Interreg Atlantic Area
European Regional Development Fund
EUROPEAN UNION
CIRCULARSEAS

DELIVERABLE
"PORTFOLIO OF BUSINESS CASES"

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

DELIVERABLE
"PORTFOLIO OF BUSINESS CASES"
Date: **30/06/2021**

Action	**A 5.4 Portfolio of Business Cases**
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Author / Partner Responsible of the Deliverable	Munster Technological University
Contributors	• LP. LEARTIKER • P2. UVI • P3. AZARO • P4. ULR • P5. MTU • P7. IPLeiria • P8. CdA-LR
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INTRODUCTION

Plastics have become a ubiquitous part of our everyday life and are found in everything from packaging, toys, micro-technology, and even biomedical applications. The prevalence of plastics is primarily due to the wide range of advantageous material properties, such as its lightweight, durability and ability to be manufactured using a diverse range of processes. Global plastic production is increasing rapidly and is projected to continue to increase to a level of 34 billion metric tons by the year 2050.

Managing and disposal of plastics across a multitude of sectors has become one of the major challenges of the modern era. Ideally for the lowest impact on the environment, re-use of plastics is desirable as part of the overall lifecycle analysis of a product. The Circular Economy action plan that is being put into operation across the world is focused on this very important challenge. The term upcycling is used in this context to describe the reuse and/or re-manufacture of these materials after having gone through the phase of recycle.

There are several large-scale marine pollution or waste plastic recycling initiatives underway across Europe, like 'Fishing for Litter' which was developed and started in 2004 by KIMO International based in Denmark and encompassing 15 European countries in an effort to tackle this problem. The project involves one of the key marine stakeholders, the fishing industry. The result of this initiative since its beginning has been cleaner seas, cleaner beaches, and a healthier environment.

__Figure 1__: KIMO International 'Fishing for Litter' bags being loaded pier side for transportation and processing.

Many projects have been funded by the European Commission through research programmes namely, European Maritime and Fisheries Fund (EMFF), LIFE, H2020 and other EU funds that support and promote scientific research and technological development, but also on harm caused by litter and microplastics, also considering human health. The Swedish led BLASTIC project funded by the Central Baltic Interreg program ran from 2016 to 2018. This project involved the mapping of plastic waste pathways into the Baltic Sea. Other Plastics Europe initiatives, such as 'Zero plastics to Landfill' contribute to sustainable solutions for tackling marine litter. This project promotes the implementation of 'life cycle thinking' methodology tools to help reduce leakage of plastic products into the environment.

Out of funding programmes like these, ships and vessels as pictured below have been modified and adapted to provide focused collection and cleaning of marine plastic. The 'Manta' ship is the first of its kind capable of collecting, processing, and recovering large quantities of marine plastic waste.

***Figure 2**: Manta ship. Self-contained processing facility (New Zealand) (left). Ocean Clean-up (right).*

Other projects like the Ocean Clean-up use a different approach for collection of ocean plastic debris as seen in the depiction on the right. Where projects like these are focused on material collection out to sea, CircularSeas is specifically focused on the use of such plastic material with a provenance in maritime operations and industrial activities at ports and harbours. As shown, there are various large-scale initiatives but also smaller scale projects tackling this challenge of maritime and coastal waste, all adopting a unique solution but adding to the collective knowledge in how to solve these problems globally as well as regionally and locally.

Project organisation

CircularSeas consortium combines expertise in additive manufacturing technologies, material development, software engineering operations and wide-ranging experience across multiple project partners relating to business development, consultation, and community outreach in numerous European projects now inclusive of Interreg Atlantic Area, funded by the European Regional Development Fund (ERDF). The Interreg Atlantic Area research grant was awarded to CircularSeas in prioritising the call for resource efficiency in Eastern Atlantic coastal nations of Europe. The projects' overall objective is to promote the development of eco-innovative or green products parts and components targeting three maritime Industries. This will be done through the combination of 3D printing technology and the use of not only recycled maritime plastic waste, but new biodegradable, renewable and high-performance polymers also. The combined access to maritime businesses across Spain, Portugal, Ireland, France, and the United Kingdom captures the economic and related environmental differences internationally, but also important similarities that can be utilised to grow the objectives and approaches of the project.

CircularSeas project consortium

***Figure 3**: Atlantic Area project partner locations.*

Leartiker S. Coop

Leartiker are a highly specialised team of internationally recognized researchers devoted to research, technological development, and innovation with specialisations in Polymer and Food Technology. Leartiker belong to the Basque Science and Technology Network (RVCTI), located in Markina-Xemein innovation centre in Biscay. Leartiker provide guidance to businesses in developing new products, advising, and supporting them to find new business opportunities as well as to improve and diversify their products. Their state-of-the-art infrastructure enables them to guarantee customers the best service compound with the highest quality in the processes, banking on personalized monitoring of each project.

University of La Rochelle

Created in 1993, La Rochelle University is one of the youngest in France. It welcomes its 8,860 students in 3 faculties (Faculty of Law, Political Science and Management, Faculty of Literature, Languages, Arts and Humanities, Faculty of Science and Technology), 1 University Institutes of Technology, and 1 management school. This university offers nationally recognised multidisciplinary courses (73 degrees), with an approach focused on each student's project. La Rochelle University favours complementarity and interdisciplinarity around major societal challenges, while strengthening its scientific excellence in disciplinary fields for which it is recognised through its laboratories.

University of Vigo

The Universidade de Vigo is a young and dynamic institution that offers a wide range of training programs in the three specialized and innovative campuses that make it up. We are present in the municipalities of Ourense, Pontevedra and Vigo with three specialized campuses where you will find more than 30 centres for training and research, as well as facilities for sports and leisure, with a continuous cultural program. We also have the Campus of International Excellence Campus do Mar lead by the University of Vigo and which adds more than 3000 researchers, forming a cross-border network of research and knowledge with the sea as a driving force.

Azaro Fundazioa

Azaro Fundazioa is an organisation whose goal is to promote the creation of new businesses and improve the competitiveness of business fabric in its immediate surroundings, with efforts primarily focused in the Lea Artibai region.

Munster Technological University (MTU) - Halpin Centre for Research & Innovation, NMCI

The National Maritime College of Ireland is a constituent college of the Munster Technological University, and a unique public - private partnership with the Irish Naval Service. Research is at the core of MTU activities. Within the Universities faculties and colleges, are several specialised research centres namely Nimbus, CAPPA, V-LINC, The Rubicon and Halpin Centres for research and innovation. All research centres and groups of postgraduate and doctorate researchers within MTU have shown through state-of-the-art technology development, innovative business incubation and creation combined with top tier physical and biological science research, to be highly successful in attracting significant project grant funding across various European Commission funded research schemes and internationally.

Communauté d'Agglomération de La Rochelle

Located between Nantes and Bordeaux, on the French Atlantic coast, La Rochelle Urban Community (CdA-LR) is a public establishment for inter-municipal cooperation which brings together 28 municipalities and aims to draw up 'common development projects within its solidarity perimeter.' CdA-LR is both a political and an administrative body which exercises compulsory and optional powers, in place of its 28 member municipalities. Its competencies are exercised in various fields, addressing the needs of the citizens (169 000 inhabitants), businesses (12 655 firms) and other public and private organizations of the territory: economic development and employment; higher education; town planning, transport and mobility, social balance of housing, water production and treatment, waste management, environment, and quality of life.

Politécnico De Leiria

The Polytechnic Institute of Leiria (IPLeiria) is to contribute to scientific and technological development, leading to new products, materials and processes that are more fitted, more effective, and more efficient, contributing to a generation of added value to the industry and promoting the conscience of the importance and of the role of the rapid and sustainable product development in the society. In order to accomplish this mission, the CDRSP-IPLeiria leads scientific and technological research and promotes dissemination, training, and consultancy actions in strategic areas of product development.

University of Plymouth

The University of Plymouth is a public university based predominantly in Plymouth, England where the main campus is located, but the university has campuses and affiliated colleges across Southwest England. With 19,645 students, it is the 38th largest in the United Kingdom by total number of students (including the Open University).

1. SECTION 1. OBJECTIVES

Project definition

CircularSeas aims at the promotion of the Green Economy in the Atlantic Area, to (a) adapt and diversify economic activities fully tapping into Green Growth potential and (b) to reduce the environmental impact of plastic waste streams entering the ocean. The target maritime industries are: 1) Fishing, auxiliary fishing, and aquaculture, 2) Shipyard and port management and 3) Nautical sports. The strategy will use a combination of Circular Economy Principles in the use of ocean plastic waste to develop new green materials and the introduction of new greener materials. Secondly, CircularSeas involves the promotion of the uptake of an advanced manufacturing 3D Printing technology (3DP) which is supple enough to adapt to the manufacturing conditions for new Eco innovative small and medium sized parts and components.

CircularSeas project brings together various strands relating to principles of a circular economy, maritime plastic waste recycling and the development of maritime sectors and business through the introduction of 3D printing or additive manufacturing technology. This is to advance the circular reuse of materials for the benefit of maritime stakeholders. These elements of the project aim to promote the adoption of additive manufacturing in industry sectors that may not have had previous use for such a process due to the market position and operational value of small batch production, compared to traditional manufacturing technologies like mass production using injection moulding for example.

With more emphasis on material development within this industry in recent years, filament or feed stock production for 3D printers has progressed into the use of recycled plastic materials. These materials come in the form of single use plastics but also materials that have a potential for circulation back into local economies. Reuse of this material through close consultation with maritime stakeholders across the Atlantic Area regions represented in the project will forge the development of partnerships between these sectors. The aim is to develop and build a framework to capitalise on the use of the technology and the redirecting of the plastic back into the sectors involved, and away from waste generation. This circular approach will contribute to the revalorisation of maritime plastic waste through harnessing the inherent value in the plastics themselves.

1.1 Challenges

Through initial diagnosis reporting as part of an important work package (WP4) for the project, material types, volumes and uses within the target sectors were mapped to gain knowledge and information about the prevalence of plastic in Atlantic Area partner countries. This was a vital step towards development of subsequent workshops carried out in all project nodes to introduce the concepts being promoted by CircularSeas to those stakeholder businesses looking to participate.

1.1.1 Plastic volume

At each partner region, similar challenges had emerged as expected. The volume of plastic material identified were significant across these target sectors. Each participating stakeholder business were acutely aware and actively engaged in initiatives to help to solve the disposal and recycling challenges in their own countries and businesses. Although evidence emerged through discussions at workshops that small scale activities were taking place to reuse plastic, there was a shared consensus that much more could be done by bringing stakeholder groups together in line with the approaches put forward in CircularSeas and other EU research working on similarly themed projects. There were differences in the level of recycling activity between EU nation states, which highlighted the associated degree to which this plastic material is handled and repurposed across each region. This is one of the outcomes that CircularSeas intends to make progress in with regards to presenting a trialled framework around the circular reuse of plastic recovered from one maritime industry or business to service the operations of another.

1.1.2 Plastic processing

In relation to plastic processing at recycling plants and facilities across participating Atlantic Area countries, a reoccurring challenge that emerged out of these workshops described the capacity of local authorities or private contracted waste companies to clean and process contaminated plastic material sourced from maritime and aquaculture activities. This challenge as part of CircularSeas will examine some methodologies around material preparation prior to filament production. Although this was an emergent challenge, finding or highlighting a set of functional or effective processes that can be carried out will add to the projects overall process innovations. This could be of great benefit to the participating stakeholders and by extension the associated regions where their operations are based.

1.1.3 Pilot testing

Work package 6 will realise the trialling and 3D printing test for the individual business stakeholders and eco-products created. This is one of the principal challenges that will involve the revalorisation of the processed maritime plastic. The challenge arises from the nature of the components or products selected during the business case analysis workshops. Because each Eco-product design will have a specified functional component, the polymer production will require multiple steps and iterations to develop the material suitable for 3D printing. This is a manufacturing process that is within the expertise and skill sets of the CircularSeas consortium, however the process still poses a challenge to be undertaken and overcome.

As part of the implementation of regional workshops at each node, stakeholders were shown the 3D printing technology that will be used to repurpose the materials recovered. Demonstrations of the technology were provided to highlight the capabilities of the machinery but also Leartikers' material development expertise that the project will capitalise on to prepare the recycled and clean plastic for product printing.

Common challenges that were highlighted across all node workshops by the stakeholders themselves, focused on the technical expertise that may be necessary for such sectors and more specifically their own businesses. 3D computer design of the selected business cases and products would require specific knowledge and technical ability, both of which are unlikely to be accessible in the target maritime sectors.

This specific challenge will be addressed through the pilot design and manufacturing work package of the project. The machinery hardware i.e., 3D printers and mobile phone devices together with the software that will be integrated as part of the innovative technology system design will be developed with this challenge in mind, to simplify and automate the system as much as possible, to provide the service and capability to non-experts operating in these business sectors.

Through the pilot testing of the framework and the manufacture of these products, development of a catalogue of computer-generated 3D designs of the products to be printed may be required. For the purposes of CircularSeas this will highlight to participating stakeholders the ease of access that can be provided to them for the manufacturing of their selected business case component part. To expand the scope for the production of further parts or tools, coupled with the outcomes of the pilot phase of the project, this may lead to a monetary investment by the business in question for personnel training in these activities.

1.2 Options

As part of this business case development which will be highlighted in the next section, each partner node or region were asked to consider options to the repurposing of the plastic material. One obvious option that was identified was that of continuing the status quo in reference to recycle and reuse practices across the participating businesses and sectors. This is a useful approach to take as it is very clear then to highlight the benefits of taking actions to modernise and improve these practices. Considering the increased uptake of recycling initiatives across EU member states, all participating businesses were engaged in these efforts to some level and involved with local initiatives. The option to approach this challenge through the adoption of a technological solution in the use of additive manufacturing expertise, polymer development and novel software innovations, showed the stakeholder businesses a channel by which a new circular treatment of maritime plastics is emerging.

The options considered beyond maintaining the status quo specifically concern the identification of the material types that have potential for reuse, the analysis focusing on the quality of the plastic that is recovered at sites at each partner node region combined with the processes and operations within these sectors related to recycle and repurposing of this material.

The solution proposed which will be trialled, is the use of FDM 3D printing technology to effectively design useful parts and components for participating stakeholders, to subsequently prototype and manufacture using the clean recycled plastic materials recovered from various maritime operations. As will be highlighted, the business cases and product ideas put forward by project participant businesses will be assessed by technology partners Leartiker from a material/polymer development perspective. The plastic will be assessed for the quality of its' properties, durability and essentially its' potential as a material resource. University of Vigo will select and assess the most appropriate 3D printing machinery to carry out the prototyping and integrated printer software, and together with the University of La Rochelle will help to develop the software component which will use the process of 3D scanning adapted to mobile smartphone devices to capture the specific product design to be prototyped.

1.2.1 Opportunities

Over the course of engagement with stakeholder groups during workshop events, although various challenges were highlighted as mentioned above, emerging from this analysis have been a host of real-life opportunities for both the stakeholder participants, and the CircularSeas research objectives.

One key opportunity is specifically related to collaboration between maritime sectors in their commitment and willingness to adopt a new strategy, in the case of CircularSeas a new technology and process. Resulting from the creation of new Eco-product ideas and associated business cases, these sectors view plastic as a valuable resource when used appropriately, if only after participation in this project.

Many of these businesses also are involved in initiatives like 'Fishing for Litter' and it was encouraging to witness the participants gaining a fresh perspective on the opportunity that is available when repurposing and reusing the plastic that they clean up on a weekly basis.

This extends out to the individual Eco-products themselves and the circular economy approach to 'closing the material loop' between these maritime sectors. The opportunity for the project is to realise the production of functional components for these businesses which will generate a host of benefits. Each business case summarised in the proceeding section defines specific foreseen opportunities for the stakeholders in things like the reduction in the use of virgin plastic, reduction in storage and stocking of spare parts, and the opportunity to establish a new level of autonomy with respect to customisable parts for their business operations.

In some cases, the replacement of components purchased by businesses with revalorised plastic made suitable for their operations, can in the short term be more sustainable and in the longer term be more cost effective. Streamlining a system and framework of recycle and reuse will yield the benefits and opportunities described.

Opportunities arising from the research being conducted is in the application of additive manufacturing and polymer science to focus governmental authorities and private sector business in the direction of investment in upcycling infrastructure and eventually towards policy recommendations to improve practices. This opportunity to prove the CircularSeas concept can form the foundation for novel or creative actions to be made in removing plastic from our maritime environments.

2. SECTION 2. BUSINESS CASES

Ondarroa, Leartiker & Azaro Fundazioa (ESP)

Spanish partners Leartiker and Azaro Fundazioa from the Ondarroa Basque region propose a business case and product focusing on the 3D printed manufacture of price tags for the fishing industry. Design and production of these tools used for tagging will be explored in the node. Valorisation of material found in the environment and sourced from port facility operations will focus on closing the loop in management and repurposing of this material for the fisheries auxiliary sector in Ondarroa. The tags can be produced in many different sizes or shapes for different operations in this business. This type of product can be easily printed, and the customizable nature of 3D printing design suits the region and the maritime operations therein.

Polyamide based nets

Price tags

3D Printing price tags using waste fishing gear

Table 1*: Ondarroa node.*

PURPOSE OF THE BUSINESS CASE				

The business case will resolve the following questions:
• Recycling of plastic polyamide-based net waste generated at the port of Ondarroa, this material is not currently being revalorized.
• Manufacturing of a more sustainable green product used currently in the port (price tags):
  • With recycled material, thus implementing circular economy principles.
  • With biodegradable material, thus removing the problem of plastic waste in the ocean.
• Engaging stakeholders of Ondarroa in Circular and Blue Economy actions.
• Introducing 3D printing as a diversifying action in the economy of Ondarroa Port.
• Reducing the use of virgin plastic materials for price tags.				

ASSUMPTIONS & CONSTRAINTS				
It is assumed that the implementation of this project will require some special equipment and resources, but the project will work on making it as easy as possible for the node to uptake the technology, especially in terms of training personnel within participant businesses.				
OPTION DESCRIPTION	**BENEFITS**	**DISADVANTAGES**	**COSTS**	**RISKS**
3D printing of Price Tags made with recycled nets from Ondarroa port	• No raw material cost. • Circular Economy implementation in the Ondarroa Port. • Diversification of economic activities. • Technological development of the region. • Flexibility of producing the product on demand or adapting the product. • Possibility of using the technology for further green products.	• Requirements on adapting to a new technology.	• Cost of 3D printing machine. • Cost of personnel training.	• Material properties not enough for the green product. • Difficulties in adapting to the technology.
ADDITIONAL RESOURCES				
• 3D printer. • Training of personnel. • Uptake of the technology by existing stakeholders or possible start-up.				

Cork, Munster Technological University (IRL)

The business case and product proposed in the Cork node is focused on the manufacture of spare component parts for processing equipment in an ancillary fish processing facility. Using plastic material sourced from fisheries ports locally, a key objective to closing the loop in material recycle and reuse in the Cork node, will trial the conversion of Nylon netting used in this sector to 3D print replacement parts e.g., bearings, bearing mounts and roller wheels. The regular use and degradation of these components onsite due to the conditions in which they are used in direct contact with seawater at the facility, has the potential to be a viable product which can be easily printed for the purposes of small volume production. This could eliminate the businesses requirement to pre-order and store stock, while removing the need for use of virgin plastic material.

Recovered EOL Nylon fishing gear

Nylon wheel bearings

3D printing of spare machinery parts for fish processing facility

Table 2: *Cork node.*

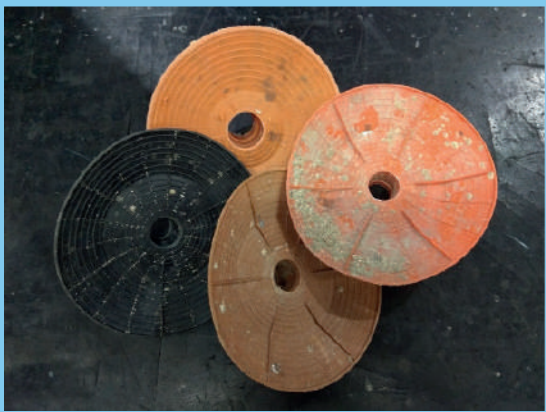
PURPOSE OF THE BUSINESS CASE
The business case development in the Cork node emerged from the identification of the most prominent but also hugely useful plastic material found across various ports in Cork. Large volumes of discarded Nylon fishing gear come ashore daily with Irish fishing fleets particularly, and this Nylon material was found to have significant value and potential to be repurposed and valorized. The business case and product to be trialed will explore the production of spare parts for ancillary fisheries processing facilities in the Cork node region. Apart from developing customized parts to replace degraded machinery components, removal and use of the valuable plastic waste material from coastal seas will have direct benefits to the fishing and coastal community. In addition, 3D printing of these components will help to minimize and even eliminate the use and need for virgin plastic parts in the processing plants operations, and across the sectors more broadly with a successful pilot test and trial.

ASSUMPTIONS & CONSTRAINTS
• Durability of the material once converted into 3D printing filament. This could take health & safety into account paying attention to the functionality of the part as used in the operations. • Use of the plastic material in a food processing facility, the plastic would be required to be of food grade quality i.e., non-toxic, and safe to use in the same space as food preparation. • Economic benefit to the business from an operational standpoint, but also cost and affordability. • Internal expertise within the company to manufacture the parts onsite. • Engineering design and printing tolerances of the component part. This takes the component specifications into consideration. Assumptions • The part or product has been readily printed from various examples worldwide. • The material is of good quality and is in abundant supply in Irish facilities. • There is a growing sectoral necessity and interest in developing a more efficient and productive plastic reuse scheme in the Cork node.
ADDITIONAL RESOURCES
• Additional resources that may be included in the business case could account for filament production in Ireland. Production of recovered recycled plastic for the valorisation of the material. • Possibly 3D printer operations e.g., trained personnel. • Manned processing facility to sort and clean material before filament production process.

OPTION DESCRIPTION	BENEFITS	DISADVANTAGES	COSTS	RISKS
3D printing of spare machinery parts for processing plant	• Promotion of material circularity between two essential industry operations. • Promote more efficient resource management processes. • Alleviate pressure on the current material supply channels. • Cost effective for business operations. • Inventory reduction onsite. • Minimize virgin plastic requirement & use.	• Small volume production. • Material supply. • Equipment expertise.	• Consumable costs of the printer. • Filament production costs. • Training of personnel.	• Cost- benefit analysis. • Recyclability. • Flexibility of the recycled plastic nylon in terms of product design.

La Rochelle, Communauté d'Agglomération de La Rochelle (FR)

The product idea and associated business case developed in La Rochelle; France relates to the production of sports equipment like surfboard fins utilizing the plastic material recovered from the oyster farming operations in the region. The business case details the design and 3D printing of nautical sports parts using the plastic spat bag material from the local aquaculture sector. This business case intends to close the material loop between two of the projects target sectors namely aquaculture and nautical sports. The material is in relatively high volumes and is believed to be a good material for the valorisation and remanufacture into surfboard components. Due to the high level of engagement in water sports in La Rochelle, an additional benefit to this use case may provide youth groups with knowledge and practices related to circular reuse of plastics in their environment and spark further positive activity in the region.



Spat Collector components

Surfboard fins

Manufacture of Spare Parts for the practice of water sports

***Table 3**: La Rochelle node.*

PURPOSE OF THE BUSINESS CASE
The main direction and purpose of this business case deals with the valorization of spat collectors used in the farming of shellfish. These spat collectors are created from plastic material, and they account for a significant amount of waste each year. Manufacturing spare parts using this material was identified after a collective intelligence workshop, where the opportunity to raise awareness among the population, of the project goals and innovations emerged. This included young people who may not have been aware of the plastic waste challenges and associated circular economy model. As this public is massively interested in water sports in the region, one solution was to add value to the production of common objects used in water sports by offering the customizable design through the technology promoted within the project, and to take the opportunity to educate on the circular nature of the product and how it would be manufactured.

ASSUMPTIONS & CONSTRAINTS
• Lack of solutions for the decontamination of waste that were immersed in the ocean during their lifecycle. • Absence of some players in the value chain at territorial level. • Impossibility of producing large volumes / Evolution of 3D printing technology. • Control of structural costs. • Quality of recycled materials may not be in line with some expectations.

OPTION DESCRIPTION	BENEFITS	DISADVANTAGES	COSTS	RISKS
Manufacture of spare parts from recycled materials (spat collectors) for the practice of water sports	• Development of a local supply chain. • Spat collectors become a resource and no longer a waste. • Compliance with waste management regulations. • Reduction in use of virgin raw materials. **Local production** • Reduction in transport / import costs of parts. • Positive image for the company. • Manufacturing on demand by 3D printing. • Customisation of products allowing a competitive advantage. • Reduction in inventory costs. • New market involvement. • Raising awareness among professionals in the oyster farming industry and citizens.	• No mass production. • Need specific equipment.	• Costs related to the equipment necessary for manufacturing by 3D printing. • Cost of recycled filament spools. • Cost of human resources required.	• Insufficient resources at local level. • Absence of some players in the value chain at territorial level. • No solution for waste decontamination. • Cost of recycled filament spools too high. • Psychological brakes for consumers to buy recycled products. • Loss of customers if the quality of the products does not meet expectations in terms of mechanical and aesthetic properties.

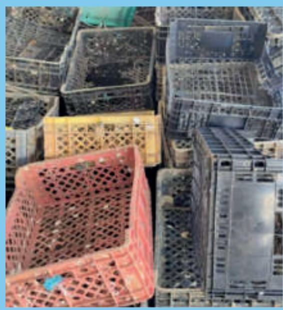
ADDITIONAL RESOURCES
• 3D printer compatible with recycled filaments. • Laboratory space.

Peniche, IP Leiria (PT)

The product idea and associated business case developed in Peniche, Portugal relates to the production of thermoplastic moulds using plastic material sourced from seagoing operations and recovery from the sea. The molds can be designed in the provision of components used in boating but also other related maritime devices more broadly. However, this use case will focus on 3D printed molds to be used in processes like injection moulding for example in the production of a boat hull design in the Peniche node. Added benefits of using additive manufacturing in this way could provide a more cost-effective process for the customisation of larger products for outdoor spaces, while also allowing the decentralised design and production of small volume mould development.

Manufacture of thermoplastic boat hull molds

Recovered plastic crate boxes



3D CAD Boat hull mold design

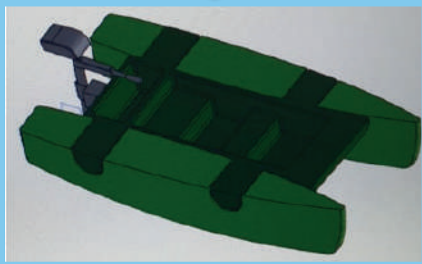


***Table 4**: Peniche node.*

PURPOSE OF THE BUSINESS CASE
This business case explores the use of thermoplastic molds produced and derived from maritime plastic for the manufacture of components for seacraft. This use case can provide a solution to specific environmental needs in replacing the linear economy with circular economy principles and reduce the cost of waste management through material valorization and effective treatments. In so doing the reuse of plastics with a provenance in local maritime operations will help the recovery of marine life in the area. From a societal perspective, maritime sectors affected by plastic pollution in the ocean is leading to a reduction in fishing and leisure activity. Removal of plastic from these environments will foster economic and societal recovery while also providing the potential for longer-term sectoral resilience. From a market/customer perspective, use of additive manufacturing can allow for more flexible production costs which can positively impact the activity of the sector or industry described. From the individual needs of people from coastal communities, a dramatic reduction in the manufacturing cost of products using 3DP will drive down the cost for the consumer to help counteract economic hardship in society more broadly.
ASSUMPTIONS & CONSTRAINTS
General assumptions: • Collection & Transport   • Inefficient collection: few port reception facilities, absence of formal guidelines for segregation of the waste.

ASSUMPTIONS & CONSTRAINTS

• Recycling
  • Capacity, Transport and segregation cost, complex gear design.
  • Need for stronger policies.
• Market Demand
  • A need to explore networking and collaborative opportunities.
 	
Project Constraints:
 	
• Molds/Parts/components not of sufficient quality (Mitigate by development).
• Mixed waste cannot be sorted
• Integrity/printability of the material
• Insufficient volumes of recycled plastics (broaden scope of collection, through credits to those that bring recover maritime plastic products, (more credit for nylon nets for example).

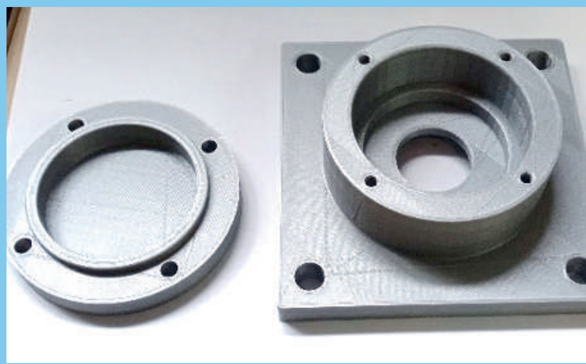
ADDITIONAL RESOURCES
Equipment required: Crushing machine/grinder, Holding Tank, Big 3D Printer. **HR:** Mechanical engineer, Materials /Chemical Engineer.

OPTION DESCRIPTION	BENEFITS	DISADVANTAGES	COSTS	RISKS
3D printing of beach/urban furniture using recycled plastic	1- Upcycling of significant volumes of plastic waste due to mold design and dimensions. 2- Made from recycled material. • at the end of life, the mold can be crushed, and the material can be reused. 3- Minimal material loss or excess. 4- Customizable product. 5- Resource efficient.	• Mixed waste cannot be reused. • Thermosets cannot be sorted. • Material viability/quality.	• Costs associated with material development which includes processing steps e.g., decontamination.	• Degradation and microplastics release to the environment.

Vigo, Vigo University (ESP)

This business case is specifically focused on seagoing vessels and the introduction of a 3D printer on-board to have access to readily available spare parts without the necessity to store spare parts on the vessel with limited storage capacity. The business case proposes the production of equipment components such as a bearing carrier and cap case. University of Vigo have already successfully printed this component at the university, while a broader use case explores an integrated system on board a vessel that would allow crew or personnel to 3D print these parts on demand using recycled ocean plastic material. Progression of the use case will require a further step of material development to ensure that the recycled plastic will have the relevant properties such as durability and 3D printing viability over repeated iterations of the part and its unique specifications.

Shredded netting plastic



Bearing carrier & cap

Manufacture of spare machinery parts for cold storage facility in Vigo

Table 5: *Vigo node.*

PURPOSE OF THE BUSINESS CASE
Due to the importance of specific equipment components onboard vessels, spare parts are often required. These spare parts are necessary in the event of breakages, and it is not viable for suppliers of these parts to deliver in the context of seagoing vessels. Therefore, a space on the boat must be allocated to store the spare parts stock. This triggers the need for vessel owners to pre purchase spare parts in large volumes. This is because normally the supplier/manufacturer requires this in order to benefit in terms of personal profit. If the parts were manufactured by 3DP when necessary, it would save space, both aboard and in the maritime industries facilities. Moreover, this would lead to savings in spare parts storage, since only what is necessary, or a small consignment of spare parts can be manufactured.

ASSUMPTIONS & CONSTRAINTS
Internal factors. The manufacture of spare parts by 3D printing, for example bearing carrier caps, requires qualified staff regarding 3D printing procedure. That encompasses part design, manufacturing process parameters, and the manufacturing environment. The main operations carried out by companies of this type in the maritime sector does not encompass the manufacture of parts, so it would not provide staff with knowledge and training in 3D printing. External factors. If the part to be printed has the necessary mechanical properties to be replaced by recycled plastic, the client company would view it favourably. If the use of green materials entails the possession of a distinctive or green seal, the client company would prefer this recycled raw material to a commercial plastic one. This green seal would be justified by the application of green products in a specific business model and the introduction of the circular economy in its activity.

OPTION DESCRIPTION	BENEFITS	DISADVANTAGES	COSTS	RISKS
3D printing spare machinery parts .	• Enabling the Circular Economy within maritime industries. • 3D printing can be carried out both on board and “on land” in a simple and transparent way for any user. Time reduction to carry out the start-up of a new printing process. Outsourcing of plastic recycling by an expert service. • Certifying seal for the use of green resources.	• Not a widely used standard framework.	• Storage of previously recycled plastic filament. • Need for an external plastic recycling service. • Savings in training of personnel with strong material expertise and purchasing of machinery. Savings in training of expert personnel in additive manufacturing.	• Data management.

ADDITIONAL RESOURCES
To carry out the business case it is necessary: • Qualified or unqualified personnel in additive manufacturing. • Availability of recycled plastic filament (external or port service). • 3D printer with modified hardware according to the integrated environment developed in the project on the WP6 and a smart device (mobile, pc or tablet).

3. SECTION 3. ANALYSIS AND OUTCOMES

3.1 Technical Innovations

To begin an analysis on these business cases and their viability in so far as repurposing the plastic material, a brief description of the technical innovations of the project are important. In order to accurately show that the technologies being used and proposed are up to the operations that are suggested, the following information and graphical depictions show the progress already made in work package 6. The material development element being carried out by lead partner Leartiker S. Coop (ESP) describes the testing and analysis of the plastic materials sourced from each partner region. University of Vigo (ESP) as mentioned are involved in the 3D printer hardware development and the electronic and printer software integration with the mobile device application. The University of La Rochelle (FR) are the partner tasked with the development and innovation of the mobile device application and scanning software to generate the file type known as STL used in Stereolithographic (SL) 3D design, which will be sent to or integrated with the 3D printer software. The following information is provided from the 'Terms of Reference' document drawn up by the partners involved in their development in WP6 activities, as mentioned above.

3.1.1 Material Development Leartiker S.Coop.

Firstly, the condition of the residues (plastic) must be analyzed. The need for cleaning regarding possible organic or other material contamination as well as specific behaviour of the residues during the shredding process will be examined. This initial process step should provide a clean and dry material and, in a condition, appropriate for feeding directly into the filamentation and/or compounding line.

The second step of this processing stage involves the analysis of the material filament production and subsequently printability of the pretreated materials. These tests will be performed without any further modification to the plastic. This will be carried out initially at a small scale using a desktop filament maker to assess the overall material suitability for filament production. Finally, material printability will be tested with the 'Ultimaker 2+' which is the selected printer for technology developments within CircularSeas. This process will serve as a foundation for the identification of material modification needs if required. Based on preliminary trials and material requirements, material modification will be carried out. After characterization/ development of the materials, filamentation and 3D printing tests will be fulfilled.

3.1.2 Hardware Solutions - University of Vigo (UVI)

UVI will oversee 3D printer hardware modification, 3D printer control software modification (Firmware) and conversion of the STL file into the relevant programming language or 'g' code.

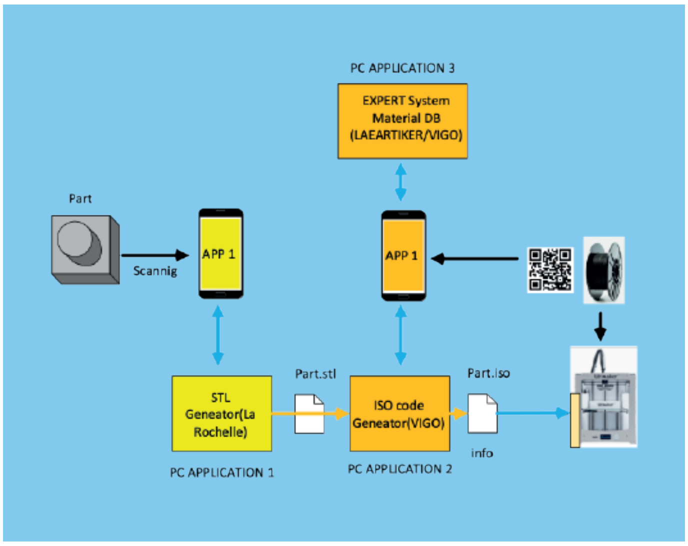


***Figure 4**: Schematic of hardware system.*

3.1.3 Software Solutions – University of La Rochelle

ULR will develop a component scanning application to be executed in a mobile device connected to a PC application. With this system/application it should be possible to scan an object using a mobile phone to generate the corresponding STL file.

For more technical parts in which more precision is required, the use of more advanced 3D scanning tools will be utilized. Connection between the mobile and PC application will be through local WI-FI.

- Additionally, and before going through the STL generation process, the system/user will have the additional option to search specific model databases for prestored designs with the corresponding STL file.
- ULR will also specify the minimum acceptable mobile phone versions for the application.

***Figure 5**: Flow diagram of software-3D printer.*

3.2 Assumptions and Constraints

As shown in the business case summaries above and stated in section 1.2, the main constraints associated with the 3D printing manufacture of these products which has emerged out of both the diagnosis reporting at each node, and the business case workshops are material development and technology/process challenges. Much of these challenges to production are shared across all partner nodes and clearly highlighting some of the common concerns among participating stakeholders.

3.2.1 Material Quality

This is an analysis of the plastic material that has been recovered from these industries across each node. Plastic like Nylon, Polyethylene, and a variety of thermoplastic compounds have been identified. Although these material types are very common and found in significant volumes, and for their properties linked to strength, relative cost of manufacture and hence viability for use across a range of products, selection of these plastics for specific parts or components described in the business cases will require extensive testing by Leartiker. These materials will be matched to the proposed product in the node region, to learn the properties of the plastic and their suitability as a feedstock material for 3D printing of the products.

3.2.2 Recyclability

As part of the material development phase of CircularSeas, a further analysis has been conducted to determine the level to which these plastics are recoverable and recyclable. At this phase of the project, the selected materials are showing significant promise in their reuse potential for prototype printing. The parts or components that will be trialled will have to go through a selection process to ensure that the plastic material is readily recyclable and suitable for the product.

As per the diagnosis of these materials during WP4 activities, a minimum of 80% recycled plastic must be used in order for the part to be considered an Eco-product.

3.2.3 Printability

This aspect of the material development phase of the project will specifically consider the overall durability of the plastic material once cleaned and processed.

The so-called printability of the material will describe how the plastic will be formed into 3D printing filament and ultimately progress onto the prototyping stage for each of the business case products developed. Depending on the functional parts that will be trialled, different properties of the plastic will be analysed and explored to develop the best material, or if required mixture of plastics/polymers to successfully print a prototyped component.

From the technical and material/polymer science activities described above, the terms and processes are laid out to show the capabilities of the consortium to design, build and deliver the integrated material – hardware – software system that will be used to trial and prototype the products described in the business cases. Each node business case has been developed over the course of three dedicated workshops.

1. Introduction to Circular Economy, 3DP technology and results from Diagnosis.

2. Demonstration of 3D printed manufactured parts and a visit to a 3D printing facility.

3. Identification of specific business cases/models for target parts in the node.

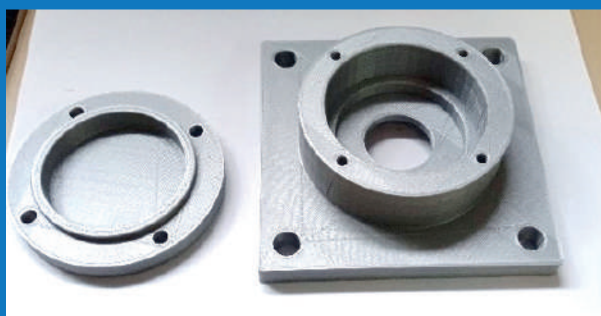
During these workshops, partners used materials and tools like the business model canvas, Eco-canvas, and value proposition modelling to generate the product ideas and build a business/use case that would be carried onto the next phase of the project. *See appendix 2 for examples*.

1. Boat Hull Mould

2. Price Tags

3. Surfboard fins

4. Nylon Ball Bearing



5. Bearing Carrier & Cap

***Figure 6**: Business case Eco-products.*

These products will be 3D printed as highlighted using plastic recovered from each of the node locations. These materials as shown in the business case summaries are sourced from recovered fishing nets, oyster farming spat collectors and various other plastic types.

Individual workshop discussions were hosted across each partner node and various ideas and challenges were submitted by the stakeholder attendees. Many of the discussions were centred around product ideation or development. However, over the course of conversation hurdles to their production were frequently identified, for example, in the event of a successful pilot testing project, how would businesses looking to adopt these new approaches gain the expertise in 3D design and operationally produce filament feedstock for their own production?

Other constraints or challenges that emerged frequently related to the processing of the plastic in situ at these facilities i.e., ports or nautical sports locations like marinas. Many of the materials that are stored at these locations as mentioned can be heavily contaminated with organic matter, known as 'bio foul'. A recommendation was made by technology attendees for consideration by the project partners related to material cleaning and processing.

This involved the potential of a methodology and equipment used in other operational sectors like agriculture. This process being 'Anaerobic Digestion' which is the use of specific bacterial cultures to digest organic matter that is found on machinery, or in the case of maritime equipment, fishing nets and plastic equipment used at sea.

Due to the diverse nature of the stakeholders that are participating in the implementation of these businesses cases and products, representation from across multiple sectors from 3D printing technology companies, sports businesses and government agencies including local authorities and waste management companies, an encouraging interdisciplinary collaboration between stakeholders has been adopted and this can provide the solutions to the overall approaches of CircularSeas.

With the material development and 3D printing activities well under way, the initial batch of products to be manufactured will realise the work that has been accomplished across the consortium and maritime stakeholders that have committed their businesses to the uptake of a new technology. Of course, the use of additive manufacturing technology is one key objective to be implemented, however providing maritime stakeholders with a credible framework, and committed methodology to its development has allowed business owners to build a vision for their own future resilience and added confidence in the approach being taken.

4. SECTION 4. CONCLUSIONS

4.1 Expected Results

The expected Impacts to emerge out of CircularSeas are in the development of a framework for the increase in recollection and valorisation of maritime industry plastic waste described in the business cases. This will be accomplished through the innovations being developed both technologically and, in the survey, and diagnosis of the status of maritime resource management in Atlantic Area coastal regions through plastic recycling efforts. This will require adaptation and a positive shift in state and local run policies to streamline activities or processes.

Secondly, positive impacts expected but are beginning to be realised will come from the changing recycling practices that European nations are already implementing, but also through development of new environmentally friendly materials aligned with the Circular Economy framework on plastic reuse.

Associated with this will likely see a reduction in the use of new virgin plastic-based products in the maritime Industries. Through these practices, plastic already found and recovered from European coastlines can be reused and valorised for the manufacture of new tools, reducing the spill over of the volumes of plastic we are currently experiencing in Atlantic Ocean nations.

Another positive impact expected from this will highlight the diversification of the economic activities in these regions. As was mentioned throughout, business owners and public government agencies participating are seeing the benefits that are associated with taking a different approach and leaving behind the so called 'status quo' and traditional industrial practices. The relationships being built among these different sectors will equip individuals and their businesses to reimagine how they can interact with the environment and other groups. This includes also forging new ways of designing complimentary business/economic opportunities as we strive to reach a better outcome for our ocean ecosystems of the future.

During work package five activities and reporting on the outcomes of the business case workshops, a common vision and commitment among stakeholder groups to improving various aspects of their operations was very evident. The collaboration between public and private entities that was facilitated through CircularSeas had brought not only awareness of technological solutions being explored in an approach to achieving more circular material supply chains, but a definite commitment and confidence within the CircularSeas consortium specifically to the successful application of this technology.

The business cases that are presented here were selected to be trialled and prototyped to prove the concept in the provision of a new set of practices to advance and promote solutions to a generational challenge. These are a short-listed selection from a much more extensive list that came out of all the regional workshop activities. This has shown the many creative ideas that were explored and the time that was given to CircularSeas by the group of stakeholders who have participated. These are really encouraging outcomes and through future milestones reached within the project, CircularSeas expects to be in a position to produce a full set of viable, well designed, and functional components for participating maritime industries. In so doing, this will help to genuinely contribute to a lasting change in the attitude and operations of all stakeholders and communities who depend on and enjoy the gifts of the ocean.

5. SECTION 5. APPENDICES

5.1 Appendix 1. Full Business Cases

5.1.1 Vigo (ES)

5.1.2 La Rochelle (FR)

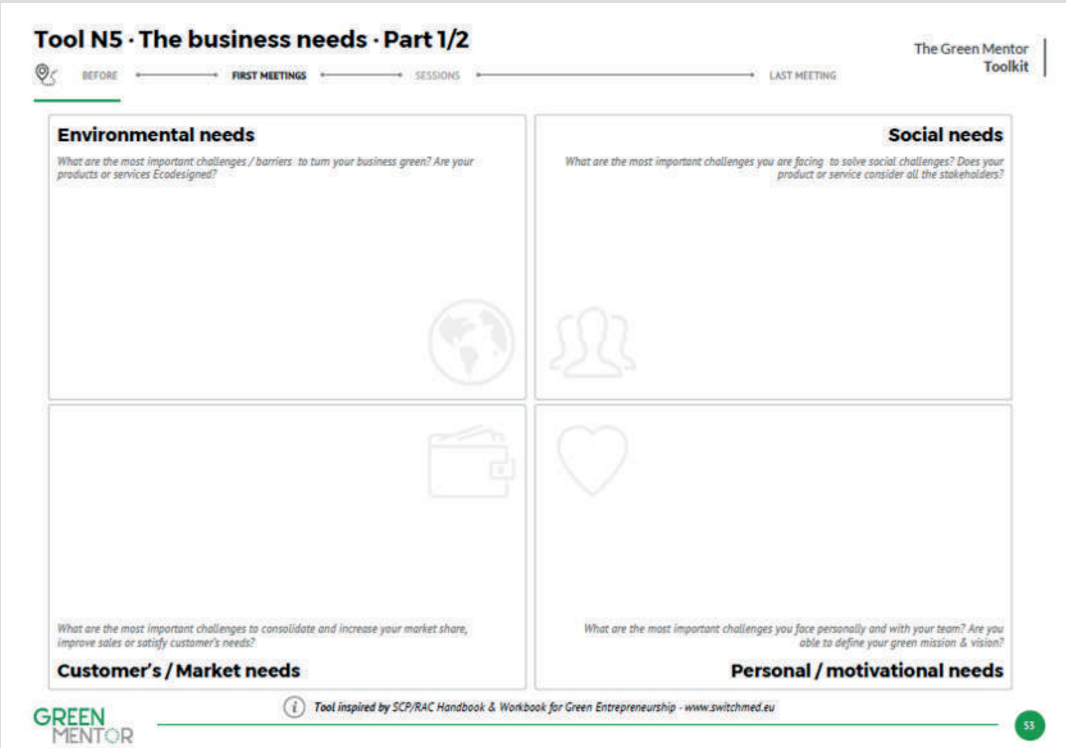
5.1.3 Ondarroa (ES)

5.1.4 Peniche (PT)

5.1.5 Cork (IE)

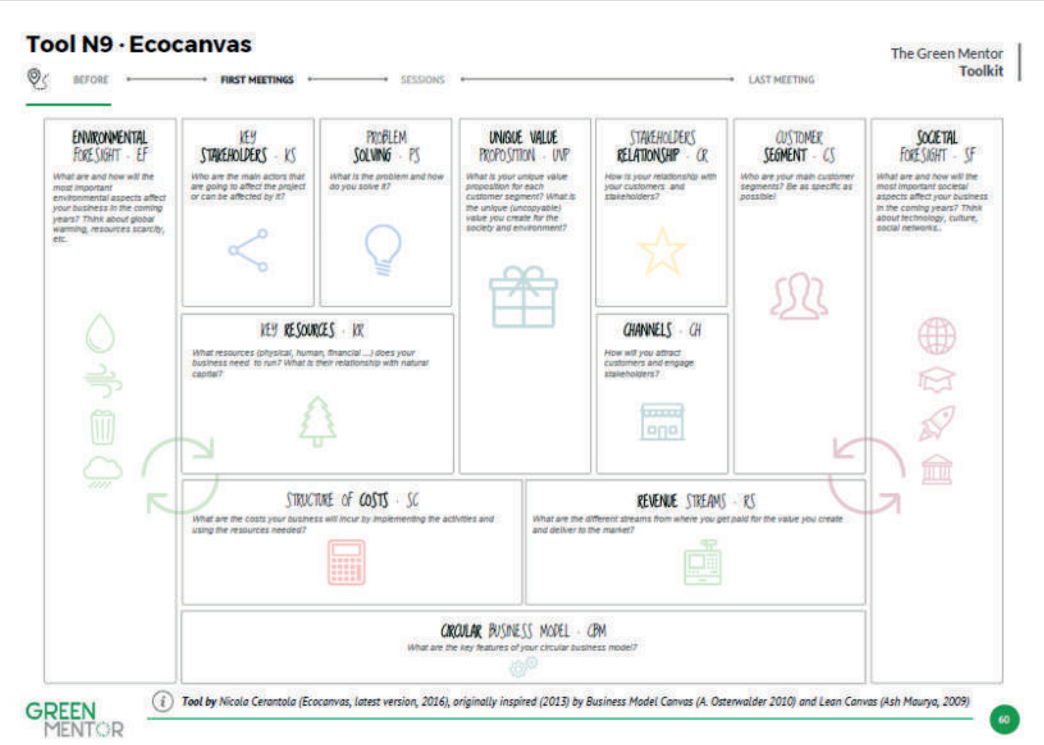
5.2 Appendix 2. Business model development material examples

5.2.1 Example 1

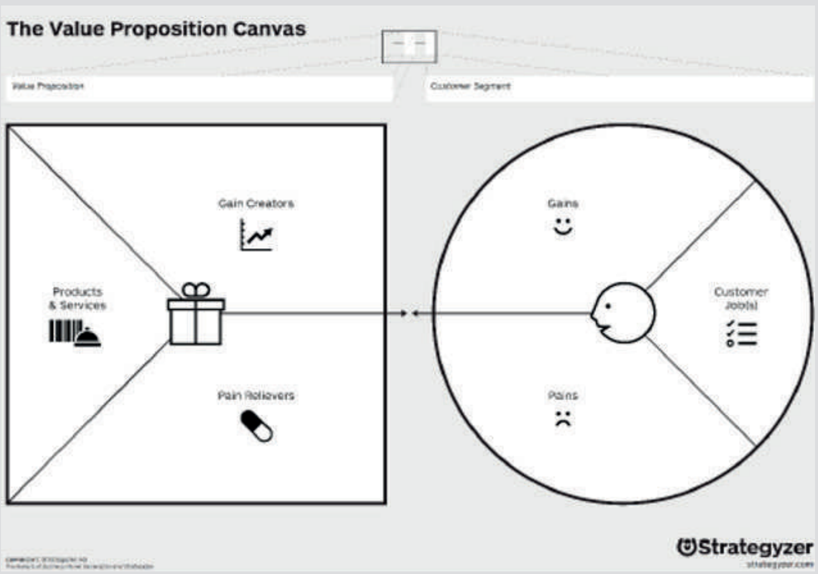


Eco-Canvas tools used in regional workshop outputs

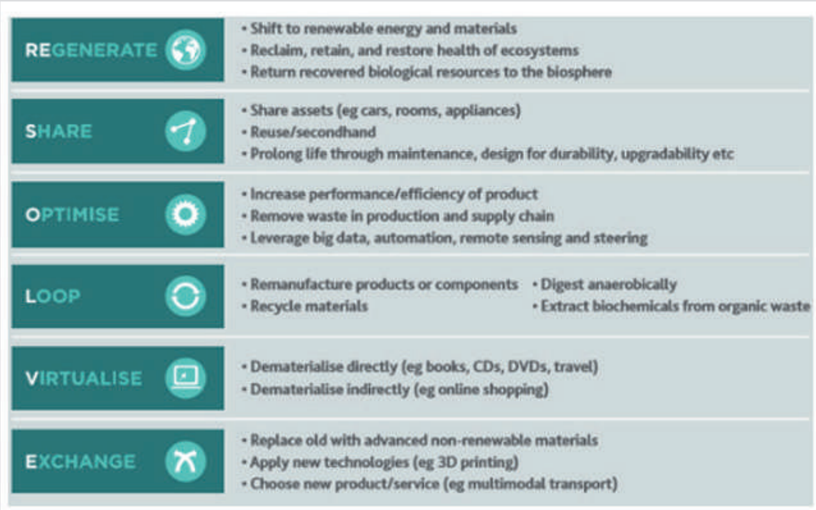
5.2.2 Example 2



5.2.3 Example 3



5.2.4 Example 4



Resolve framework tool for the creation of a circular economy business model

6. LIST OF FIGURES AND TABLES

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