONA, etc.) and other medium supermarkets have logistic platforms for distribution (of their own or rented) specifically for fresh fish.

Actually, they have some platforms in different locations because their activity reaches several countries or big areas of the same country.

Raw material and processed products arrive to these platforms. Sometimes they're re-packed and re-classified before supplying the outlets in the network of the distributor.

Info box 2. EPS and XPS boxes flow.

Species from **extractive fishing**:

- ✓ Products come from local fish markets in plastic boxes used by ship owners which are returned to their origin later, or in EPS boxes when purchased by companies working for platforms in other ports or when arriving by plane from other countries.
- ✓ Specimens from the different sources are washed, classified and packed in **EPS** boxes of a given weight into predefined categories. Then they're sent to outlets to be sold.

Species from aquaculture (**fish farming**):

- ✓ Products purchased directly from fish farms that work with different species come in **EPS** boxes already classified with a given weight. These products are not usually re-packed or re-classified and are distributed directly to outlets to be sold.

Bivalve molluscs:

- ✓ Products are purchased directly to companies working as depuration centres of different species. Goods come in different types of packaging but **not necessarily EPS** boxes. They are distributed directly to the outlets usually without re-packaging.

Crustaceans:

- ✓ Products are purchased directly to crustacean storage facilities, either alive or cooked and they come in different types of packaging but **not necessarily EPS** boxes.

Processed products:

- ✓ Products are purchased directly to processing companies in low weight formats and in **XPS** or **PET** trays prepared for final consumers. They are usually distributed directly to outlets without re-packaging.

3.3. Modern supply chains (Big supermarkets)

They represent big and small supermarkets and hard-discount stores. Goods are mainly supplied by logistic platforms for distribution (not always owned by the supply chain), although outlets have a certain margin to stock up with local suppliers.

Info box 3. EPS and XPS boxes flow.

- ✓ From their distribution platforms they receive all the raw material and aforementioned processed products.
- ✓ Processed products in **XPS** trays are placed on showcases where final consumers take it straight.
- ✓ Raw material from extractive fishing and aquaculture coming or not in EPS boxes are offered to final consumers in stands by specialized staff and dispatched with different packaging systems, **not necessarily XPS**.

3.4. Wholesalers

Most of them have their facilities into the ports and even into the fish markets. Some of them are also ship owners and/or processors. They mainly purchase fish directly in fish markets or they receive it from other ports by truck. Early in the night the products are washed, classified and placed in EPS boxes with flake ice fulfilling the specific demands from wholesalers and retailers located in the central markets of big cities (MERCAS). The orders are loaded in trucks and arrive to MERCAS in the early morning where they are received and distributed among the different wholesalers/retailers working in these markets or elsewhere according to their orders.

Apart from fish, wholesalers can also supply crustaceans, molluscs and processed products bought from other companies. The EPS/XPS packaging used for each of these products is the same as described for logistic platforms for distribution.

3.5. Central markets of big cities - MERCAS

MERCAS are big infrastructures where wholesalers and retailers rent a space to sell products. They have common areas for the reception and management of goods and orders.

Info box 4. EPS and XPS boxes flow.

- ✓ Wholesalers and retailers receive their goods from other wholesalers located in the ports. Goods arrive in **EPS** boxes, or **XPS/PET** if processed.
- ✓ Wholesalers may also receive fresh fish through third countries, which arrive by plane in **EPS** boxes and go through the PIF border inspection points.
- ✓ Some modern supply chains (big supermarkets) have facilities inside MERCAS and receive their goods from the distribution platforms in **EPS** boxes or **XPS** if processed.
- ✓ Wholesalers may also be retailers and have outlets inside the MERCAS. Like that they can supply other retailers located outside, that's to say, in different spots around the city.

3.6. Retailers

Unlike wholesalers, they do not have big warehouses and sometimes they focus on the HORECA market. They are usually stocked up on products from wholesalers. They may be located in big MERCAS or in small shops in the city/town.

They represent the outlet for final consumers. Besides the species from extractive fishing they can also sell processed products and aquaculture products.

Info box 5. EPS and XPS boxes flow.

- ✓ Raw material from fisheries and aquaculture (fish farming) come in **EPS** boxes.
- ✓ The different species are sold for final consumers but not in EPS packages, so the last responsible of EPS is the retailer, not the consumer.
- ✓ In case they also sell processed products, the final consumer is the last responsible of the **XPS/PET** trays in which the product is served.

4. Conclusions

1. Fishery and aquaculture supply chains are complex. This flowchart covers the more important and common flows in the Atlantic area. The main stakeholders who act in these countries are shown in the flowchart. Importance of each of them, as well as the role they play and the volume of products may vary depending on each country, but all options are mentioned in this chapter.
2. Expanded Polystyrene EPS uses begin with suppliers of raw materials, who firstly use these boxes to commercialize their products. Uses covers all value chain stakeholders until the HORECA market. EPS does not reach final consumer (citizens), however, XPS is used from the first level of the supply chain: *Processing Companies, Logistic platforms for distribution* and *Wholesalers,* and it ends in the homes of final consumers (citizens).
3. Through the entire value chain, different stakeholders generate EPS/XPS waste that goes through a series of procedures relating the management cycle, treatment and valorisation, as it is stated in the chapter 2. The efficiency of this cycle depends mostly on stakeholders' good practices over waste.

CHAPTER 2.
EPS fish-boxes waste cycle through the European market.

1. Introduction

This report, as well as the flowchart included (stakeholders through the value chain; Figure 1), has been specifically designed for the type of EPS packaging most used in Europe: fish-boxes for fresh fish and its derivatives.

At the present time, there is no real alternative to this material for the transport of fresh fish and seafood, so after-use management is the key to avoid loss of raw materials and environmental issues.

The stakeholders represented in the flowchart (Figure 2) are common for other priority products of the Oceanwise project (XPS trays for example), so it can lay the groundwork for the development of flowcharts for other products.

The value chain (flowchart) of the commercialized raw materials (fish) and of the packaging in which they are sold (EPS boxes) have some parts in common, but at a certain moment, when the fish-boxes become waste, the paths diverge.

Although EPS fish-box waste is considered a non-hazardous waste, it receives the qualification of industrial, commercial or household waste (Info box 6) depending on where in the value chain it is produced, and hence the differences in treatment and management pathways.

This flowchart has been built based on interviews made to different stakeholders along the value chain, so it largely follows to the real status of EPS fish-boxes. Although it intends to include all possible existing alternatives, it is a work "in progress" that will still evolve.

Its objective is to **identify problems or aspects that would present an opportunity to improve and increase the tonnage of proper valued EPS**. Improving EPS waste management is one of the best ways to prevent possible marine litter or other ways that may damage the environment.

Info box 6. Types of waste according to waste producer.

- ✓ **Industrial waste**: waste materials resulting from the manufacturing, transformation, application, consumption, cleaning or maintenance processes generated by industrial activity. Waste producers (the industry) has the legal obligation to correctly manage these wastes by hiring a private waste manager for proper treatment.
- ✓ **Commercial waste**: waste generated by the activity of commerce, wholesale and retail, catering services, cafes and bars, offices and markets, as well as the rest of the services sector. The legal obligation on the treatment of this type of waste belongs to the producer who must take care of it through a private waste manager or adhere to a municipal commercial waste system if it exists.
- ✓ **Household waste**: Waste generated in households, as well as those generated in urban services and industries that are similar to those of household activity. This section also includes waste from cleaning public roads, green areas, recreational areas and beaches that could include traces of EPS. Municipalities have the legal obligation to take care of household waste so it is managed through the Municipal Waste Management System.

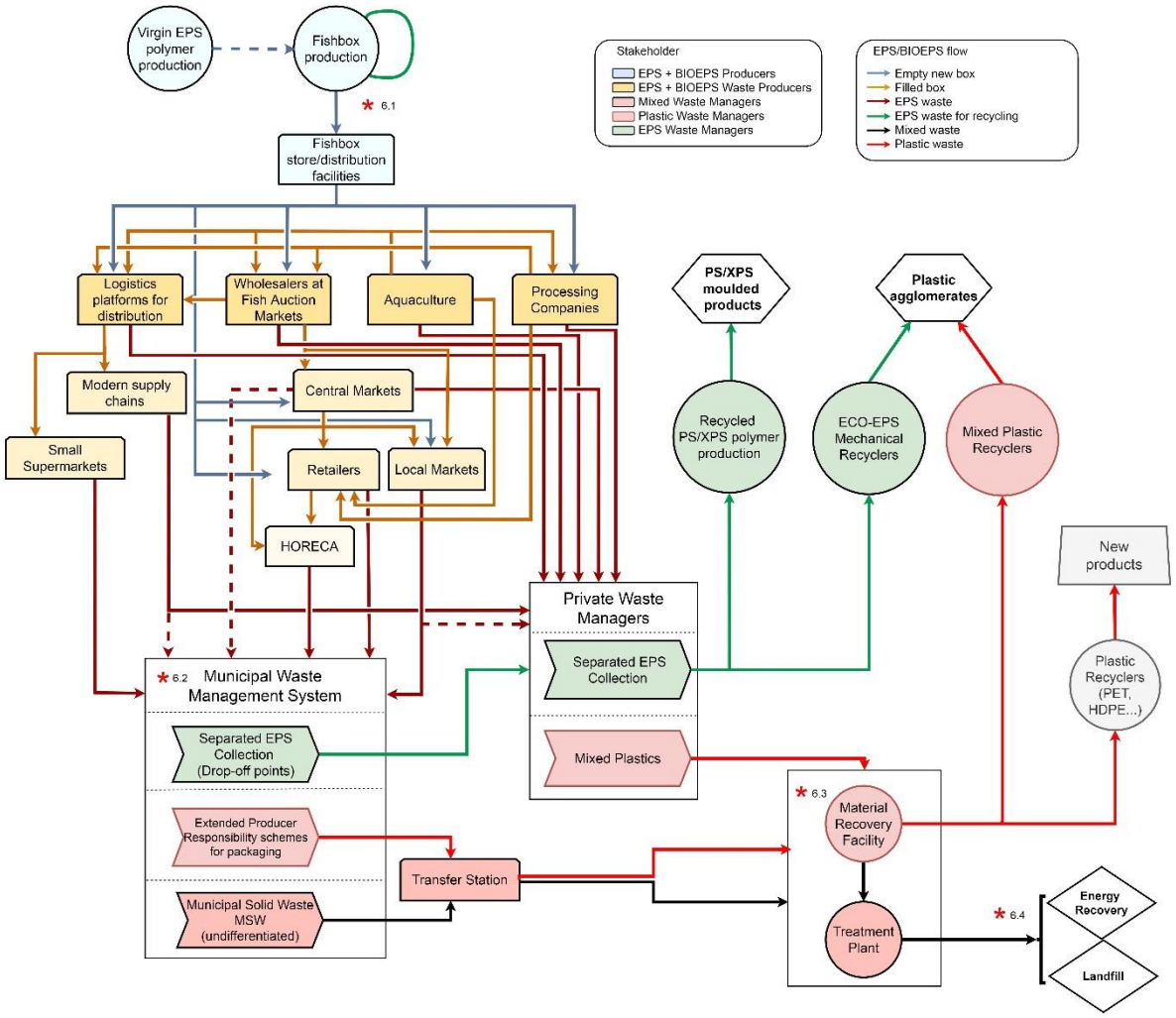


Figure 2. Flowchart of the EPS fish-boxes along the supply-commercialization-waste management system in Spain. Numbers identify specific sections of this report where (*) critical points are discussed in detail.

FLOWCHART 2 DESCRIPTION

- **Blue**: represent empty boxes flow
- **Yellow**: represent EPS boxes filled with fish
- **Dark red**: represent EPS waste flow
- **Green**: represent EPS waste separated for recycling
- **Red**: represent mixed plastic waste
- **Black**: represent mixed waste that cannot be recovered

1. The first level produces **industrial waste**. Most EPS residue is from broken boxes can be reintroduced to the production chain.
2. The second level produces **commercial waste**. Includes both distributors and commercialists of fish. In this level, EPS is used to transport fish from one stakeholder to another. Waste can be separated at source or not. As commercial waste, it is usually managed by private managers but, in some cases, small markets and retailers can use the Municipal Waste Management System for mixed waste. The HORECA channel uses the MWMS as well, as their waste is similar to households.
3. Final consumer (citizens) do not receive EPS, but XPS/PET trays.

2. EPS packaging manufacturers

The first step to consider is the manufacturing companies of EPS packaging, leaving aside the previous step of the large petrochemical companies selling virgin raw material (PS, polystyrene).

- Manufacturers of EPS packaging are usually specialized in food boxes (EPS moulding), although they can also commercialize other EPS products (insulating material for construction, protective packaging for heavy items, or protections needed to be extremely light, such as in helmets, medical packaging for delicate goods, etc.). Their catalogues usually have a great diversity of box models that vary in capacity and dimensions.
- EPS boxes have very low density. Large volumes imply high distribution costs (transportation). Because of that, this type of manufacturers carries out their business in a reduced geographical radius of about 200 km. Distribution to remote geographical locations would not be profitable.
- Their customers, regardless of the size of the company, do not usually have high storage capacity but require a quick supply of boxes according to their fluctuations in demand. To meet their customers' needs, EPS packaging manufacturers have intermediate warehouses distributed in their area of influence from where they can quickly supply the goods to their customers.
- Fish-boxes are considered industrial/commercial packaging, because they are used for distribution of goods, but not to reach final consumer. Anyway, both manufacturers and converters (commercial and industrial sectors) have a legal obligation to take care of the waste they generate. Nevertheless, local legislation regarding industrial and commercial waste differs between countries.
- The implementation of reverse logistic mechanisms is demanded by costumers of EPS boxes. This might improve the separate collection and recycling rates of EPS but it faces several difficulties which are analysed later in this report (7. Considerations and conclusions).

Info box 7. EPS packaging manufacturers waste management.

- ✓ EPS waste from the fish-boxes manufacturing process is considered industrial waste and must be managed by an authorized waste manager (Section 5), if the collection of these EPS fish-boxes is mixed with other plastic materials, it is more likely to end up as a waste that is sent for energy recovery or landfill.
- ✓ Fish-box manufacturers do not generate a large volume of EPS waste, because they manage to reuse part of it (e.g. clean EPS from defective boxes) in the manufacture of new boxes.
- ✓ There is a small fraction of dirty EPS waste, commonly called "sweeps", which is not recoverable. This fraction is highly susceptible to become marine litter if not correctly managed.
- ✓ EPS sweeps should be collected separately from other plastics by an authorized waste manager, that supplies containers for selective collection and removes them periodically. However, depending on the volume of waste produced, EPS is sometimes collected together with other plastic waste.

3. Commercialization and Distribution Channels

3.1. First level of the commercialization and distribution channel

The first level of the commercialization and distribution channel is comprised of **Processing companies, Aquaculture, Wholesalers** (port environment) and **Logistic platforms for distribution**.

- Aquaculture companies serve their products in EPS boxes to logistic platforms for distribution, wholesalers, processing companies and retailers. Depending on the size of the aquaculture company, they can have a packaging centre, where orders are prepared for different customers.
- The wholesalers included in the first level of the distribution channel, are those who receive their products directly from the fish auction markets or port environment (not packed in EPS) and supply fresh fish to large central markets, logistic platforms for distribution or processing companies.
- The logistic platforms for distribution receive part of their products packed in EPS boxes and re-packed them in new EPS boxes according to their customers' needs (Large Distribution Chains or Supermarkets).
- Similarly, processing companies receive part of their raw materials in EPS boxes and, for certain elaborations (mainly products to sell in bulk) they are re-packaged using new EPS boxes. They distribute processed products to logistic platforms for distribution, wholesalers, and retailers.

Info box 8. First level of the commercialization and distribution channel waste management.

- ✓ For **aquaculture companies**, the EPS waste generated comes from broken boxes during the packaging process (≈ 0.7%). The volume of waste is usually small, although some large companies have briquetting machines (e.g. Culmarex Group; http://www.culmarex.com/).
- ✓ The same happens with **wholesalers** located around the port environment, which do not receive their products in EPS box, but redistribute the fish in this type of packaging.
- ✓ On the other hand, **logistic platforms for distribution** and **processing companies**, generate EPS waste from the packaging in which them receive some of their products in addition to the breakage of clean EPS boxes during re-packaging.
- ✓ This waste is managed by authorized managers, who, depending on the volume of EPS generated, can decide to collect it individually (compacted or not) or mixed with different plastics.
- ✓ **Processing companies** and **logistic platforms for distribution** usually manage their EPS wastes through a private waste manager. In fish auction markets and port environments where many wholesalers are concentrated, their waste is usually managed jointly through a single authorized manager.

3.2. Second level of the commercialization and distribution channel

- The second level of the commercialization channel is comprised of **Modern Supply Chains**, **Small Supermarkets**, **Central markets of big cities - MERCAS** -

(wholesalers), **Local Markets** (Retailers), **Retailers** located outside these Markets and the **HORECA** channel (hotels, restaurants and coffee shops).

- Point out that, within most of these stakeholders, companies whose activity belongs to different sectors (not only fishing) coexist simultaneously. On the contrary of first level of the distribution chain, where all the EPS waste comes from the fishing sector; at this second level, and with the exception of some retailers, the EPS waste generated is the sum of wastes from various activities (fishing, fruits, meat, vegetables, etc.).
- Fish wholesalers located in the large central markets are the only ones that redistribute their merchandise in EPS boxes for sale to retailers or the HORECA channel. The rest of those involved in the second level of the distribution chain have the final consumer as their main customer who does not receive the products in this type of packaging, but XPS/PET.
- The management of commercial waste is carried out through a public or private authorized manager, who will carry out a different EPS management:

Info box 9. Second level of the commercialization and distribution channel waste management.

Large central markets (MERCAS)

- ✓ They receive all kinds of food from peripheral areas.
- ✓ They have a large number of wholesalers (not just for fish) and some retailers. These wholesalers usually supply retailers located outside these markets, elsewhere in the cities. In many cases they also supply to the HORECA channel.
- ✓ The size of these markets, as well as the profile of their wholesalers / retailers, will depend on both the size of the cities and their geographical location (coastal or inland cities).
- ✓ The waste management is variable, but basically two types can be distinguished:
    - **With a specific area for waste deposition**: Markets in large cities usually have a space enabled for all the stakeholders that operate there to deposit their waste designated area. Both the management of this space and the subsequent management of all waste is subcontracted to a Private Manager (see 4.3. Private Waste Managers).
    - **No specific area for waste deposition**: Markets in medium or small sized cities do not usually have a space for waste segregation. In most cases, they delegate waste management to Private Managers or, in few cases, to the Municipal Waste Management System (see 4.2. section).

Large Distribution Chains

- ✓ They usually have a space for the joint management of their inorganic waste; however, they always turn to private waste managers for their periodic removal. Depending on the volume of EPS waste generated, it is collected separately or mixed with other plastic waste.

Medium-sized distribution chains

- ✓ Focused on food, they usually do not have waste storage areas and require daily collection. These establishments manage waste through a Private Manager or in some cases through the MWMS.
- ✓ Local markets, small retailers, small supermarkets and the HORECA channel, are generally integrated into Municipal Waste Management Systems.
- ✓ They can use rest fraction containers on kerbsides or request specific containers for selective collection also managed through the Municipal Waste Management System.

4. Waste Management

Waste generated by fish-boxes manufacturers and the stakeholders of the first and second level of the commercialization channel, needs to be managed by an external Waste Manager.

- Waste management covers different operations: collect, transport, recycling, treatment and recovery.
- The “waste manager” is rarely involved in the integral management from collection to treatment. Usually, there are different players covering any of each operation.

- Waste management can vary depending on the country/region. Nevertheless, there are mainly two groups: Municipal Waste Management Systems fund by municipalities for household waste, and authorized private Waste Managers for commercial and industrial waste. The different players across the fish-box value chain use one of them or both at the same time. In the flowchart (Figure 2), red arrows identify the most common pathways between stakeholders for EPS waste.
- Plastic packaging EPR Schemes (Extended Responsibility Producer schemes) have a key role regarding packaging waste from households. And, household packaging waste covered by EPR Schemes is logistically managed by Municipal Waste Management System.

4.1. Relation between Municipal Waste Management Systems and EPR Schemes

- The Municipal Waste Management Systems are in charge of all household waste. Citizens dispose their waste in specific waste containers located on the kerbside.
- EPR Schemes (Info box 10) have agreements (usually multiannual) with municipalities for management of the plastic packaging from households (yellow container).
- Even though EPR schemes are in charge of management of the packaging fraction from households, municipalities use to cover collection, logistic and transportation of waste to Material Recovery Facilities (MRF).

Info box 10. EPR schemes and household packaging.

- ✓ Directive 94/62/EC on packaging and packaging waste introduces the "polluter-pays principle" and the "Extended Producer Responsibility" (EPR).
- ✓ EPR Schemes (Extended Producer Responsibility Schemes) are environmental not-for-profit organisations, with a social mission: they are responsible for sensibilization campaigns, collection and recycling. All these activities are economically fund by producers, who pay to EPR Scheme according to the material and weight put in the market.
- ✓ Packaging covered by EPR Scheme have a Green Dot identification logo. The Green Dot symbol represents that the producer pays into the packaging EPR schemes and that the business therefore contributes towards the funding of packaging recycling. Packaging with the green dot are to be deposited in the selective kerbside containers, so they are collected and transported to material recovery facilities (MRF).
- ✓ The EPR schemes do not cover EPS fish-boxes because they are commercial/industrial waste. Nonetheless, there are other EPS waste which is in fact covered by EPR schemes such as small electronic packaging.

4.2. Municipal Waste Management System (MWMS)

- The Municipal Waste Management Systems (MWMS) are the most established system to collect household waste and waste of a similar nature and composition. They also cover management and logistics of household packaging accordingly to EPR schemes agreements.
- MWMS do not cover commercial or industrial waste. Even though, some retailers from different sectors located in the cities/towns are allow to deposit their waste on the rest fraction containers (Municipal Solid Waste, MSW) from MWMS. There are many retailers which implies that, as a whole, they generate large amount of waste to be managed by the MWMS.
    - Many municipalities allow the deposition of EPS waste (and all type of waste) on the rest fraction containers (MSW) in exchange of a waste tax, established based on the characteristics of the commercial activity (activity, store size, etc.).
    - Some other municipalities establish public prices for waste collection and/or treatment services for commerce, thus, waste producers (stakeholders from the commerce and distribution channel) can choose the most competitive service (MWMS or private).
    - Most EPR schemes manage only household packaging, so they cover EPS from households, but not EPS from retailers or commerce.
- Municipal Waste Management Systems are not homogeneous within territories, because they attend to different needs of each municipality (Info box 11). The most widely used system is kerbside collection.
- EPS fish-boxes are industrial/commercial waste, not covered by plastic packaging EPR Schemes. If they are not collected by private waste managers, they can often be disposed on the rest fraction containers (MSW).
- Collection decides waste treatment. Rest fraction and/or packaging do not follow the same path/flow.
- As municipal waste generation is big, it is common to use transfer stations, reception centres closer to the collection centres to condition waste in larger containers for transfer to **Material Recovery Facilities (MRF)** or **Treatment Plants**.

Info box 11. Different collection systems of municipal waste management systems for commercial waste.

- ✓ There are different municipal collection systems for commercial waste:
  - Integrated: same infrastructure and logistic as household waste.
  - Mixed: different containers and same collection logistic as household waste.
  - Segregated: different collection and logistic infrastructures (specific containers with different frequency of collection).
- ✓ MWMS waste collection systems:
  - Door-to-door collection: waste is collected in bags or small containers placed in front of the door of the house/building/commerce following a schedule for each fraction.
  - Kerbside collection: containers are located in the kerbs and collected using specific pick-up trunks, typically in in urban and suburban areas.
  - "Drop-off points"/civic amenity sites: centres for segregation and storage of waste that are not subject to household collection in order to properly manage non-ordinary fractions. There is no governmental regulation on the number and typology of waste fractions collected in these centres, so they are highly heterogeneous.

4.3. Private Waste Managers

- Industrial and most commercial waste are managed by authorized private waste managers.
- The same manager can take over the integral management of waste, including the supply of containers for segregation, collection, treatment, recovery and disposal, or subcontract different agents for certain parts of the process as well. But usually, each manager is specialized in only two or three of these activities.
- When EPS volume is high, it is compacted by a briquet machine which can reduce EPS waste up to 40 times. Collection and storage of compacted EPS is easy and reduces transport costs.
- If EPS waste collected is clean, it can be sorted and sent directly to recyclers to process it. If it is not segregated at source and it is mixed with other materials, the manager decides the final treatment, that can be energy recovery or even landfill.
- **Private waste managers** use to have their own **Material Recovery Facilities (MRF)** to segregate each plastic polymer that can be sold to recycle. The number of fractions sorted depends on volume collected and market demand.

5. Waste treatment

Treatment and recovery are the last steps of the waste management chain. Treatment aims to maximize segregation of materials by quality. Fractions obtained on the treatment process are managed by different recovery processes depending on the specific characteristics of each

of them. Recovery adds value by creating new industrially useful products, making the process circular.

Treatment and recovery companies are within the waste managers, but they are highly specialized, and they are very different from the previous companies on the management chain.

- Their role is the recovery and recycling of materials, use them as refuse-derived fuel for energy recovery or pre-treat them to be safely disposed at landfills.
- Level of EPS waste recovered depends on collection and treatment:
    - Briquetted **clean EPS** has a high market demand. It is sent on to recycling companies to process it. Mostly, all industrial waste from processors and some of the commercial waste is managed this way.
    - **EPS from the plastic packaging fraction** of Municipal Waste Management System managed by EPR schemes is dispatched to Material Recovery Facilities (MRF). EPR schemes only cover household packaging that has low volume of EPS. Also, Material Recovery Facilities (MRF) do not segregate a specific EPS/PS fraction. EPS ends up mixed alongside other materials on the mixed plastic bale (MP).
    - **EPS on rest fraction** containers managed by Municipal Waste Management System is mixed with different materials (organic waste included) and recovery and reuse levels are very low. It is treated for final disposal at landfills or incineration with energy recovery.
- Every treatment process (even recycling) produces a small reject fraction of non-recovery material. This fraction goes to landfill or energy recovery (waste to energy, WtE).

5.1. Material Recovery Facilities (MRFs)

- The Municipal Waste Management System manages all household waste, undifferentiated (rest container) as well as segregated at source waste (coloured containers funded by ERP schemes). Sometimes, both containers are transported to sorting facilities.
- **Plastic packaging fraction** is separated in households and deposited in the waste containers as determined by municipalities (usually yellow containers). This fraction is collected and transported to sorting facilities, the **Material Recovery Facilities (MRFs)**.
- These plants sort materials in order to obtain and sell all recovery fractions. Not selected materials are prepared to disposal in landfills or energy recovery (WtE).
- Different types of materials are separated: **PET, HDPE, LDPE, steel, aluminium, cardboard for liquids**.
- Once sorted into a single material type and baled, the material is sent for recycling. **EPS is not separated in a specific fraction**, but is mixed with other plastic materials in a mixed plastic bale.
- The Material Recovery Facilities (MRF) are closely related to EPR. The payment of a fee (green-dot fee) allows the EPR scheme to fund packaging waste management: maintenance of recycling drop-off containers, collection, transport logistics and MRFs

costs as well as promoting environmental education and awareness-raising for consumers via media campaigns and support for local authorities.

- Funding municipal councils by ton of selected material.
- Incentives by percentages and quality of selection.
- Funding MRFs equipment for automatic segregation.
- Funding Research & Development programmes to foster the market for recycled products and materials.
- All materials (PET, HDPE, LDPE, mixed plastic, paper and cardboard, metal and bricks) are sold to recyclers/managers.

5.2. Recyclers

- These companies represent the last step of the management chain. They are specialists in obtaining new recycled products (pellets or others) from EPS waste for industrial application.
- EPS waste is 100% recoverable. Odour in fish-boxes have been a constrain for the recyclers in the past but, industrial processes nowadays can remove it to be fully recoverable.
    - Limitations for recycling are: purity, cleanliness of the collected EPS (table 8) and difficulties obtaining large volume due to its low density and costs of transportation.
    - Collection of EPS waste limits valorisation. Purity is crucial for the recycling process and final applications.
    - The role of recyclers is key to prevent losses and leakages to the environment, and approaching a more circular economy.

PS/XPS pellet producers

- These companies are the most important players in terms of recycled EPS volume. They are highly specialized companies with few in the Atlantic area.
- They use EPS briquettes made of EPS from separate collection of fish-boxes and other EPS products to obtain pellets of PS. It is a highly caloric process: grinding briquettes and passing them through a cyclone or fan, so that all dust and solid particles can be removed; next step is a magnetic separation to remove metals and the extrusion process. Construction and automotive sectors are the main recipients of this recycled PS pellets
- These companies process industrial EPS waste and well-segregated commercial EPS, but no EPS sweeps or EPS from the mixed plastic bale (MP).

Industrial EPS moulded goods producers

- These companies use only industrial and commercial EPS waste from EPS fish-boxes and other EPS products, both briquetted or not.
- The EPS is grinded and added in the manufacture of new EPS moulded products along with virgin EPS (mainly insulating sheets for construction, light bricks and concretes, etc).
- The recovered EPS can also be incorporated into other construction materials like bricks and light concretes, etc.

Producers of agglomerates and pellets from the Mixed Plastic fraction

- These companies use the mixed plastics (MP) bale that contains EPS and other plastic materials. Down-cycling.
- This process consists in a preliminary selection to remove contaminants, followed by grinding and extrusion. Next, a second process followed by another extrusion results on pellets used for producing plastic wood for urban infrastructures (for example walkways, garden furniture, etc.; Solteco http://solteco.org/).

Info Box 12. Projects focused on eliminating problems for recycling of fish-boxes.

- ✓ Recycling EPS from fish-boxes have had some difficulties due to cleanliness and odours. Currently, these drawbacks are solved through various mechanisms like limitation of the percentage (≈30%) of waste used to development of new products, or specific cleaning processes to eliminate these difficulties (EEA Grant-EPS FISH).
- ✓ Food safety legislation forbid using recycled EPS in food contact, but there are projects that are trying to open this recovery line in order to increase value of waste and products that from it (Life EPS-SURE Project).

5.3. Energy recovery (WtE)

- Energy recovery is the conversion into energy of waste that cannot be recycled, whether in the form of electricity, steam or hot water for homes or industrial use. This process usually consists on drying process, and then combustion of the waste: Refuse-Derived Fuel (RDF). Electrical energy is generated due to the heat energy that activates steam turbines.
    - EPS from rest fraction and part of the reject fraction may end up as RDF in energy recovery plants. Reject and rest fraction that cannot be recycled or material recovered, can be used for energy recovery (Waste to Energy, WtE) and/or disposal. In this fraction there may be fish-boxes and other EPS waste that, due to their small volume or because they are very dirty, cannot be used for recycling.
    - EPS is a plastic material with high calorific value, that makes it an interesting residue for using it as RDF to feed boilers.
- Some MRFs have energy recovery plants in their facilities so they can use this reject fraction to produce energy to power the plant itself.
- The EPS waste that end up in this recovery route is part of the commercial and household waste managed through the Municipal Waste Management System or industrial that has not been separated at source.

5.4. Landfill

- A landfill is a site for the disposal of waste materials through underground or surface deposit.
- Landfills where plastic waste can be deposited, including EPS, are those that host non-hazardous waste that do not undergo significant physical, chemical or biological transformation.

- All waste destined for landfill must be treated before its final disposal to ensure the materials do not present any danger to the environment or health.
    - EPS in the reject fraction from the MRFs is disposed in landfills.

6. Critical points and recommendations

This survey, after a detailed analysis of the EPS waste management chain, has a double purpose: on one hand, to identify critical points and; on the second hand, to suggest recommendations to achieve it. The objective is to avoid EPS leakage from the management flow and to increase recycled and recovered EPS volume.

Even though this waste management flow is well established and there are stakeholders covering the whole chain steps, the system is not perfect and there are process or activities where to improve. Some of them are described below:

6.1. Reverse Logistics System (RLS)

Description

Implementation of Reverse Logistics Systems between different suppliers would allow the EPS separate collection. Also, its treatment (briquetting) and recycling would be more profitable because waste would be more concentrated, reducing the transportation costs.

Two possibilities have been found:

1. Boxes manufacturers / First level of the distribution channel
2. Logistic platforms for distribution / Modern supply.

Box manufacturing companies are showing interest in reverse logistics processes to collect EPS waste generated by their customers (first commercialization level). The aim of this is:

- Taking responsibility for its obligations as producers by creating an effective disposal-collection system from the market;
- Offering a full service to their clients, that demand that more frequently;
- Helping their clients to approach a more circular economy;
- Assuming all costs from waste management;
- Favouring the selective concentration of EPS waste and supplying directly to recovery companies.

Limitations

- In order to achieve this, packaging manufacturers have to be licensed as Authorized Waste Managers, what implies long and expensive administrative procedures (at the regional and municipal level: fees, environmental bond, etc.). Furthermore, they would have to adapt their infrastructures to specific requirements that may require large economic investment.
- Current food safety and health legislation do not allow to transport used boxes (EPS waste) in the same vehicle that transports new food contact boxes. This limits efficiency, increases costs and jeopardise economic viability of this model.

Recommendations

- The OCEANWISE project should urge the different administrations to simplify procedures and reduce time to obtain a non-hazardous waste manager license for manufacturing companies.
- Through EPS associations, the OCEANWISE project should promote measures and specific protocols like cleaning, disinfection… or a CEN/ISO Standard to food safety and health authorities, to make the system profitable.

6.2. Implementation of separate collection for commercial waste

Description

Many retailers in urban centres - outside big markets- as well as the HORECA channel (from the second distribution level), generate commercial/industrial EPS waste (not from households).

- Some municipalities have waste taxes to allow retailers to dispose their waste on the rest fraction containers (MSW), where all kind of materials are mixed.
- EPS boxes cannot be deposited in the EPS schemes containers as these are not household packaging. The EPR schemes do not cover commercial/industrial waste.
- Even though the rest fraction is sometimes transported to MRF, the EPS on rest fraction is dirty and mixed with many materials in small pieces. Sorting this fraction is expensive and with low quality results, so it is mostly used in energy recovery or landfilling.
- Non-quantified (but high) amount of EPS commercial waste escape the recycling/valorisation flow.

Limitations

- Implementation of any collection system for retailers and HORECA would face the issue of EPS low density and collection costs.
- Small retailers and HORECA can use "Drop-off Points" but these facilities do not collect EPS as a fraction itself and in many cases do not have a proper area for store it. Furthermore, they are located on the city periphery, so stakeholders have to transport them frequently.

Recommendations

- Integrate selective EPS collection on a municipal level for commercial waste by having containers for EPS waste in places like markets, fish auction markets, or by implanting the door-to-door collection system for high EPS waste generators (fisheries, small supermarkets…).
- Authorities should better define household packaging and commercial packaging (*for example, in Portugal, if the waste production is under 1100 litres/day is considered equivalent as being household packaging*).
- Legislation on EPS collection in Drop-off Points, in order to achieve more volume of EPS. Incorporate incentives for using Drop-off Points (economic or fiscal compensations).
- Incorporate mobile Drop-off Points with a weekly collection agenda.

Specific recommendations

- Directive 2018/852 establishes that Member States shall ensure that, by 31 December of 2024, extended producer responsibility schemes are established **for all packaging**.
- Directive 2018/852 establishes various objectives, but the most relevant according this study is the application of EPR to commercial and industrial packaging.
- As it is a legal obligation, OCEANWISE could work on encouraging the implementation of these EPR schemes for commercial waste on all Atlantic Area countries before 2024.
- OCEANWISE could contribute to this end by analysing, through some pilot projects, the technical and economic feasibility of implementing this new EPR scheme and its logistic difficulties.

6.3. Implementation of the selection of EPS fraction in Material Recovery Facilities

Description

Most EPS commercial waste (retailers + HORECA from outside the markets and shopping centres) is deposited in kerbside rest fraction containers managed by Municipal Waste Management System. Sometimes, fish-boxes may end up in the separated collection containers (yellow container of the EPS scheme).

- Both containers (rest fraction and plastic packaging fraction containers) are dispatched to a sorting facility, where they are processed separately. Most of these companies have advanced sensor technology (near infrared, visual spectrometry) to sort some plastics by polymer, but not PS/XPS/EPS. EPS is never separated in a specific fraction.

Limitations

- All EPS waste (even fish-boxes) on the Municipal Waste Management System flow ends up on energy recovery facilities or landfills. It is very difficult to obtain good quality material in Material Recovery Facilities (MRFs) from this fraction, even though MRFs are highly equipped.
- All household XPS and commercial EPS on EPR Scheme flow for household packaging can neither be fully recoverable as they end up on mixed plastic fraction and its valorisation is difficult.
- There is sensor technology to segregate EPS and XPS specifically, for it would not end up in the mixed plastic fraction, but equipment is expensive. Polystyrene (PS) quality obtained shall be enough to cover expenses.

Recommendations

- Generation of a polystyrene bale for crystal PS, XPS and EPS for valorisation into products with more added value (http://styrenics-circular-solutions.com/videos/).
- OCEANWISE could encourage interlocution between administrations and MRFs to analyse measures to incorporate PS selection. Those measures could vary from subsidies, equip themselves with new sensor sorting systems (near infrared and visual spectrometry), investment in waste recovery and chemical recycling.

6.4. Increase of municipal landfill rates

Description

Commercial EPS generated by retailers (located outside of Shopping Centres and Markets) and HORECA, is deposited in the rest fraction containers (MSW) of the Municipal Waste Management System and, once in the treatment plants, it may be deposited in landfills. Additionally, EPS waste from industrial/commercial activity managed by private waste managers can also ends up at landfills.

- Directive (EU) 2018/850 of 30 May 2018 amending Directive 1999/31/EC is the landfill framework in Europe. Even though, each country and municipality establish their own landfill rates, so they differ within the EU.
    - Directive (EU) 2018/850 prohibits landfilling of more than 10% of rest fraction by 2035.
    - Some countries have very low landfill taxes, which is a lack of incentive for waste segregation and recovery.

Limitations

- The shortage of reverse logistic systems, Deposit-Return Systems (DRS) or specific EPR scheme for commercial EPS waste (or other types of waste), limit waste selective collection and promote the use of landfills.
- Municipalities are responsible for management of landfills through municipal ordinances. This means that landfill rates are very unequal, and that harmonization and homogeneity are difficult for municipalities (although the orographic characteristics and their location justify certain inequalities).

Recommendations

- The implementation of segregation at source systems would only be possible by increasing landfill rates.
  Incineration and landfilling are not the best option for OCEANWISE, as the project promotes the circular economy. OCEANWISE aims to promote eco-design, waste reduction and reuse in order to avoid marine litter.
- Increasing rates would not be effective if, at the same time, alternative source segregation systems such as reverse logistics or EPR schemes are not implemented. Without these measures, commercial waste could not be rescued from the Municipal Solid Waste flow.

6.5. Creation of Recycling Areas in Large Central and Local Markets

Description

Only Central Markets of big European cities have specific areas to deposit and manage waste, including EPS (see 3.2. Second level of the distribution). If they do not have a specific recycling area, waste is managed through the Municipal Waste Management System and, as a consequence, EPS waste ends up in energy recovery facilities or landfills.

This also happens with waste from medium-sized distribution chains, local markets, retailers, small supermarkets and the HORECA channel.

Limitations

- Market administrations vary from one to another and depend not only on local administrations. Even in this case, not all municipalities follow similar guidelines.
- Adopting measures improve waste management in these markets will depend on the economic viability of these measures. Sometimes, improvements are not possible due to financial problems.
- To avoid EPS waste in the Municipal Waste Management System and increase waste segregation, landfill rates should be increased (some countries in the Atlantic Area, as Spain, have lower landfill rates than other European countries). If municipalities themselves cannot establish landfill rates and organize their markets simultaneously, it will be difficult for waste management systems to be improved.

Recommendations

- Creating Recycling Areas (or exclusive EPS delivery areas) in all central markets of big cities – MERCAS – for segregation of waste. Its size may depend on the specific needs of each market and its management.
- The infrastructure and equipment (briquetting machines, compactors) should be financed by the municipalities. However, a private waste management company should be in charge of the management by administrative concession. The difference with the Large Markets in big European cities is that they can directly contract external Private Managers, while the municipal nature of the local or smaller Markets forces the municipality itself to contract the manager.
- Another solution, would be to create a specific Extended Producer Responsibility scheme for commercial EPS (see 6.2. Implementation of the selective collection of commercial waste).

6.6. Promote the use of good cleaning practices

Description

All the stakeholders throughout the whole EPS chain generate sweeps: a fraction of dirty and small EPS waste. These sweeps are present in all phases, from the manufacture of packaging, through the transport of briquetted EPS, and in the recycling / recovery companies themselves.

If sweeps are not managed properly, they can be carried away by the wind, rainwater or cleaning water, leaking into the environment.

- **Operation Clean Sweep** OCS https://www.opcleansweep.org/ is a global initiative of the plastics industry to reduce possible leaks of microplastics, in the form of pellets, flakes or resin powder into the environment. It is a voluntary program aimed at any company related to production, transport, storage and transformation of plastic raw materials.
- Although **OCS** was created to avoid the environmental problem generated by pellets of plastic raw materials, it is a flexible program that incorporates companies that use these raw materials (pellets) and generate other pollutants such as the sweepings of the EPS processes. In fact, the OCS has already adhered several companies from the EPS sector.

Limitations

- Many stakeholders of the EPS value chain have adopted specific protocols to tackle the sweep problems, acquiring specific equipment for collection. However, measures may be insufficient and as it is voluntary, many stakeholders do not.
- Certification of environmental quality systems, which include the correct management of the sweepings among its requirements and obligations, should guarantee that companies are establishing controls to achieve it.

Recommendations

- Promote the adherence of all companies involved in the EPS cycle to Operation Clean Sweep OCS, as well as its certification (as well as by Circular Economy) by an independent entity.
- The OCS certification is specific for pellets and sweeps, but the ISO 14001 certification for Environmental Management, which many companies already have, covers this problem by establishing specific protocols. Therefore, the promotion of ISO14001 quality systems should also be promoted as a solution to this problem.
- Apart from the voluntary certifications, the legal framework should require a series of measures for infrastructure and transport linked to the EPS cycle, for example:
    - Improving the perimeter of factories and external storage areas.
    - Having a rainwater harvesting system isolated from the public sewer.
    - Blowing of trucks and containers before use.
    - Acquisition of industrial sweepers.
    - Using big-bags that close at the top or containers with lids / canvas to avoid blowing in the wind, etc. at collection points (markets, electrical appliance stores, etc.).

7. Considerations and conclusions

The objective of the OCEANWISE project is, as its title says, the reduction of EPS in marine litter. This reduction can be achieved through different routes, and one of them is **prevention**. The present survey fits into this path: after analysing the EPS flow and all considering possibilities, there have been suggested a series of actions to improve.

increasing the percentage of EPS in the management flow, we will avoid it to escape and potentially become marine litter. All measures and improvements proposed are directed to this line, that also has another aspect: bringing the management of EPS waste closer to the concept of circularity.

Proper waste management is one that aims to reduce its environmental impact. Reuse, recycling and material recovery are the best options available. However, when the technological equipment is insufficient, or the economic balance is deficient, energy recovery could be a right choice, since it avoids EPS waste becoming marine litter. Therefore, critical point 6.3. Recommendations may not be applicable and energy recovery or chemical recycling would be the only possible options.

The recommendations proposed in points 6.1. Reverse Logistics and 6.2. Implementation of selective collection for commercial waste try to tackle the same problem, although in different ways. It is the most important problem that has been identified. The lack of a specific selective collection system for EPS waste from retailers and the HORECA channel represents a leakage of EPS from the valorisation cycle. Advantages and disadvantages of both proposals:

- The implementation of an EPR scheme would increase the unit price of the boxes. As in other EPR schemes, it would be financed by an ecotax that users pay when purchase the boxes from the manufacturer.
- The logistical problems from EPS management, due to low density and high volume, would entail high expenses, so ecotax would have to be high enough to cover the expenses and, the price of the boxes would increase remarkably.
- Directive (EU) 2018/852 establishes that by the end of 2024 there should be EPR Schemes for all types of industrial and commercial waste. A specific EPR Scheme for EPS waste would only be feasible if the collection system reduce volume during the pickup process or if EPS is collected alongside other materials generated in those companies. This would require an R&D project to create an innovative system focused on this purpose.
- Reverse Logistics Systems bear many similarities to EPR schemes.
  Box manufacturers propose Reverse Logistic Systems (RLS) to stakeholders from the first level of commercialization. On the other hand, those proposed by Distribution Platforms would affect their points of sale that can be considered as retailers.
- The advantage of the RLS over the EPR scheme is that RL does not increase the price of the boxes. Logistic costs from the sale of the collected EPS waste to the recycling companies (TRAXPO, ACTECO) would be covered by stakeholders of the first level of commercialization.
- The disadvantages of RL over EPR are several:
    - Geographical limitation: any RLS would have to be profitable to last in time and, therefore, it would only be possible when collection points and destination are not far from one another.
    - Partial coverage: due to the previous problem, not all customers could benefit from using an RLS.
    - Health and food safety incompatibility: the profitability and existence of these RLS would depend on the possibility that the transports could be used for both virgin boxes and used boxes. For this, a consensus protocol or standard would be required to abide by.

Now, pellet producers are only recovering/recycling segregated at source and briquetted industrial EPS. Commercial EPS (from retailers and HORECA) ends up in energy recovery or landfills while household EPS is used in mixed plastic fraction to create less value, non-recoverable plastic.

CHAPTER 3.
Alternative to EPS fish-boxes materials waste cycle (biodegradable bioplastics) in the European market.

1. Introduction

Through the Chapter 2 of this document, ***EPS fish-boxes waste cycle through the European market***, the whole EPS waste management chain is analysed and transcripted to a flowchart figure 2.

New materials are getting more relevancy in the fight against plastic pollution. Thereby, bioplastics are the main EPS alternatives. There are some fish-boxes made with bioplastics already in the market, as well as some other box options as wool or mushroom fibres, or cardboard that are competing with EPS properties. In this chapter, we are analysing the waste management possibilities for the most relevant bioplastic alternatives to EPS, as done previously on traditional EPS fish-boxes.

Although bioplastics do not represent a huge amount of plastic in the market yet, if they would replace EPS/XPS in the near future, they would need a well stablished waste management system. For now, new materials are more expensive than traditional plastics but, as they are supposed to have less environmental impact, they are gaining ground in the market and demand is expected to grow in next years.

In this third chapter, following the flowchart from figure 3, a theoretical scenario that does not exists -at the moment- is described: management and valorisation of the waste of compostable fish-boxes (BIOEPS onwards). The only route that exists and can be really analysed is manufacturing of boxes/other tools, none of the next phases are ready to adopt and adapt to these materials so there are some possibilities and limitations that are described in the next epigraphs.

Some actors through the value chain of BIOEPS are the same as on Chapter 2 and they will not be explained again to avoid redundancy. BIOEPS would still be industrial, commercial or household waste, and the main players in the management and recycling chain there would be the same, with the exception of composting facilities that would play an important role.

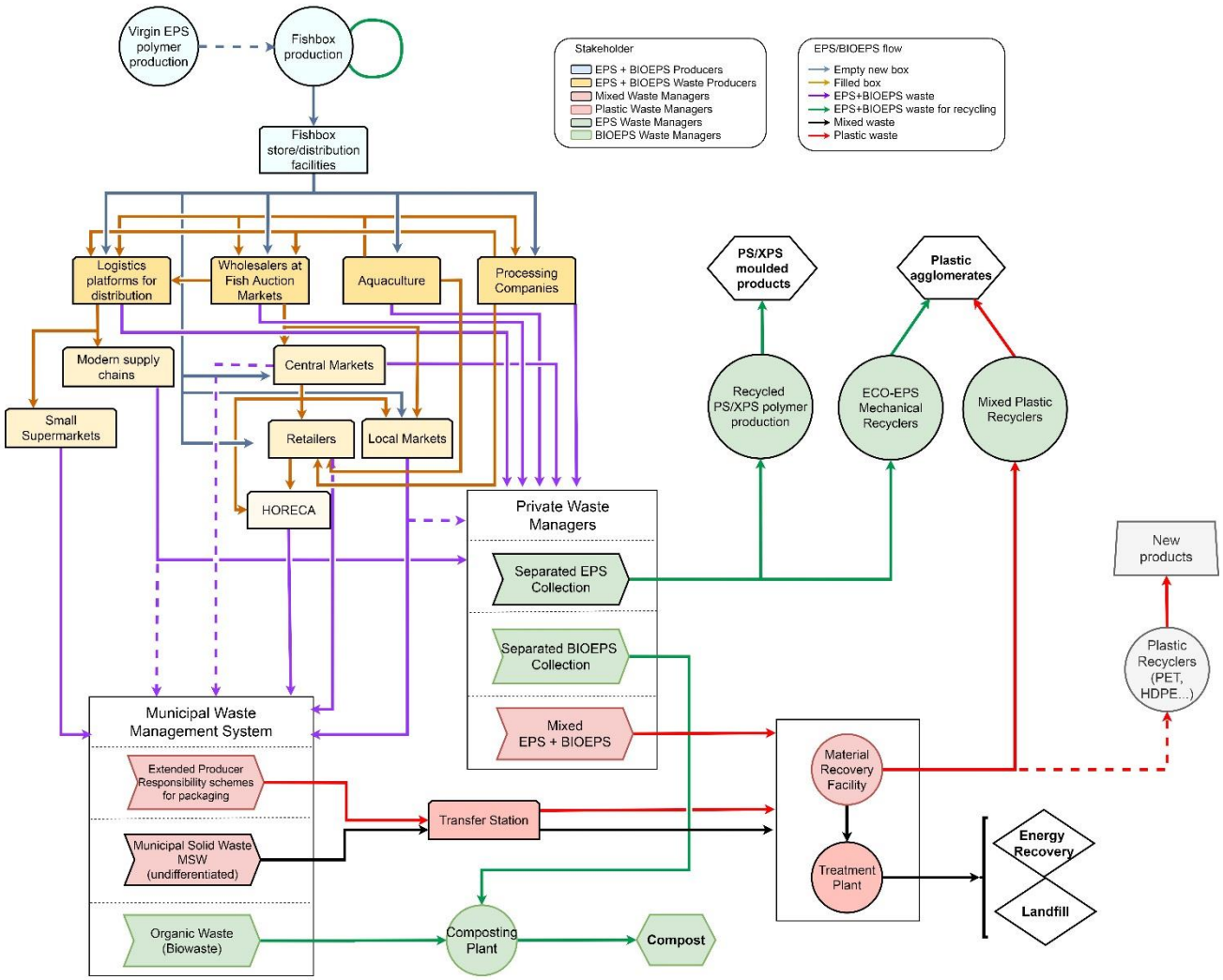
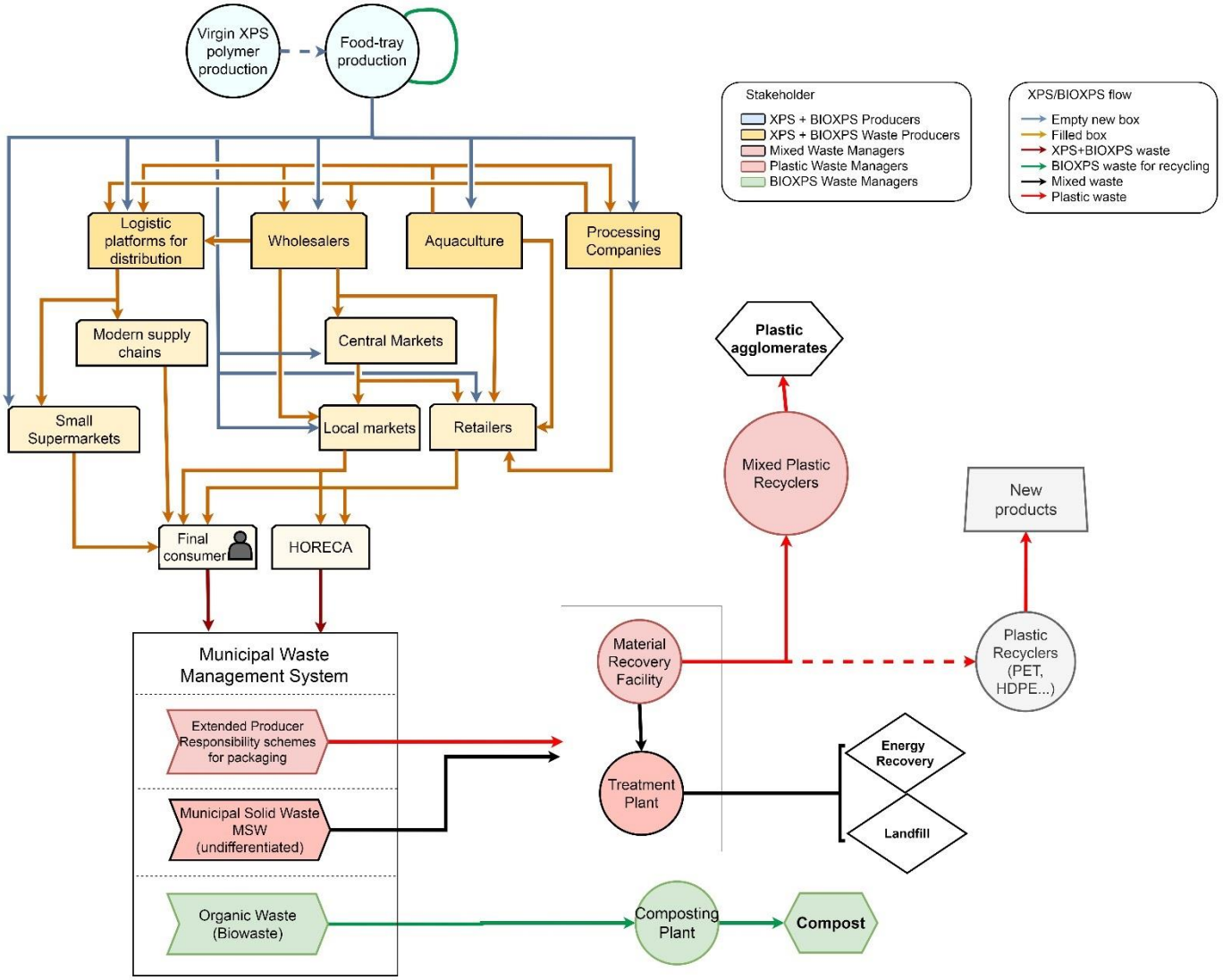


Figure 3. Flowchart of the BIOEPS fish-boxes along the supply-commercialization and waste management cycle.

FLOWCHART 3 DESCRIPTION

- **Blue**: empty new boxes flow EPS/BIOEPS
- **Yellow**: EPS/BIOEPS boxes filled with fish
- **Purple**: EPS+BIOEPS waste flow
- **Green**: EPS/BIOEPS waste separated for recycling
- **Red**: mixed plastic waste
- **Black**: mixed waste that cannot be recovered

1. The first level produces **industrial waste**. Most EPS residue is from broken boxes can be reintroduced to the production chain.
2. The second level produces **commercial waste**. Includes both distributors and commercialists of fish. In this level, EPS is used to transport fish from one stakeholder to another. Waste can be separated at source or not. As commercial waste, it is usually managed by private managers but, in some cases, small markets and retailers can use the Municipal Waste Management System for mixed waste. The HORECA channel uses the MWMS as well, as their waste is similar to households.
3. Final consumer (citizens) do not receive EPS, but XPS/PET trays.



FLOWCHART 3 DESCRIPTION

- **Blue**: empty new boxes flow XPS/BIOXPS
- **Yellow**: XPS/BIOXPS boxes filled with fish
- **Dark Red**: XPS+BIOXPS waste flow
- **Green**: BIOXPS waste separated for recycling
- **Red**: mixed plastic waste
- **Black**: mixed waste that cannot be recovered

1. The first and second level of the flowchart represent both distributors and commercialists of fish. In this level, EPS is used to transport fish from one stakeholder to another. They produce mostly EPS waste. They use XPS to sell products for final consumer and HORECA.
2. Final consumers (citizens) are the ones responsible for disposal of XPS. XPS is mostly **household waste**.

2. Types of Bioplastics: clarifying terms

Bioplastic term is not simple and includes some concepts and important definitions to understand this third chapter. Some definitions and key concepts regarding bioplastics and its end-of-life are described in this epigraph.

2.1. Definitions and types of bioplastics

As Bioplastic Europe states: bioplastics are not just a material, but a series of material's family with common features and applications. They are defined as bioplastics if they meet one of the following conditions: to be biodegradable, biobased or both. All materials are biodegradable (degradable by the action of microorganisms), but the term puts effort on the time of the degradation process. This biodegradation can be on soil, water or under composting conditions.

Info box 13. Types of bioplastics:

1. Fully or partly **bio-based and non-biodegradable** polymers, such as bio-based polyethylene (PE), polyethylene terephthalate (PET) (known as "drop-in solutions"), bio-based technical performance polymers such as polyamides (PA) and bio-based polyurethanes (PUR).
2. Polymers that are **bio-based and biodegradable**, including for example polylactic acid (PLA), polyhydroxyalkanoates (PHA), polybutylene succinate (PBS) and starch blends.
3. Polymers that are **based on fossil resources and fully biodegradable**, such as polybutylene adipate terephthalate (PBAT), but that may well be produced at least partly bio-based in the future. These materials are biodegradable as defined by accepted standards (e.g. EN 13432).

It is important to not confuse biodegradable bioplastics with oxodegradable plastics (misnamed oxo-biodegradable). This term is applied to traditional plastics, supplemented with specific additives that accelerate an irregular and only physical disintegration. This means that the plastic fragments into tiny particles that cannot be assimilated by microorganisms. This degradation can be induced by ultraviolet light (photodegradation) or by oxidation (oxofragmentation). All conventional plastic degrades, but this process can take centuries: oxo technology makes it possible to reduce this period from several hundred years to several months.

Bioplastics are being introduced in the market as a solution against plastic waste and marine litter. Through this chapter, only biodegradable and compostable bioplastics are being analysed, mostly EPS/XPS foam alike, because they are the most used bioplastics in the fish sector.

2.2. Biodegradability evaluation. UNE Norms.

There are some different labels regarding biodegradability of polymers/materials. Bioplastics can be classified as biodegradable (soil, water, marine environment) and compostable (industrial or home). Biodegradable products deteriorate naturally over time, and compostable products require a specific environment to become compost.
All compostable plastics are biodegradable, but not all biodegradable plastics are compostable.

A **compostable** bioplastic can be composted and, at the end of the process, only natural products remain: carbon dioxide, water, biomass and inorganic compounds, without any toxic waste, and at similar composting speed as other well-known compostable materials.

All items that are compostable are biodegradable, but biodegradable often doesn't entail compost-ability.

Materials certified according to ASTM D6400 (US norm) or EN 13432 and EN 14995 (EU norms) will disintegrate within 12 weeks and biodegrade at least 90% within 180 days in a municipal or industrial composting facility. Approximately 10% of solid material will be left at the end of the six-month-long process in the form of valuable compost, or biomass and water. These standards also ensure that the leftover compost will be free of toxins, so the compost will not cause harm when the facility sells it for gardening or agricultural applications.

A **soil biodegradable** plastic can biodegrade totally within 45 days to 6 months in aerobic conditions when it is deposited isolated in soils. The international norm is **EN ISO 175561**. This norm is based on measuring CO2 by gravimetry or automatic detection.

A **water biodegradable** plastic can biodegrade within 30-60 days when in the water column and it is certificated by international norms **ISO 196791 and ISO 162212** which determine % CO2 evolved.

Oxodegradable plastics do not fit any of these EN norms as they are not biodegradable, so they are neither compostable, nor biodegradable in water or soils.

2.3. Types of bioplastics of new biofoams

There are some companies selling similar to EPS foams made with biodegradable bioplastics. Commercial brands must be differentiated from raw materials, that are in fact different plastics.

Biocompostable are the most used plastics in manufacturing of foam boxes, but it is important to know they can degrade only under composting conditions (EN 13432 and EN 14995, means specific temperature, moisture and bacteria) but not in soil or water environment (ISO 196791 and ISO 162212) where EPS becomes a part of marine litter.

A compostable plastic is biodegradable under composting conditions, but not in natural soil, water or marine environment.

For now, there are not any option biodegradable in water or marine environment and suitable as an EPS alternative. That would be the best material to face marine litter. A Japanese company, KANEKA CORPORATION, has developed poly 3-hydroxybutyrate-hexanoate derived

from biomass to manufacture and sell PHBH boxes, biodegradable both in marine and composting conditions (marine safe standards are non-certified yet).

Within the OCEANWISE project scope, we are developing an action to compare traditional EPS boxes versus some BIOEPS boxes in the market. The trials are simulating transportation, conservation and storage of different fishes in a 5 days period, and further analysis both of biochemical and microbiological characteristics. Also, biodegradation and ecotoxicity of materials are being analysed. The market brands and companies chosen for these trials are in the box below (Info box 14).

Info box 14. Companies and market brands in the Oceanwise living-labs:

STOROPACK https://www.storopack.es/

- ✓ *SEAclic BOX BIOBASIERT* based on the ECOVIO polymer developed and made by BASF, based on ecoflex (a biodegradable plastic developed by themselves) and PLA.
- ✓ It fits the requirements by EN 13432, so it is industrial compostable.
- ✓ ECOVIO is a very versatile raw material, not exclusive for foam packaging. It is used in many products as paper coat, films, etc.
- ✓ This material can be processed/moulded on EPS processing equipment's.

BEWISYNBRA https://bewisynbra.com/

- ✓ *BIOFOAM – PLA* boxes based on a BioFoam E-PLA polymer developed with polylactic acid (PLA) obtained from sugar cane.
- ✓ It accomplishes EN 13432 standards, so it is industrial compostable.
- ✓ This material can be processed/moulded on EPS processing equipment's.

KANEKA CORPORATION https://www.kaneka.co.jp/en/

- ✓ *PHBH* boxes based on a PHBH polymer. It is a biomass-based bioplastic (poly 3-hydroxybutyrate-hexanoate) obtained by bacterial fermentation of biomass.
- ✓ It follows ASTM D7081 standards (equivalent to EU EN 13432) so it is compostable under industrial conditions.
- ✓ It is a versatile material that it is already used by many single use products as cutlery, food packaging, straws, etc.
- ✓ This material can be processed/moulded on EPS processing equipment's.
- ✓ The PHBH follows "OK biodegradable Marine" standards by TÜV Austria-Vinçotte, so it is also biodegradable in marine environment material. It is pending on its certification.

TÜV Austria-Vinçotte, in accordance with regulations on biodegradability of plastics (such as EN 14987 or ASTM D7081) and ISO 17556, has promoted the Ok Biodegradable certification system, which determines the time necessary for biodegradation and the environment necessary for it to be decompose. Thus, it certifies biodegradability in the marine environment (90% of the total mass of the product must biodegrade in six months), fresh water (90% biodegradability in 56 days) and soil (90% biodegradability in two years).

As it is stated on the previous epigraph and glossary, any box made with biodegradable plastics will be referred as to BIOEPS, both degradable in soil, water or under composting conditions.

3. EPS packaging manufacturers

Until date, most alternatives to traditional EPS are also expansible materials which may result in boxes similar to EPS boxes and are moulded in the same equipment as EPS. These BIOEPS boxes are sell by EPS boxes manufacturers as well. Nevertheless, some limitations are mention below:

- There may be some differences in the manufacturing process: variables, parameters, and equipment needed in each phase of the process may be different than to traditional EPS.
- manufacturing EPS and BIOEPS boxes at the same time, may require huge investments in space, infrastructure and machines in order to avoid contamination of materials, energy needs, cleaning, water consumption...
- Storage facilities and logistic have to be adapted to this new approach.

4. Distribution channel

4.1. First level of the distribution channel

- Processing companies, aquaculture, wholesalers (nearby ports) and logistic distribution platforms are detailed in the 3.1 First level of the commercialization and distribution channel (page 19) in the second chapter of the document. It describes actions of these stakeholders relating EPS uses (fish-boxes) and waste.
- In this new approach, EPS and BIOEPS boxes might be used simultaneously and that would generate waste of two different materials.
- Private Waste Managers are who collect and manage waste from this first level. Separation of waste at source or collection of mixed waste to be later segregated at the managers' sorting facilities.
    - In small ports, wholesalers are located in auction fish markets or nearby. Waste management depends on Port Authorities, who delegate in a private waste manager. EPS waste volume is high, so they usually have briquette machines. Problems:
    - EPS and BIOEPS are made with different polymers that cannot be valorised altogether. Materials have to be segregated before briquetting.
    - Small pieces of BIOEPS in the EPS waste could decrease valorisation of EPS into XPS pellets. Materials shall not mix while briquetting.
    - End-of-life of BIOEPS is mostly composting, so composting facilities would have to acquire machines to undo the briquettes.
- Info box 3 on epigraph 3.1 First level of the commercialization and distribution channel (page 19) shows in detail how EPS waste is managed through the different stakeholders in this level. Having EPS as well as BIOEPS altogether wouldn't change much that epigraph, despite of the fact that those stakeholders and managers who had both EPS and BIOEPS would have to facilitate the separation of the different materials.

4.2. Second level of the distribution channel

- **Modern Supply Chains**, **Small Supermarkets**, **Central markets of big cities - MERCAS** - (wholesalers), **Local Markets** (Retailers), **Retailers** located outside these Markets and the **HORECA** channel (hotels, restaurants and coffee shops). the 3.2 Second level of the commercialization and distribution channel (page 19) of chapter 2 describes the stakeholders management of EPS and EPS waste.
- With the exception of some retailers, the EPS and BIOEPS waste generated would come from diversity of activities as fishing, fruits and vegetables, meat industry, etc.

- Wholesalers located on the big MERCAS are the ones who supply their own products on EPS/BIOEPS to sell them to retailers or the HORECA market. All the other players from this second level of the distribution channel sell products to the final consumer/citizens without using EPS.
- Management of commercial EPS and BIOEPS would be through a private or public authorized manager who operate differently:
    - Private waste managers collect EPS/BIOEPS separately or mixed with the plastic fraction. At the same time, EPS and BIOEPS could be collected separately or mixed at source. When collected mixed, separation would be in the managers' infrastructures.
    - There is no selective collection for EPS or BIOEPS in the MWMS. These materials would be more likely deposited and collected with the packaging fraction or the rest fraction.
- Info box 4 in 3.2 Second level of the commercialization and distribution channel (page 19), describes EPS waste management. The presence of BIOEPS would not change that 3.2 epigraph. It is important to note that EPS and BIOEPS must be completely separated because they have different way of valorisation. So, either BIOEPS is separated at source or in the manager's facilities.

5. Waste Management

Waste management is described in 4. Waste Management (page 21). As a recap: stakeholders from the distribution levels usually manage their waste through two main groups: *Municipal Waste Management System* (public) and *Private Waste Manager* (private).

5.1. Municipal Waste Management System (MWMS)

Details about the MWMS are described in 4.2 Municipal Waste Management System (page 23). They are in charge of the management of household waste and logistics of the packaging fractions as agreed with the different EPR schemes (ECOEMBES, SPV, REPAK, etc.).

- MWMS manages only household waste, not commercial/industrial waste. In some cases (depending on the municipality and business), small retailers (commercial waste) can deposit their waste in the same containers as citizens if they pay a specific tax.
- The presence of BIOEPS does not change the scenario. Waste collected as Municipal Solid Waste (MSW) is a mixed of many organic and inorganic and cannot be selected in the MRF facilities. This waste is likely to end up as EtW or landfills.
- Household plastic packaging waste is collected in specific containers (usually yellow containers) managed by the EPR schemes. The scope of these containers is exclusively for household, they do not cover commercial nor industrial waste.
- Bioplastics can reach final consumer (citizens) as they can be moulded in a lot of different forms of packaging (as bags, protection foam for small electronic devices, food trays, etc.). This implies a risk of bioplastics being deposited into the yellow containers of the EPR schemes, mixed with traditional plastics.

5.2. Private Waste Managers

In 4.3 Private Waste Managers (page 24) are the details about these Private Waste Managers.

- All the stakeholders from the first level of commercialization and some of the second level (the clients of the waste managers) can generate both EPS and BIOEPS waste. Valorisation of both materials at the same time is not possible and, if BIOEPS is mixed with EPS, valorisation would be more difficult. It is important that waste is separated. There are two options to do this:
    - Separation at source by the stakeholders
    - Selection at the waste manager facility
- Waste likely to end up as waste to energy (energy recovery) needs no segregation.

6. Waste treatment

Epigraph 5. Waste treatment (page 24) describes a global view about treatment and valorisation, companies which develop these activities and how EPS valorisation depends on collection and treatment systems.

It is important to note that even though EPS waste can be recovered into PS/XPS pellets or construction panels, BIOEPS is not recoverable: it can only be composted or transformed into WtE (energy recovery).

6.1. Material Recovery Facilities

Epigraph 5.1 Material Recovery Facilities (MRFs) (page 25) describes the main characteristics of these facilities. To sum up, the aim of these companies is to separate packaging accordingly to typology (PET, HDPE, LDPE, steel, aluminium…). They sort materials from household packaging and some commercial packaging waste managed by the Municipal Waste Management System MWMS (yellow containers of EPR schemes).

These facilities sort recyclable materials and prepare them to be sold to end-user manufacturers. Non-recyclable and low-valuable materials are prepared to dispose in landfills or energy recovery WtE.

- These MRF do not have implemented technology to sort bioplastics. BIOEPS (and all biodegradable plastics) mixed with other plastics (PET, HDPE, LDPE) would devaluate their valorisation.
- Profitability is a key factor in these public-private companies, and the separation of bioplastics would increase recycled plastics' prices.

6.2. Recyclers

Epigraph 5.2 Recyclers (page 26) describes the main characteristics of these companies. To sum up: they are the last step of the management chain, specialized in obtaining pellets from EPS waste. BIOEPS are not an exclusive material, but they can be made with different polymers. BIOEPS polymers are not designed to be recycled.

PS/XPS Pellet producers

They product PS/XPS pellets from EPS waste. Pellets are use in the construction and automotive sectors.

- The only material accepted is EPS. It must be 100% pure, briquetted.
- BIOEPS would be a constraint in the recycling process and quality of the final product.
- BIOEPS are a different polymer that cannot be recovered in the same process as EPS.

EPS panels for construction producers

EPS waste is used mixed with virgin EPS to manufacture aisle panels for the construction sector.

- The thermal manufacturing process is complex and there is no place for contamination by any other material. BIOEPS could not be processed with EPS in this process.

6.3. Energy recovery (WtE)

Epigraph 5.3 Energy recovery (WtE) (page 27) describes the main characteristics. To sum up: energy recovery (waste to Energy) is how waste is transformed to energy: as electric energy, steam or hot water for homes or industrial uses.

When a subproduct/waste cannot be reintroduced in an industrial process or recycled, it is used as WtE. Not only plastics, but all materials are susceptible of being managed this way.

- BIOEPS and most packaging made with bioplastics have much calorific power. It can be recovered as energy in these plants.
- BIOEPS can be mixed with all type of materials, even EPS or another plastic, to be transformed into energy (mix of materials does not affect the process).

6.4. Landfill

Epigraph 5.4 Landfill (page 27) describes the main characteristics. To sum up: landfills are sites for disposal of waste materials.

- Most biodegradable materials are not biodegradables in soil, but under composting conditions. In the case of BIOEPS, some products would degrade with time, but not all of them.
- Directive (EU) 2018/850 on the landfill stablishes restrictions on landfilling and sets as non-acceptable waste in landfills all waste that has been separately collected.

6.5. Composting

Biodegradable plastics are not designed to be recycled. Valorisation of these materials is by biodegradation and composting.

Compost is a soil amendment/fertilizer resulting from organic matter that has been decomposed. It is a biological, aerobic and termophilic-process in what some microorganisms break down organic matters (biodegradable) obtaining compost, a soil conditioner with high agriculture value, water and carbon dioxide. The microorganisms that transform organic matter into compost require specific conditions to live in and survive: temperature,

oxygen/aeration and moisture. Composting is not a spontaneous process in the natural environment.

Composting is a long process. It takes around two to three months until the last stage: maturation. After that, compost is stable and ready to use. A mixture of organic materials (grass clippings, leaves, hay, straw, weeds, manure, chopped corncobs, cornstalks, kitchen and garden refuse…) are required for having an optimal final product in terms of nutrients, organic matter, moisture and aeration to optimize the necessary oxygen conditions.

- BIOEPS for composting must be well separated at source, because traditional (fuel-based) EPS would not degrade in composting conditions and it would damage the final product (compost).
- Composting plants do not have the ability to recognise biodegradable bioplastics. They have to discard all plastics that may enter their facilities.
- Companies can decide the usage of BIOEPS as raw material for composting, they are not obliged by law. It is not clear that all BIOEPS on the market would be composted because the capacity and number of composting plants are not enough.

7. Considerations and conclusion

Some points to improve within the value-chain (critical points) and also recommendations to achieve them are discussed through the second chapter of this document, *EPS fish-boxes waste cycle through the European market,* 7. Considerations and conclusions (page 34). All of these points are structured in 6 small epigraphs: 6. Critical points and recommendations (page 28).

In the third part of this document, a theoretic value-chain for BIOEPS is introduced as there is none for real evaluation. Bioplastics are not well stablished yet into the market and there are no measures for management and recovery.

7.1. Considerations

1. Biodegradable plastics are introduced into the market as an alternative to traditional durable plastics. In some cases, these biodegradable bioplastics can be moulded in different shapes to be similar EPS boxes. These BIOEPS boxes are biodegradable under different conditions: marine safe, compostable or soil degradable. These properties must be certificated under UNE norms.
2. Within the many companies that manufacture BIOEPS boxes, only one of them certify water biodegradation. This is key regarding marine litter because a compostable material may biodegrade under certain conditions, but not when it is disposed in the natural or marine environments.
3. Managing and valorisation of EPS and BIOEPS waste:
   - BIOEPS is not recoverable. The end-of-life of these materials is composting. If there are no composting facilities, they only can be used as waste to energy and landfills.
   - For the time being, there are no stablished management system for biodegradable plastics. Most of the Atlantic Area countries do not have implemented the Directive (EU) 2018/851 on waste that obliges to collect biowaste separately. For now, biowaste is not collected separately for composting. When the Directive is implemented and

biowaste collection is well-stablished, management of biodegradable materials that reach consumers are to be managed through biowaste selective collection.
   - It is necessary to manage (segregate) EPS and BIOEPS at source because they have different options of valorisation. Pellets of one into the valorisation chain of the other may be an issue and compromise the process and final recycled product.
   - EPS waste is highly demanded for valorisation/recycling to manufacture PS/XPS pellets.
4. Stakeholders using EPS and BIOEPS are from the first and second commercialization level. If they use both materials, they generate both residues:
   - Stakeholders should segregate them at source but, this is not probable to happen. In one hand, they would have to increase human resources for this action and, on the other hand, EPS and BIOEPS are not the only residues they have, but many other materials.
   - With some exceptions, private waste managers usually collect mixed waste. Collection of waste from selective containers imply more infrastructure and logistic costs.
5. Rest fraction containers of the MWMS and yellow containers from EPR schemes would also collect some EPS and BIOEPS waste, both household and commercial (mostly from retailers). In both ways, waste would reach the Material Recovery Facilities (MRF):
   - Technology on MRF facilities cannot segregate biodegradable plastics.
   - BIOEPS waste must be segregated at source and collected in a specific kerbside container for biowaste.
   - EPR schemes do not cover biodegradable bioplastics management. This should be reconsidered in order to collect and manage these materials correctly.
6. New materials and new waste involve new challenges. Segregation should be adequate:
   - Citizens and companies must be aware of the importance of segregation, and learn to recognize plastics and bioplastics. Bioplastics must have label differentiation.
   - Some companies are launching BIOEPS boxes with brown coloration into the market, but some other BIOEPS have a similar colour than EPS. There is no stablished norm for this matter.
7. Composting is the optimal end-of-life for the BIOEPS boxes. R+D are looking for some environmentally friendly products: sustainable and within the circular economy. Some issues were found regarding this matter:
   - UNE norms 13432 and 14995 set ranges between 45 and 180 days for materials to biodegrade. In case of biodegradable plastics, each material may have different degradation paces.
   - Maturation (last stage of composting) of compost in the composting facilities take up to 90 days. Organic matter used in the plants would degrade much faster than most BIOEPS so there would be a slower rate to obtain a quality compost, which decrease profitability of these facilities.
   - As different BIOEPS take different time to biodegrade and have different polymer composition, using BIOEPS would change the final product as well. BIOEPS may have to be segregated to adapt the composting process according to the rates of degradation and desirable final composition.
   - In an agronomic approach, specific nutrients and fertilizers/amendments are usually sold for a specific crop or plants. In terms of launching this compost made of BIOEPS into the market, it seems necessary to look at what crops would benefit the most from

this new product. The product has to prove advantages in comparison with other fertilizers/amendments in order to be competitive and increase demand.

7.2. Conclusions

1. Using biodegradable bioplastics as raw material for manufacturing similar to EPS fish-boxes does not seem to be a solution for the problem of EPS litter in the ocean. In many cases, alternative to EPS boxes launched in the market are made of compostable BIOEPS that will remain as a problem of marine litter once they reach the ocean.
2. There are some marine safe materials (biodegradable in marine environments) that could represent a baseline but they are not well stablished yet.
3. Compostable bioplastics (the most used bioplastics) are in line to sustainability and circularity, but only when valorising them as compost. Dependency on composting plants is huge and biowaste management systems are not stablished yet.
4. Biodegradable bioplastics are not recoverable. Composting is the only end-of-life for these materials (aside from WtE and landfills).
5. Biodegradable plastics do not always contribute positively into the plastic littering situation, on contrary:
    - Additional containers, new EPR schemes strategies, labelling and awareness are some of the measures needed for stablishing a new management system. There have been some pilot actions of implementation, but no real plans.
    - Compost companies are not ready to manage big amount of BIOEPS boxes (or even biopackaging in general): a very good segregation at source is mandatory for this purpose because, as stated before, BIOEPS usually takes longer to compost than other compostable materials. Furthermore, there are no agronomical proof validating the advantages of using BIOEPS as a raw material for compost elaboration (in terms of nutrients and soil benefits), so there is no demand for this product.
    - Composting companies cannot differentiate biodegradable plastics vs non-biodegradable. They have to discard all plastic that may enter their facilities to avoid contamination of the final product.