CIRCULARSEAS

WP4 - DIAGNOSIS REPORT ON CIRCULAR PLASTIC FOR MARITIME INDUSTRIES IN ATLANTIC AREA

Compilation of results and conclusions from:

- Regional Diagnosis in 5 Nodes (Ondarroa, Vigo, La rochelle, Cork and Peniche)
- Benchmarking of Plastic Waste Removal Models
- Characterization of Plastic Waste Samples
- Plastic Parts Needs of Maritime Industries
- Technology Trends in 3D Printing Technology

INTERREG
Atlantic Area

EAPA_117/2018 – CIRCULARSEAS
"Turning ocean plastic waste into green products for maritime industries"

1. INTRODUCTION

1.1 The CIRCULARSEAS Project

The CircularSeas project aims at the promotion of the Green Economy in Atlantic Area, to i) adapt and diversify economic activities fully tapping Green Growth potential and ii) to reduce the environmental impact in the ocean. The main objective is turning Ocean Plastic Waste into Green Products for Maritime Industries.

The overall objective is to promote the development of eco innovative or green products, parts and components by three Maritime Industries, by the combination of 3DP technology and the use of recycled ocean plastic waste and new biodegradable, renewable and high-performance polymers.

1.2 Diagnosis Report in Circular Plastic for Maritime Industries

1.2.1 Introduction

This document collects the information regarding the plastic waste that is generated in the port of all Nodes involved and, in the industries, related to the activity of the port. Once the mapping and characterization of the plastic waste has been carried out, the ways to manage that waste are detailed. And finally, possible green products that could be created from the plastic waste as well as biodegradable materials are presented with real application in one of the target industries defined in all Nodes, thus generating new activity in the Nodes.

The target industries considered for the diagnosis are the following:

- Fishing, auxiliary fishing and aquaculture.
- Shipyards and port management.
- Nautical sports (surf, sailing, diving).

There are five nodes that have made the diagnosis: Ondarroa (ES), Vigo (ES), La Rochelle (FR), Cork (IE), Peniche (PT). In this report, the diagnosis of all Nodes is collected under the coordination of Azaro Fundazioa.

Therefore, 5 Diagnosis Reports have been generated, one per node, containing information from:

- Mapping and characterization of Ocean Plastic Waste.
- Ocean waste disposal or management practices.
- Identification of Industrial parts and auxiliary components based on plastic.

For more information about the reports please see in annex number x all reports.

A proposal is being made to try to use recycled plastic and greener materials in the maritime industries using 3D printing technology for the manufacture of necessary parts in the maritime industry.

The diagnosis will also be taken into account for the elaboration of 6 Policy Briefs with results at regional level of Diagnosis (WP4).

1.2.2 Method for diagnosis

In each Node the steps that have been taken to carry out the diagnosis are the following ones:

1. Description of each Node.

   1.1 Short History of the port, current situation of the main economic activities that take place in the port and main characteristics.

   1.2 General characteristics of each Node-Port: economic activities in each target industry and main agents of each Node and target industry.

   - Economic activities that take place in the selected target industry.

   - Number of companies for each economic activity.

   - Number of jobs for each economic activity.

   - Main Manufacturing technologies for each type of economic activity.

2. Definition of the sample to realize the questionnaire

in each Node.

2.1 Detail of the people who are going to be interviewed and visits/ interviews planning.

3. Execution of the questionnaire, according to the defined visit plan.

4. Transfer to Leartiker, Leader Project, the 3 templates filled in by each company interviewed in each Node.

Notes and observations on how it has been done:

- Azaro has provided a workplan, along with the schedule and templates to carry out the diagnosis in the same way, and thus obtain a homogenized diagnosis.

- Thus, one of the templates has been the quantification and description of each Target Industry in each node.

- For this, each Node has collected the characteristics of each target industry, quantifying the number of companies and employment and describing the main activities of each target.

- In this way, it has been possible to classify the companies with the most employees, and thus prioritize who could carry out the interviews.

- Due to the different dimensions of each node or port of the partners, it has been agreed between the partners to interview at least 5 companies from each target industry.

- Thereby, the companies that have the biggest number of employees have been classified, or companies that have a link with plastic waste have been taken into account as generators or managers.

- It should be noted that in some Nodes it has not been possible to describe in detail each of the activities of each target industry, due to the breadth and variety of activities in some territories.

- In these cases, cases have been extrapolated and some Nodes have focused on the economic activities of greater volume or linked to the material or plastic waste. As has been the case in Vigo and Cork for example.

- On the definition of GREEN PRODUCT, the partners of CircularSeas agreed:

A green product could be a product made by:

- 100% recycled plastic or other materials.
- Bio-plastics.
- X % recycled plastic or other material.
- Non recycled material – other materials that could enlarge the product's life.

GREEN PRODUCT IDENTIFICATION: (Template 3 – survey).

Another point of view to identify the green product in the interviews:

a. Could be a product that has a high breakage so it could be replaced by a product made by one of the possibilities mentioned before.

b. Maybe nowadays the product does not exist physically – the identification of the green product could be a diversification opportunity for one of the target industries interviewed. i.e. a supplier of plastic packaging (tanks) would like to produce a film/box/plastic bag.

Note: The green product has to be part of the economic activity of one of the 3 target industries. i.e. a part of the bench of the port is NOT a green product but a part of the bench of a sailing boat YES.

- The identification of the green product has been based on a survey with scripted questions and some of the partners have adapted it to the character and needs of their business characters for the good of the project.

- During the entire process of diagnosing the Nodes, Azaro Fundazioa has coordinated the partners through e-meetings and face-to-face meetings with the leader.

- Due to COVID-19 the work schedule has been altered in some Nodes.

- Due to COVID-19 some of the interviews could not be done in person or the sample waste was collected later than expected, which has delayed the analytics, etc.

2. REPORTS' GENERAL CONCLUSIONS

Introduction:

In this section of the document, the objective is to summarize the diagnostic reports of 5 Nodes in the Atlantic Area. The objective of each Node is based on 3 sections summarized as follows:

a. Description of Target Industries: each Node has quantified and described the three ITs of its Node, with the aim of analyzing the evolution of each sector, they have identified the weight in each IT, quantifying companies and the number of employees, technologies and capabilities they know.

b. Identification of waste and its management: Each IT has been analyzed by breaking down each economic activity for the identification of the plastic waste in each activity, its quantification and its management. To find out whether these wastes are managed in a sustainable way nowadays.

c. Identification of the green product: in order to close the circle, each partner has asked different economic activities of their Node the need for a more sustainable product following the questionnaire. In this way, the potential Green products to be taken into account in each Node have been identified.

General conclusions of each target industry in 5 Nodes:

2.1 TARGET INDUSTRY 1

Here a summary of each of the activities within target industry 1 is collected with a generalized vision taking into account the 5 nodes analyzed. In this first target industry these economic activities have been analyzed:

1- Fishing: Economic activity that consists of fishing and producing fish, shellfish and other marine products for human consumption or as a raw material for processes.

2- Auxiliary fishing: Activities linked to fishing such as: transport, conservation and processing, maintenance, distribution, classification, recovery and production of food products.

3- Aquaculture: Set of activities, techniques and knowledge of breeding of aquatic species and animals. It is an important economic activity of food production, raw materials for industrial and pharmaceutical use, and living organisms for repopulation or ornamentation.

2.1.1 Fishing

The fishing sector has historically been the source or main economic activity to support the territories linked to the analyzed Nodes. But over the years, as shown in the data from La Rochelle, Peniche and Ondarroa, the extractive fishing fleets have been decreasing due to the fishing policy implemented from the EU and the strategies towards more sustainable and selective fishing. However, it should be noted that in the nodes participating in the diagnosis there are two very important fishing ports such as Vigo with around 600 registered boats and Castletownbere in Cork, with a turnover of 90M euros.

Although the fisheries activity has been decreasing, the auxiliary industry activity has innovated and both activities together has more volume of activity than the rest ones. Therefore, the 5 Nodes have chosen the first target industry as the main activity for the analysis in the diagnosis.

It should be noted that fishing has been the driving economic activity that has contributed to the growth of auxiliary industries. This has also caused that technologies related to fishing have evolved remarkably, from fishing gear, navigation, netting, rope to the handling of fresh or frozen fish.

2.1.2 Auxiliary fishing

In some nodes of TI 1 such as Peniche and Vigo, the auxiliary industry has more weight than fishing. In Vigo, for example, the largest number of employees (1,015)

resides in auxiliary fishing. For instance, "Nueva Pescanova SL" is a stakeholder company that has 10,000 employees in 4 continents and 70 vessels fishing in the southern hemisphere. It has fishing activity, farming, processing and shell.

In Peniche auxiliary fishing is also the highest sector in terms of employment (1,327 jobs) compared to Fishing (294 jobs), and aquaculture is almost imperceptive with only 4 jobs. In auxiliary fishing the processing and preserving of fish, crustaceans and molluscs is a sector responsible for a huge employability compared to Wholesalers of other foods, including fish, crustaceans and molluscs. Retail sale of fish, crustaceans and molluscs in specialized stores is the sector with the lowest employment rate within auxiliary fishing activities.

2.1.3 Aquaculture

Comparing Aquaculture to the two mentioned activities above within TI1, the former is less relevant in overall Nodes. But in the case of La Rochelle aquaculture has more weight in terms of employment and registered companies. Oyster and mussel farming employs more than 300 people in 116 companies, considering that TI 1 in Rochelle is no less than 240 companies in the territory of CdA-LR and accounts for around 790 jobs.

In Cork Node, aquaculture also stands out as the main activity of TI 1. Aquaculture provides just under two thousand people with employment across all farming and processing businesses. This industry in Cork mostly deals with mussel farming, with a small number of operations in the South focused on crustaceans and oyster harvesting. Across all these branches of the fisheries sector, just over nine thousand people are employed which elevates this sector of Cork node to a primary sector.

In the case of the Ondarroa Node, it is one of the growing activities also promoted by the fisheries and aquaculture policies in order to obtain a strong fishing-aquaculture binomial activity in the Atlantic ports.

2.1.4 Technologies in TI 1

The technologies used in TI1 are compiled in Table 1. A wide variety of technologies are used, considering that several different economic activities are comprised within this target industry. This opens an extensive range of applications for materials developed within the CircularSeas project.

***Table 1**: Compilation of the main technologies in the Target Industry 1.*

Most relevant economic activities	Most relevant related technologies
Marine fishing	• Classification technologies • Handling technologies • Cold technologies • Machining technologies • Freezing technologies • Extraction technologies • Trawling • Longline (line) • In the net • Locker • Unloading by crane • Pallet trucks • Splitting of fishing nets • Beam and pelagic trawling • Radar, sonar, GPS equipment • Radio & Internet • Fishing with Nets, mainly by Purse and Trawling • Harvesting Shellfish, mainly by Traps, Pots and Dredge
Aquaculture	• Bouchot breeding (mussels) • Aging on an oyster table (oysters) • Aging on the chain (oysters) • Rearing on rope (mussels) • Collection by spat collectors • Detaching • Elevation by crane • Refining • Classification / sorting process: warehousing and storage. • Packaging, wrapping • Marine aquaculture technologies • Grower beds / netting • Tanks • Vessels for dredging • Radar, Radio communications
Fish trade and wholesale trade of other food, including fish, crustaceans and molluscs and warehousing and storage	• Cold technology: cold room. • Classification / sorting process for seafood: sorting machine (conveyor belt). • Weighing • Warehousing / storage • Handling (Packaging / Labeling / Pallet trucks) • Food handling technologies: fish cutting (nets cut with a knife). • Auction sale

INDEX

Retail sale of fish and seafood in specialized stores	• Cold technology: cold room. • Warehousing / storage • Packing / Conditioning • Food handling technologies • Retail
Processing and preserving of fish, crustaceans and molluscs	• Freezing technologies • Food handling technologies: cookers... • Freezing technologies • Cold technologies • Handling technologies
Manufacture of cordage, rope, twine and netting	• Machining technologies • Braiding technologies • Injection technologies • Extrusion technologies
Preserves: fish processing for human consumption	• Canning technology- grinding and mixing, curing, inlaying, cooking, cooling, coat, dyeing, filleting (Conservation of fishery and aquaculture products in olive oil and other vegetable oils and other sauces) • Food processing technologies • Weighing scales • Knives • Packaging/ wrapping machinery • Panel and container haulage equipment • Food processing technologies
Wholesale of other food, including fish, crustaceans and molluscs and warehousing and storage	• Cold storage • Fish classification process: warehousing and storage. • Warehousing and storage machinery, e.g. fork trucks • Classification technologies • Vision technologies • Food handling technologies
Storage	• Cold storage • Warehousing and storage machinery, e.g. fork trucks
Net manufacturing	• Weaving equipment, • Textile machinery • Fishing net needles • Net and line haulers
Vessel manufacture and repair	• Injection moulding • Furnace/oven equipment
Transport / Haulage	• Panel and container haulage equipment
Coastal protection & conservation Transport / Haulage	• Mapping software • Survey equipment • Panel and container haulage equipment

INDEX

2.2 TARGET INDUSTRY 2

The economic activities linked with Target Industry 2 are the following ones:

1- Shipyard. Place where ships are built and repaired.

2- Port management. Management of human resources, channels, lighters, warehouses, movement of ships, maritime economy applied to ports, efficiency and other information.

After all Nodes were analyzed, it has been found that La Rochelle has the most weight in this target industry with 51% of the total economic activity and 3,000 jobs. It comprises the following economic activities: preparation and maintenance of boats; equipment; distribution; supply of services; training and organization infrastructures.

In summary, it must be said that none of the Nodes has focused on this Target Industry. One of the reasons relates to the generation of plastic, since the economic activities linked to target industry 2 are not big generators of thermoplastic materials. In La Rochelle case, there are more managers of plastic waste and their activity is more related to the revalorization of the waste.

2.2.1 Technologies in TI 2

The following table summarizes technologies used in target industry 2. As it can be observed, here technologies focus mainly in those used for composites based on thermoset plastics, which are used in ships and boats. These are more difficult to recycle nowadays, but it will be of importance in the next years, especially to recover high-value materials such reinforcement fibers (carbon or glass fibers). Steel, wood and aluminum processing technologies are also observed. All these materials fall out of the scope of the CircularSeas Project, however, applications might be found where those materials are replaced by recycled thermoplastics.

***Table 2**: Compilation of the main technologies in the Target Industry 2.*

Most relevant economic activities	Most relevant related technologies
Construction	• Infusion technology • Injection technology • Simultaneous projection technology • Antifouling
Equipment manufacturers	• Machining technology • Design by 3D software • Anodization technology
Shipbuilding and floating structures	• Machining technologies • Light Resin Transfer Molding, Lamination and Infusion technologies
Regulation of economic activity and contribution to its greater efficiency	• Management technologies
Building of ships and floating structures	• Construction technology in composites, steel, wood and aluminum
Cathodic protection anti-corrosion	• Zinc casting
Repair and maintenance of ships and boats	• Stripping, washing, cleaning and painting • Metal repairs, welding • Overhaul of machinery and mechanical repairs • Overhaul and repair of hydraulic systems • Overhaul and repair of electrical systems

2.3 TARGET INDUSTRY 3

Nautical target industries include different industries, most related with sport practice, spare time and tourism: surfing activities, sailing activities, diving activities, nautical clubs, design, manufacture and installation of marinas, etc.

After diagnosing the Nodes, it can be deduced that TI3 and the activities related to them are still a complement or complementary activities in the economy of the Nodes analyzed. However, it is one of the activities on the rise in the Peniche Node since tourism is very close to the coastal areas and is one of the activities that is also promoted in local development programs such as the GALP in the Basque Country.

Cork is one of the nodes that has more weight in this target industry and has concentrated its analysis also on this activity. That sees the need for the implementation of a green product for this sector.

2.3.1 Technologies in TI 3

Observing the technologies used in TI3 (Table 3), different processes are observed using several materials. Here applications for recycled or new greener materials through 3D printing are identified, as for example manufacture for utensils or equipment for surfing or related activities.

***Table 3**: Compilation of the main technologies in the Target Industry 3.*

Most relevant economic activities	Most relevant related technologies
Sport clothing making	• Packaging technologies
Sailing, sport material	• Small products, merchandising
Manufacture of utensils for surfing and related activities	• Injection technologies
Manufacture of equipment for surfing and related activities	• Surfboard technology, including EPS / Epoxy and other high-tech materials, Future Shape Technology – FST, Linear Flex Technology – LFT, and Timbertek – TT • Wetsuit technology (neoprene, inner lining, seam technology, zip system) • Fins (Fiber, Composite, Glass fiber, Carbon etc): - Fiber Glass- Layer by layer. - Composite Fins- Resin Transfer Molding tecnology, or RTM. - G10 Materials- epoxy and fiberglass laminate. • PC Materials and fin flex (Carbon, kevlar and texalium) • Leach (urethane Cord), Extrusion technologies • Construction technology in composites, steel and aluminium
Education facility – Kayaking, surfing, mountaineering	• Online & radio communications
Sailing club – training & membership Vessel mooring and maintenance Hospitality	• Radio, maintenance equipment/tools • Sonar and other echo sounding technology
Diving centre	• Respiratory equipment, decompression technology • Sailing/boating technologies as above

3. WASTE SAMPLE IDENTIFICATION AND MANAGEMENT

According to the diagnosis of the 5 participants Nodes the fishing activity, the fish classification, the auxiliary industry activity of netting and the aquaculture of bivalves are the main activities in the target industry 1 which generate plastic wastes in maritime industries.

In this way, these are some plastic samples that have been recollected to make the preliminary analyses by Leartiker: Broken plastic boxes, plastic films, nylon nets, floats and oyster pockets among others.

***Figure 1**: Plastic bags.*

***Figure 2**: Fish boxes.*

***Figure 3**: Floats.*

***Figure 4**: Polyethylene film used to wrap fish boxes.*

Some Nodes have this kind of samples in common, for example: Peniche and Ondarroa have taken into account the fish boxes; nylon nets are common for all Nodes (except LR) and plastic covers, films or bags are found also in almost all of them. The Node showing most differences is La Rochelle who is linked with the aquaculture Node and its samples are mainly oyster pockets, mussel nets or cup collectors.

To sum up about the management of the plastic sample, here are some characteristics and considerations:

AWARENESS AND CAPACITY OF ACTION:

- Fisheries are not used to do the classification and revalue the plastic waste.

- The fishing sector, as traditional sector, it is not able to keep plastic waste cleaned and storage in their facilities on board.

- The harbors or ports are the places to classify the plastic wastes.

- In some Nodes, each company has its own managing containers and in others, the Port is the main organization in charge of that. In the latter case all Port activities have common containers.

- Which are the incentives fishermen would need to land the selected plastic?

PLASTIC WASTE QUALITY:

- The waste samples are produced after the contact with fish and saltwater, so it can be called dirty waste.

- Most of the times, the plastic waste is linked with organic waste, so it must be cleaned up.

ORIGIN AND DESTINATION OF THE WASTE:

- In case of the fish distribution, the plastic material is the proper one to be used in order to maintain the quality, but in this way part of the waste goes sometimes directly to the final client and its management is difficult to trace. That is why other types of plastics could be used for this application as for example compostable bioplastics.

- Waste such as nets can sometimes end up in the sea, in the Harbour or in the netting company. Accounting for waste is a complex issue, since the management chain is not unique, it has variations. Many different types of plastics are also used in nets, are these types necessary (is each one used for anything different)? Or would it be possible to stick to some type of plastic to facilitate classification?

- How could consider options for closed circles of plastic material? With the objective of recycling them...Could it take the case of Tepsa as an example?

BEST PRACTICES:

1. The good practices of the following Nodes can be highlighted: Vigo_plastic bags: In the Port of Vigo, the plastic waste is managed by each company in the port. They classify, store and collect them and they are subsequently compacted with a machine. Afterwards, the management is finished out of the port to compile it.

***Figure 5**: «Conservas y Frigoríficos del Morrazo S.A.» unloading dock.*

Next figure, 6, illustrates the whole process up to the plastic waste storage in the company's facilities. Next step would the withdrawal of the accumulated waste from the port by a specialized company.

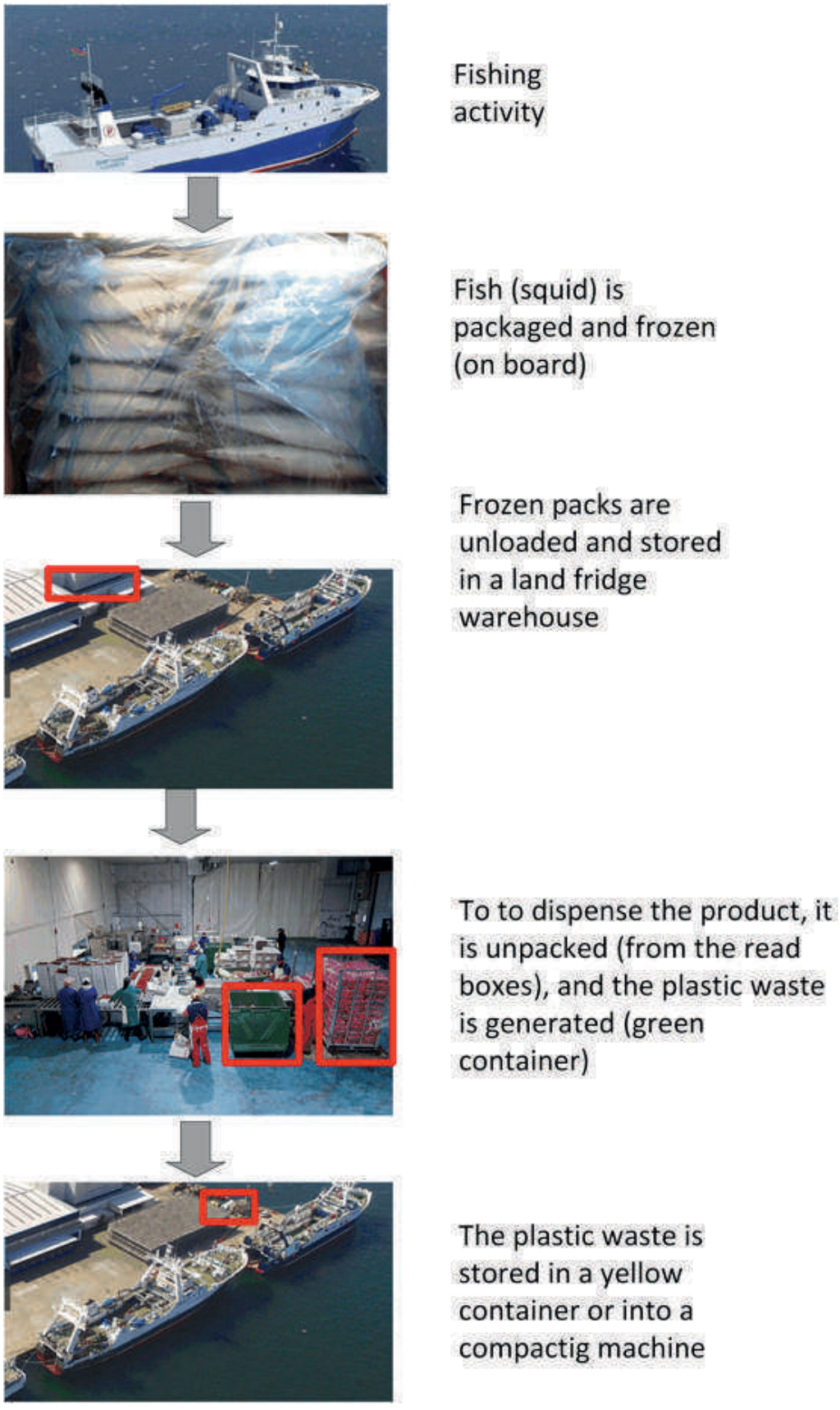

***Figure 6**: Oceanic plastic waste path.*

2. Cork plastic compactor: In ports across Ireland both commercial and fishing, waste management programmes are in place to collect and store waste of all types coming ashore. These waste streams include cruise liner plastic waste, oily and hazardous materials, which includes galley waste and other types of recyclable products. Each port has a designated protocol and contractor in place to collect and dispose of waste appropriately. These come in the form of skips and wheelie bins. The two main Cork port compactor facilities are located at the Tivoli Terminal and the Ringaskiddy Terminal in Cork Harbour. All other facilities both private and public, are provided with mobile bins and skips that are either removed to landfill sites when filled or are transferred to the port compactors, which are processed as required. All skips and wheelie bins are clearly marked and labelled for relevant disposal.

***Figure 7**: Ringaskiddy terminal showing location of waste compactor on site (Port of Cork - 2017).*

3. Ondarroa Node fish boxes: The brotherhood of fishermen buys the plastic boxes. The brotherhood sells the fish to the marketer with the box. The marketers distribute the fish. The dirty boxes are returned to the brotherhood for cleaning and reuse. The brotherhood sends back the broken boxes to the company supplier. The company supplier recycles the broken boxes to reuse the material and to produce in this way other products/boxes which must not be linked with food use.

In the list below, are compiled the waste samples, followed by identified green product, by node:

ONDARROA NODE	
Waste samples	**Identified green product**
1- Broken Plastic boxes_18.250 units	1- Part of longline to cultivate mussels in a **bioplastic "bag"**
2- Nets	2- Hand-packs or industry **packaging material**
3- Floats	3- **Earplugs for diving** to solve the problem of decompression
4- Ropes	4- Net mending **utensils**
5- Plastic Films	

VIGO NODE	
Waste samples	**Identified green product**
1- Bags, strapping tapes, plastic films, films_ 236.880 kgs	1- **Packaging/containers and clipping**. Bags. Film. Nets. Strapping tape.
2- Nets	2- **Spare pieces** (maintenance). "Bearing carrier cover"
3- Containers	3- **Prototypes pieces: roller stops, bearing carrier caps, lab tools...**
4- Boxes_expanded polystyrene	
5- Clothes, cartons and small containers...	

***Figure 8**: Prototypes pieces.*

INDEX

Peniche Node:

Using existing resources (recreational, fishermen and leisure boats) to pick up ocean plastic waste- Financial Incentives converted into printed green objects crucial for their economic activity

PENICHE NODE	
Waste samples	**Identified green product**
1- Nylon Nets _35.000kg	1- **Bubble.net**- to replace nets and ropes, great agents of marine pollution
2- Nautical Ropes_ 20.000kg	2- **Fish cooler boxes (cover)** (eventually)
3- Fish box	3- **Softboards** to solve the problem of lifecycle
4- Fish cooler boxes	

LA ROCHELLE NODE	
Waste samples	**Identified green product**
1- Oyster pockets: 268 t stored on land + 6 T thrown / year.	1- **Packaging boxes for TI 1 with health standards**
2- Cup collectors: 845 t stored on land + 5250 kg thrown/year.	2- **Farming baskets** – bioplastic or 100% recycled plastic from T1
3- Mussel nets or catin nets: 1.4 t stored on land + 1.92 T thrown/year.	3- **Knife handles** – bioplastic or 100% recycled plastic from T1
4- Tube collectors: 61 t stored on land + 171 kg thrown/year.	4- **Sheave boxes** – bioplastic or 100% recycled plastic from T1
5- Waste from composite	5- **Waterproof scans** – bioplastic or 100% recycled plastic from T1
	6- **Furniture for the equipment of boats** based on composite waste from the nautical industry

CORK NODE	
Waste samples	**Identified green product**
1- Plastic containers, bottles, buckets (HDPE)	1- **Paddle handles**
2- Nylon fishing/growing nets/rope (primary target sector and plastic samples)	2- **Kayak paddle blades**
3- Dachron (polyester) boat sails	3- **Storage containers**
4- Plastic bottles, clothes hangers, buoyancy aid straps (PETE)	4- **Rope**
5- Fibreglass (boat hulls)	5- **Cups, plates, cutlery**
	6- **Activity helmets**

4. GREEN PRODUCT IDENTIFICATION

The Green products or parts / products that could be more sustainable have been identified in each Node following the criteria discussed in the introduction to this document.

Each Node, after conducting the interviews corresponding to the companies identified and prioritized in each Target Industry, has set up a list of possible Green products. Which should be worked in the workshops of each Node, activity corresponding to action 5 of CircularSeas.

In this way Ondarroa Node raises, to close the circle using the material of the fishing such as plastic boxes and drag nets, to revalue them in mussel cultivation tools or for other utensils within the auxiliary industry such as needles to repair nets fishing.

The Vigo Node, being its most demanding auxiliary industry, believe it is possible to close the circle taking into account the plastic waste of its fishing fleet and food processors and revaluing it through 3D printing in auxiliary products. For this, they have analyzed two situations: Plastic products to replace or to generate new ones by a green product and other material products to replace or to generate new ones by a Green product.

At the La Rochelle Node, they have made the following considerations to better reflect on the preselected Green products. Production considerations tend more towards:

- Useful equipment for water sports such as waterproof cans which could be made from 100% recycled plastic from waste from the fishing and shellfish farming industries.

- Material useful for the target industry 1 from 100% recycled plastic from its own waste, such as auction bins, provided that they meet current health standards

- Furniture for the equipment of boats based on composite waste from the nautical industry.

In the Cork Node, they propose to close the circle from fishing, revaluing different types of materials, nylon nets, PETE, HPE ... to print utensils for the TI 3. But for this, they have identified a great obstacle, who tries to clean and prepare the material. This has shown that the biggest challenge in this industry is the cleaning and processing of their plastic materials. From the perspective of CircularSeas it is this raw material in which the project should be interested in redirecting back into the manufacturing supply chain. This could be accom-

plished using processes as above to allow the preparation of the plastic before the addition of the primary technological offering of the project 3D printed parts.

In Peniche Node the proposal is based in using existing resources (recreational, fishermen and leisure boats) to pick up ocean plastic waste. For that, financial Incentives could be converted into printed green objects crucial for their economic activity. And the green products could be:

1. Bubble.net- to replace nets and ropes, great agents of marine pollution
2. Fish cooler boxes (cover) (eventually)
3. Softboards to solve the problem of lifecycle

Leartiker analyses the samples of each node and these are the technical conclusions :

Mainly rigid or flexible polyolefin materials were found during the characterization of wastes, but also polyesters such as polyethylene terephthalate or polyamide, all very valuable materials. Characterization shows that most of the wastes received are suitable for 3D printing purposes, except for thermoset-based materials that fall out of the scope of the project. However, a more detailed analysis will be made when higher amounts as well as waste types are available for characterization and material development.

Further materials should be analyzed after use to be able to draw further conclusions about the influence of long-time use and/or contact with marine water or food of the materials on their degradation or changing of properties.

For more information about the Sample analytics Report please see the report in *Annex number 3*.

5. IDENTIFICATION OF PARTS, TECHNICALLY

Based on the diagnosis reports of each node, a first identification of green products and possible waste material inputs for their manufacture was made, as it can be seen in Figure x. Waste is mostly generated in target industry 1 and several waste types are common in each node. Mainly rigid or flexible polyolefin materials are found, but also polyesters such as polyethylene or polyamide, all very valuable materials. However, the state of the samples will have to be analyzed to see if any degradation has taken place through the long-time use or/and contact with marine water or food of the nets, boxes, bags... etc. The use of bio-based and biodegradable materials is also possible is several cases. As can be observed in Figure x, there are several possibilities regarding materials for each of the selected green products.

Even though potential green products were already identified in each node through surveys carried out, it is important to analyze several technical factors besides other aspects such as economic viability and other criteria that will be considered in the business case identification. On the one hand, 3D technology has some limitations, starting from limitation in size, depending on the available 3D printing machine. The use of medium size printing machines is expected within the CircularSeas project, except for the Peniche Node, in which a BigPrint Laboratory for larger objects is planned. Another constraint is longer manufacture times needed compared to other processing technologies as, for example, injection molding. In some cases, it is more advisable to use faster and cheaper technologies. On the other hand 3D printing technology offers the possibility to add value to products and adapt them to specific situations. It is also a technology that is relatively easy to use, once materials have been optimized and adapted to the machine, which is an advantage to introduce the technology to maritime sectors. All these advantages and disadvantages must be taken into account for the technological assessment of green products.

In the Ondarroa node, the fishing net mending needle was selected as the green product with more potential. Several recycled or bio-based materials could be used for its manufacture, and possibilities were identified to add value to the product: improved design for ergonomics or manufacturing of several sizes. In the case of Vigo, two components show great potential for green product manufacturing. On the one hand, end and lateral covers of ball bearing units could be produced based on recycled polyolefins or bio-based materials. These components break regularly, so it could

be a great advantage to be able to produce them on demand. Additionally, new designs could be developed and tested to decrease the breaking frequency. On the other hand, the prototyping of parts offers a good opportunity to find applications for recycled materials. In La Rochelle, sheave boxes of yachts could be manufactured with polyamides generated in the node, thus closing the loop and opening the possibility to recycle a material with high mechanical properties, reaching upcycling of materials. In Cork, one of the components with more potential are paddle handles to be used in aquatic sports. Here, value can be added to the product also, regarding ergonomics and different size manufacture. Peniche node is a unique case in the CircularSeas project. Soft board fins were identified as a possible green product in this node. However, the planned Big-Print laboratory opens up a great deal of possibilities to manufacture big dimension products.

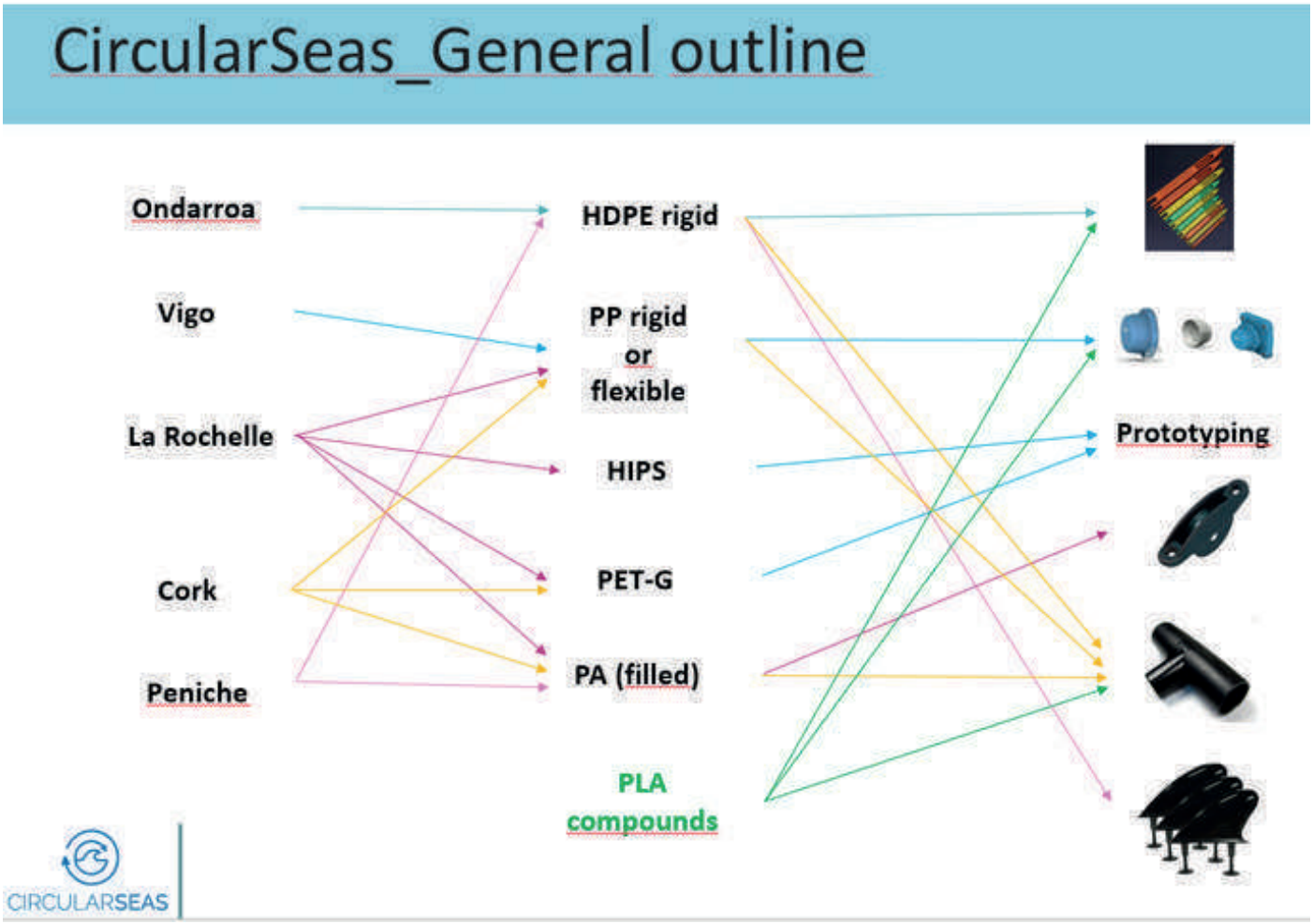

***Figure 9**: First approximation to input flow of waste materials and green product output.*

6. BENCHMARKING

6.1 3DP technology and materials trends

LEARTIKER – MATERIAL AND TECH TRENDS

The main objective of this report is to describe the state of the art in 3D-Printing technology related to the materials, hardware and software that are used nowadays. Additionally, this report also aims at identifying advances being made in research, current challenges and limitations, as well as future trends.

The partners participating in this analysis are:

- Leartiker S. Coop. (ES)
- Universidade de Vigo (ES)
- Université de La Rochelle (FR)

This information will be comprised in a single report generated in collaboration of the above-mentioned partners. The report will serve as a basis for the technical developments that will be carried out within the CircularSeas project, and also as a means of public service through the open dissemination of the compiled information.

6.1.1 Method for the analysis

In each part the steps that will be taken to carry out the analysis will be the following:

- Description of the actual situation.
- Description of future trends we identify, challenges and limitations.
- Conclusions and implications for the project: Which technologies/materials are most suitable for the CircularSeas project and why.

Conclusions:

FDM technology is the most widely used for 3D printing of plastics and thus, filament extrusion in additive manufacturing is the most popular material nowadays. It is also the most cost-effective technology. This, together with its simple technology compared to the rest of 3D printing technologies, makes FDM technology suitable to be implemented in a wide range of economic environments as the Oceanic one, which is the aim of the CircularSeas project.

In addition to this, main waste types identified in the 6 Nodes involved in the project are thermoplastics based, excluding those wastes from the shipyard industries that use thermoset materials to build ships and boats. These materials are not the most relevant regarding quantity in the nodes and they are difficult to recycle and apply in 3D technologies. That is why they fall out of the scope of the project. For this reason and considering the variety of thermoplastic materials that are found in the different wastes, compounding of materials is the best option to be able to upcycle materials and establish the foundation for a circular economy in the nodes. In this way, it will be possible to add several additives, a percentage of base virgin polymer, secondary polymers or reinforcements to the recycled materials in order to tailor required properties for green products.

Regarding the 3D scanners hardware, the recommendations tend to choose two main categories of scanner: Time-of-Flight scanners as they are now incorporated into smartphones, where a deep study of their relevance towards the project needs has to be done; hand-held laser scanners which are the most suitable devices in such context. For the software part, the STL 3D file format appears to be the most suitable as this corresponds to the most used open format, allowing its usability with many different devices and softwares.

The documentation available in the fields of hardware, software and materials to introduce improvements to current 3D printers and the expiration of the FDM patent makes this technology and materials suitable for the project. Using recycled plastic in the printing filament for FDM technology has been proven successful as can be seen in several small projects like The Trash Printer (open-source project) [151] or having a filament partially based on recycled plastic like the EKOCYCLE Cube 3D printer [152].

For more information about the Benchmarking of MATERIAL AND TECH TRENDS please see the report in *Annex number 2*.

6.2 Benchmark plastic waste removal models within and beyond the Atlantic Area

To introduce the following benchmarking, Azaro Fundazioa has tendered for the services of Ecologing company. In this way, Nicola Cerantola´s expertise in circular economy has defined 5 best practices in order to compile or register some crucial projects to have different references in CircularSeas project Target Industries.

Here it is the summary of the 5 cases references:

6.2.1 MARVIVA

MARVIVA is a project for the collection and characterization of marine litter carried out by the Fishermen's

Association of Barcelona together with the Agència de Residus de Catalunya (ARC) and the Port of Barcelona (October 2015- December 2016). It involved 11 trawlers, 55 fishermen and 54 km of coast.

6.2.2 Upcycling the Oceans UTO

The Upcycling the Oceans (UTO) project collects littering that is polluting the oceans and turns it into a premium thread for the production of fabrics and the making of garments and accessories. In September 2015, ECOALF, through its Foundation supported by HAP Foundation, began to extract garbage from the seabed thanks to the collaboration of the fishermen of Levante (east Mediterranean coast of Spain). This project is articulated in different phases and aims not only to clean the oceans but to demonstrate that part of the recovered waste can be converted into pellets, yarn, fabric and products of high quality and design.

The Vigo Port Authority has participated and participates in numerous projects and initiatives aligned with sustainability and environmental protection. Below is a brief description of the most prominent ones:

- OMAR Observatory
- 3R-FISH
- Nada pola Borda
- REPESCA PLAS
- BLUE GROWTH

6.2.3 Port of Vigo

The ML-Style project, in collaboration with CETMAR proposes to design a comprehensive management system for waste from fishing ports (food plastics, polystyrene boxes, disused rigs and marine litter) and study the possibilities of recovery of recovered materials of the marine environment, like raw materials for the manufacture of clothing and fashion accessories by INDITEX, the company that promotes the project. The project will begin in the Port of Vigo but will promote the participation of other Galician ports in order to achieve a greater supply of materials that make valuation economically viable. Actions for cleaning and removal of waste by fishing fleets are contemplated both following the passive garbage fishing schemes (removal and management of the waste that arrive in the rigs during fishing activities), like directed marine litter removal campaigns from areas of accumulation (hotspots) and withdrawal of lost or abandoned fishing nets / gear. Recovered polystyrene might be upcycled in the future by Agylix technology.

6.2.4 Aquaculture waste collection & management

This cooperation between companies, has set up a fully recycling system along the coast of Norway. Fishing ports in Norway are organised as municipal or inter-municipal enterprises that act as landlords with some quays being privately owned. Private companies such as fishermen, fish processors and fishing net suppliers may rent space and facilities from the ports.

6.2.5 Fishing for Litter (FFL)

The Fishing for Litter initiative was originally started by the North Sea Directorate of the Dutch Government in co-operation with the Dutch Fisheries Association in March 2000.

In 2004 KIMO International started a simple yet imaginative project to tackle the problem of marine litter. Fishing for Litter aims to reduce marine litter by involving one of the key stakeholders, the fishing industry in the Atlantic area: Netherlands, UK, Faroe Islands, Ireland, Norway, Germany, Spain, Belgium.

For more information about the Benchmarking plastic waste removal models within and beyond Atlantic Area please see the report in *Annex number 4*.

7. FINAL CONCLUSIONS

After the study in each CircularSeas Node, the most common waste from the classified maritime industries are: plastic film, plastic boxes, buoys, nets ... the most abundant materials being fishing nets and fish boxes.

Today the plastic waste from the maritime industries in the Atlantic area is not being managed in a uniform way which has led to considering improvements in its management. These improvements should be applied from vessels and crops on the high seas to waste manage-

ment organizations on land and industries and services attached to the port area. Each and every one of them is responsible for the end of life of the different kinds of plastic waste generated there.

In general, management today is linear and the needs for a collection of plastic from the sea to the most conscientious port have been identified. For this, more policies of this type should be promoted and subsequently incentivize the revaluation and subsequent use of managed plastic. Being the key for it the link of collection, selection and cleaning. Even so, it should be noted that there are some initiatives that can also be taken as a reference for the policy brief proposals and thus incorporate improvements in the management and revaluation of plastic waste in different target industries.

For example, in the port of Vigo a selective plastic collection is carried out and the aim is to minimize its volume. For this there is a management area in the port. In the port of Ondarroa, for example, plastic fish boxes are returned. The broken ones are selected and the same material is revalued to make other packaging.

This concludes the mapping of waste and mapping the waste removal.

As for the technical part, the analyzed residue samples show a strong presence of various thermoplastic materials. With these results and based on the report on technological trends carried out by technology partners, it is concluded that FDM printing technology is the most suitable for the manufacture of green products. This will allow the improvement of recycled materials as well as products through ecodesign and the customization advantages that 3D printing allows. Another objective of the project is to bring the technology closer to the maritime sector, so that the process of capturing images and using files for subsequent printing, which is proposed following current trends, will be easy to use and accessible.

Several products have been identified as waste that proceed a linear economy, such as fish boxes and nets, as previously discussed. These products can and should be revalued within a circular economy and in this case they will be used to create more sustainable green products through 3D printing. These green products have been identified after an analysis of needs at the nodes such as needles for sewing nets, handles for oars, pulleys or spare parts for bearings. Various strategies will be developed to use both improved recycled materials and biodegradable and bio-based materials depending on the application and requirements of each green product.

8. ANNEX (See the reports here)

8.1 ANNEX 1: All Nodo Reports.

8.1.1 Ondarroa (ES)

8.1.2 Vigo (ES)

8.1.3 La Rochelle (FR)

8.1.4 Cork (IE)

8.1.5 Peniche (PT)

8.2 ANNEX 2: Benchmarking of material and tech trends Report.

8.3 ANNEX 3: Benchmarking of Sample analytics Report.

8.4 ANNEX 4: Benchmarking of plastic waste removal models within and beyond Atlantic Area.

9. LIST OF FIGURES AND TABLES

List of figures

List of tables

EAPA_117/2018 – CIRCULARSEAS

"Turning ocean plastic waste into green products for maritime industries"