Interreg
Atlantic Area
European Regional Development Fund
EUROPEAN UNION

NEPTUNUS

PROJECT

Policy brief #2

Seafood packaging

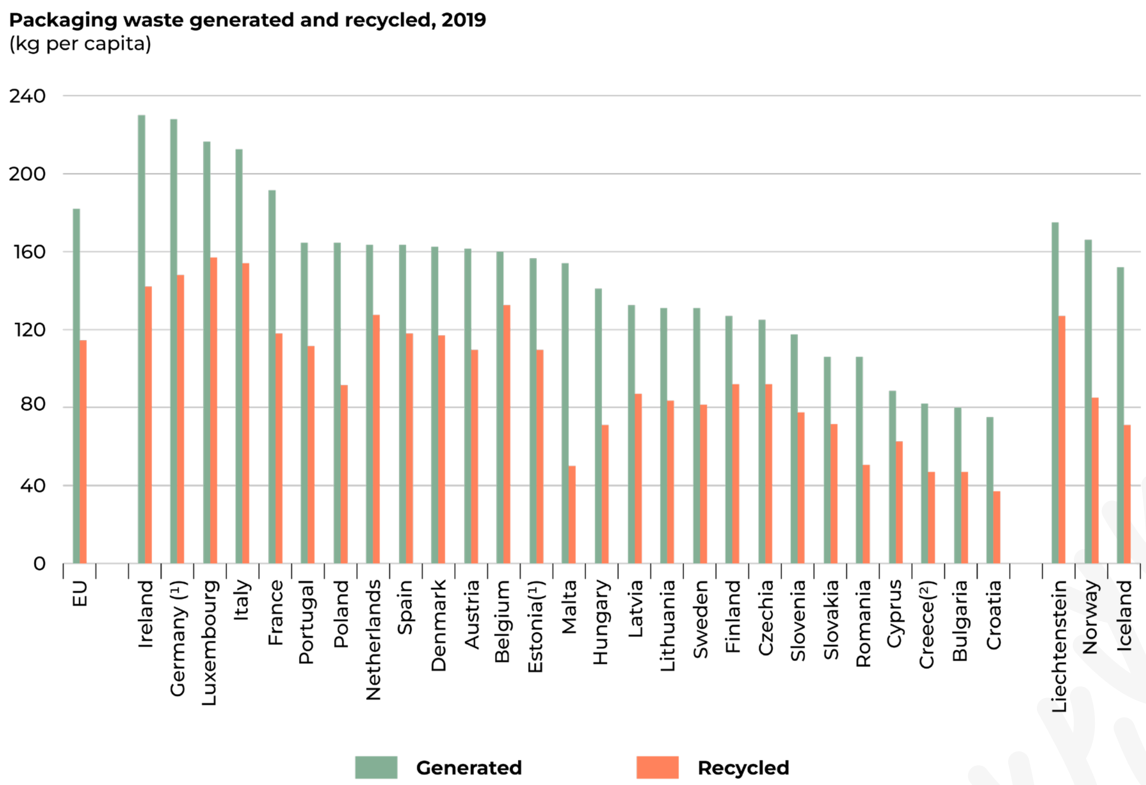
Environmental improvements
and trade-offs

IPMA
ANFACO CECOPESCA
NUI Galway OÉ Gaillimh
universidade de aveiro
UC UNIVERSIDAD DE CANTABRIA

1. Policies and circular economy related with packaging

The transition towards a circular and low-carbon economy, with its goal of extending the useful life of materials by encouraging recycling whilst reducing resource use, has become a priority in the European Union (EU) vision (Tallentire and Steubing 2020). The recycling rate of waste in the EU has shown an increase trend in recent decades, indicating that progress is being made in using more waste as a resource and reducing the demand for virgin materials. However, the rate of progress is slowing down, with little improvements over the past 5 years. The amount of waste recycled is still less than half of total waste generated (809 million tonnes in 2018) and recycling rates range from 66 % for packaging to 39 % for electrical and electronic waste (European Environment Agency 2021a). The packaging sector is one of the major contributors to total waste generation.

It includes materials as paper, cardboard, plastic, metal, composite materials and glass. About 80 million tonnes of packaging waste are currently generated annually and the EU intends to increase the amount of packaging waste that is recovered or recycled (Eurostats 2022). The evolution of packaging waste recycling and recovery rates in the EU showed that the recycling went up from 63 % in 2009 to 64 % in 2019. The amounts of generated packaging waste among the EU Member States in 2019 ranged between 74 kg per inhabitant in Croatia and 228 kg in Ireland, while the amounts of recycled packaging waste ranged from 36 kg per inhabitant in Croatia to 155 kg in Luxembourg (Figure 1) (Eurostats 2022).



Note: Countries are ranked based on "Waste generated".
(1) Break in series.
(2) Estimated data.
Source: Eurostat (online data code: env_waspac)

Figure 1. Evolution of packaging waste recycled generated and recycled in Europe in 2019 (Eurostats 2022).

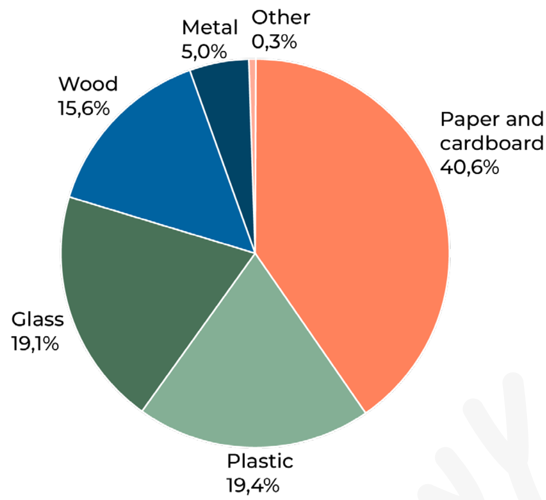
A positive sign is that more than 90 % of the waste generated in the EU is treated in the country in which it was generated, respecting the proximity principle underpinning EU waste legislation to avoid the environmental impacts of transport (European Environment Agency 2021b). On the other hand, facilitated but still well-controlled shipments of waste within the EU may lead to building of economies of scale, reducing the cost of waste treatment and therefore the price of secondary raw materials leading to a higher uptake in production processes. By contrast, the export of low-value waste is typically associated with exporting polluting activities elsewhere. Recyclable waste that is shipped to other EU countries accounts for a significant share of the quantities generated, dominated by ferrous metals (European Environment Agency 2021b).

The EU stablished the rules on packaging and packaging waste with the Packaging and Packaging Waste Directive 94/62/EC and respective amendments. The regulations cover both packaging design and packaging waste management, and seek to cope with the increasing quantities of packaging waste and existing barriers in the EU market. The latest amendment on the Packaging Waste Directive contains updated measures to prevent the production of packaging waste and to promote reuse, recycling, and other forms of recovering packaging waste, instead of its final disposal (European Commission 2018). It stablishes the following recycling targets to be achieved by 2030: 70 % for all packaging types, 85 % for paper and cardboard, 55 % for plastic, 60 % for aluminium, 80 % for ferrous metal, 30 % for wood, and 75 % for glass. Such rules are linked with the Circular Economy Action Plan that aims to make all packaging fully recyclable by 2030 (European Commission 2020a). The EU countries are required to take measures such as enhancement of the circularity of the waste systems, reduce the complexity of packaging, set up a minimum percentage of re-usable packaging, design for bio-based materials application and reuse, and define deposit-return schemes. All these measures are to be coupled with national programmes and economic instruments and incentives (e.g., taxes, subsidies, charges, loans) to achieve the final targets. On another side, the new Directive on Single Use Plastic Products, addresses the problem of marine plastic pollution, ensuring the development for the first time of rules on measuring recycled content in products (Directive 2019/904).

2. Packaging materials

In 2019, packaging waste generated was estimated at 178 kg per capita in the EU. Figure 2 shows that paper and cardboard (41 %), plastic (19 %), glass (19 %), wood (16 %) and metal (5 %) were the most common types of packaging waste, while other materials accounted for just 0.3 % of the total (Eurostats 2022).

Packaging waste generated by packaging material in 2019 in the European Union



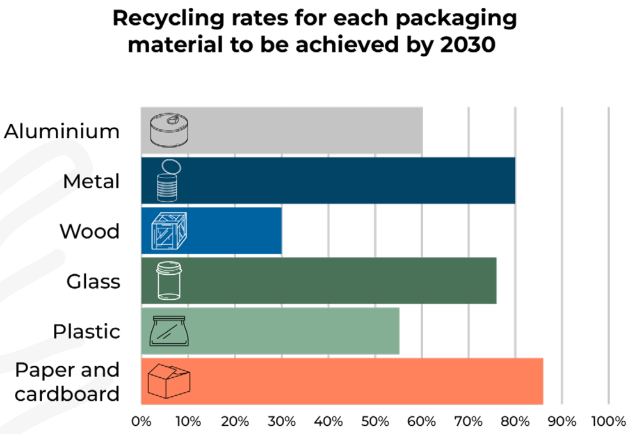


Figure 2. Packaging waste generated (%) by material in the EU in 2019 (Eurostats 2022) and to be achieved by 2030.

Unfortunately, not all materials are equally recyclable. In practice, only a limited number of materials (e.g., metals and glass) can currently be recycled without a loss of quality. A major obstacle in this respect is material mixes and additives that cannot be separated, together with contamination by hazardous chemical properties. Recycling codes are used to identify the different material from which an item is made and to facilitate easier recycling process. Plastics have seven different recycling codes. PET and HDPE are classified in codes 1 and 2 respectively, are very common, easy to recycle, and accepted by most municipal recycling programs. Regarding glass, there are three types of glass recycling codes: GL-70 (clear glass), GL-71 (green glass) and GL-72 (brown glass). Glass is 100% recyclable and can be recycled endlessly without loss in quality or purity. Most paper products can also be recycled and there are three types of paper recycling codes: Cardboard (PAP-20), Mixed Paper (PAP-21) and Plain Paper (PAP-22) (Minos 2021). Only dirty or greasy paper, along with laminated paper, cannot be recycled.

3. What is the problem with plastic?

Packaging materials play a crucial role in ensuring that food is preserved with the desired shelf life and ensuring space optimization during handling, distribution and storage. Petrochemical plastics have typically been used in food packaging industries because they are cheap, have good tensile properties, and represent an effective barrier against oxygen, water, microorganisms, gases, or odors (Ncube et al. 2020).
Thermoplastics can be processed using heat and that ability makes them recyclable, as they can be easily molded to different shapes, and as such, are more ideal for food packaging. The most widely used thermoplastic in food packaging are low-density polyethylene (LDPE), polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), high-density polyethylene (HDPE), polystyrene and expanded polystyrene (PS). The first step to recycle plastics is to separate them by type since not all plastics are recycled in the same way and it is difficult to differentiate at first look the type of material. Therefore, it is needed to check the Plastic Identification Code (PIC), where plastics are ordered on a 1 to 7 scale depending on how easily they are recycled (Figure 3).

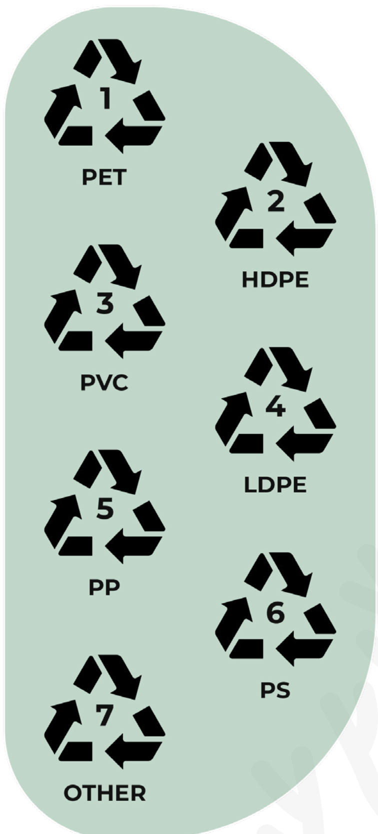


Figure 3. Classification according to the type of Plastic Identification Code (PIC) (ECOEMBES 2021).

The easiest plastics to recycle are the ones with codes 1 (PET) and 2 (HDPE). For example, PET is the most commonly used plastic in water and beverage bottles and can be recycled into new bottles. Code 7 (OTHER) refers to a mixture of different plastics or plastics as, for example, polycarbonates or nylon, which are difficult or even impossible to recycle. The arrows forming a triangular ring are a signal that the plastic product can be recycled in some way, and if the acronym is accompanied by an "R" (e.g., R-PET), it means that the product contains recycled plastic. The plastic types will offer different degrees of strength, utilities, and uses after recycling. Other materials as resins and proteins can be added to plastics making the final material more moldable and durable.

TYPOLOGY	CODE	RECYCLING	MAIN CHARACTERISTICS	MAIN USES	USES AFTER RECYCLING
PET	1	Simple	Transparency, color acceptance, resistance, light weight.	Water and beverage bottles.	New bottles, textile fibers, cosmetic bottles.
HDPE	2	Simple	High impact, chemical and temperature resistance. Flexible, light and water resistant.	Milk bottles, oil bottles, yogurt.	New packaging, boxes, toys, plant pots, furniture.
PVC	3	Simple but not entirely	Rigid or flexible depending on the process. High resistance and low density. Ductile.	Pipes, blister packs, synthetic fabrics, etc.	Drainage or irrigation pipes.
LDPE	4	Possible	High resistance to impacts and chemicals, flexible and transparent (depending on thickness).	Plastic film, bubble wrap, frozen product bags, bottle caps, straws.	Litter bins, shopping bags.
PP	5	Possible	High resistance and easy to mold.	Bottle caps, food containers, disposable plates and cups.	Beams, battery boxes for cars.
PS	6	Complicated but possible	Characteristics are widely varied depending on the format: expanded and extruded.	Thermal materials, packaging fillers, coat hangers, insulating materials.	Packaging, compact blocks for non-food uses.
OTHER	7	Complicated	Dependent on the plastic mix.	Plastic CDs, informatic equipment.	Nylon fibers, car pieces.

Table 1. Characteristics of plastics types, main uses, and ways to recycle them (adapted from ECOEMBES (2021).

Recycling can follow different technologies, including mechanical, chemical and biological. However, these technologies have not yet reached full maturity and have still challenges as, for example, plastics used in food packages can be contaminated with food, and a degradation of its mechanical properties can happen harming its recycling chances. Currently, 31% of all plastic waste in Europe is sent to landfill, while 39% is incinerated and, although the landfill rate is decreasing, incineration rates are increasing, rather than shifting towards recycling or reuse (Ncube et al. 2021). When plastics are not properly collected, plastics can persist in the environment and take many years to degrade (Groh et al. 2019).

Growing concerns have placed packaging activities under scrutiny as it is a constant source of high amounts of plastic, and this has brought about the need to do extensive research into alternative materials and end-of-life options. The European Commission set an ambitious goal of 55 % of plastic packaging recirculation in 2025, and all plastics should be recyclable (or reusable) in 2030, following a Circular Economy approach (European Commission 2020b). This puts pressure on increased recycling and reuse of plastic packaging for food that in EU represents around 47%, the largest fraction of all plastic packaging (Beltran et al. 2021).

Alternatives that involve the development of bio-based materials (i.e. bioplastics) with biodegradability potential are essential to meet the demands of an increasingly environmentally friendly society.
Bioplastics comprise a whole family of materials with different properties and applications. A plastic material is defined as a bioplastic if it is either bio-based, biodegradable, or features both properties.

- **Bio-based:** means that the material or product is (partly) derived from biomass (e.g., corn, sugarcane, or cellulose).

- **Biodegradable:** biodegradation is a chemical process during which microorganisms that are available in the environment convert materials into natural substances such as water, carbon dioxide, and compost (artificial additives are not needed). The process of biodegradation depends on the surrounding environmental conditions (e.g. location or temperature), on the material and on the application. The property of biodegradation does not depend on the resource basis of a material but is rather linked to its chemical structure.

Bio-based plastics include: i) chemically synthesized polymers, ii) polymers extracted from biomass (e.g., cellulose, starch, chitosan), and iii) polymers derived from microbial fermentation, or bacterial cellulose.
Bioplastics have different properties and can be either biodegradable or non-biodegradable bioplastics. Bio-based substitutes for petroleum-based plastics such as bio-polyethylene (Bio-PE), bio-polyamide (Bio-PA) and bio-polyethylene terephthalate (bio-PET) are no more biodegradable than their petroleum-based counterparts (Zhao et al. 2020). However, the greenhouse gas emissions (GHG) generated from producing bio-based polymers can be significantly less than that for polymers that use fossil fuels as raw material (Hamed et al. 2022). Bio-based polymers require less energy to be produced and have less environmental impact, but they must nonetheless be recycled.
A problem with bio-based plastics is that they cannot be commingled with recyclable plastics, they must be recycled in separate streams.
In the case of biodegradable bioplastic, composting is often considered as an environmentally attractive and sustainable way to reduce the municipal waste problem.
However, in some cases, the recycling of these materials needs to be done with anerobic digestion.

4. Contribution of packaging to carbon footprint and waste management of seafood products

The main materials used in seafood packaging are aluminium, tinplate, plastic, paper, wood, and glass, which can be used in primary, secondary, and tertiary packaging. Packaging has a remarkable range in the environmental burden of seafood products (Almeida et al. 2021).
The carbon footprint (CF) of packaging goes from almost zero up to 19 kg CO_2 eq per kg of seafood, corresponding to less than 1 to 89 % of the total CF of seafood products, differing substantially depending on the type of material and its post-harvesting processing.
Aluminium and tinplate materials have the largest contributions to the CF of seafood, with 10 -83 % and 6 – 89 % respectively. As they are the most widely used materials in the canning industry, the CF of packaging in canned products is significant, representing on average 42 % of the product life cycle.
In frozen, chilled and cooked seafood products, packaging consists mainly of paper, plastic and wood (e.g. for oysters), and on average contributes to less than 5 % of the CF of seafood, corresponding to less than 1 kg CO_2 eq per kg of seafood.

Viewed through a recyclable commitment, aluminium cans and glass containers perform relatively well due to recycling rates of 75 %[1] and 78 %[2] respectively for aluminium and glass in Europe. If instead we prioritize climate impact, plastic appears more favourable because aluminium cans packaging can have two times the carbon footprint when compared with plastic packaging (Almeida et al. 2014). This is largely the result of a more carbon-intensive production processes and transportation of aluminium, which are difficult to offset even with the high overall recycling rate.

When switching from single-use to multiuse using, for example, a glass container used for two different products would further cut significantly the CF, while also reducing waste. This reflects the current market trend about introducing more returnable or refillable containers in food packaging.

Other measures to reduce the environmental footprint of the packaging system itself are through the removal of excessive packaging. In fact, seafood LCA studies usually focus on direct environmental effects from packaging materials, with recommendations to reduce packaging volume/weight.

Less attention has been paid to other packaging functions such as those that reduce food waste. Such measures often can be more important than those that reduce the volume/weight of packaging materials (Williams and Wikström 2011; Wikström et al. 2014). Packaging effectively decreases the environmental burden of the product life cycle when considering the food loss related to damages during transportation or environmental burden of additional production to compensate the food losses (Sasaki et al. 2021). To proper assess the environmental impacts from food-packaging systems, it should be quantified the trade-off between investment in packaging and potential reduced food waste (Molina-Besch et al. 2019).

5. End-of-life of packaging

To raise packaging recycling rates and fulfil targets substantial improvements are necessary at the product design, collection systems, and market level (Antonopoulos et al. 2021). Designing packaging to reduce its environmental impact, can cover several key elements. Apart from ensuring that the packaging protects the product reducing the risk of damage and waste, it is possible to explore opportunities to use less material through better design and less weight of material, and plan packaging so that it can be readily and recycled easily. It is also important to consider the overall packaging impact from primary, secondary and tertiary packaging when reviewing savings throughout the supply chain.

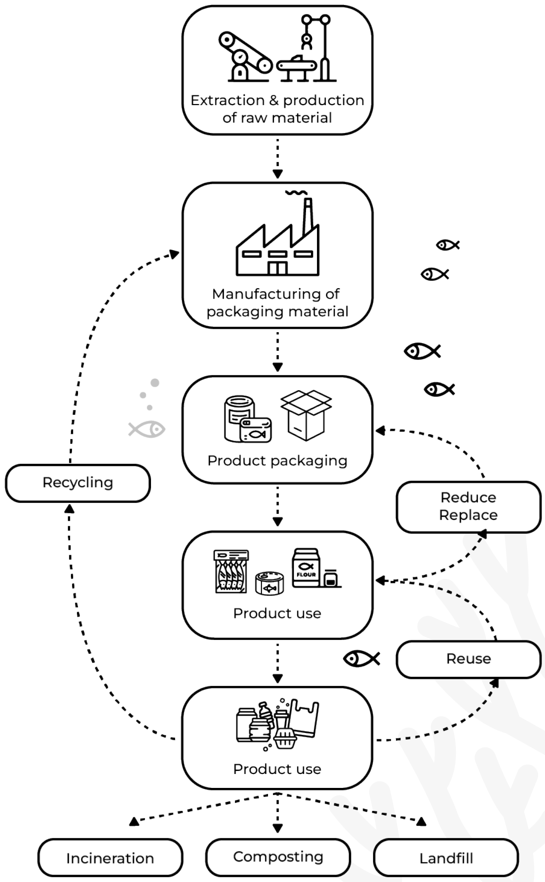


Figure 5. Circular economy principles applied to seafood packaging. Adapted from Laso et al. (2022).

1 https://international-aluminium.org/resource/aluminium-recycling-fact-sheet/

2 https://www.glass-international.com/news/glass-containers-recycling-rate-hits-record-european-high-in-2019

The collection systems can work differently depending on the region or country but the end-of-life option applied will compromise the end contribution of the packaging to the environmental assessment of the products.

Undifferentiated waste container. Depending on the waste treatment facility, undifferentiated waste usually goes to both landfill and/or incineration. Waste in a landfill decomposes slowly, releases GHG (e.g., mainly carbon dioxide (CO_2) and methane, and runoff, and requires large areas of land and treatment facilities. If going to incineration, although it serves as an energy recovery system, it emits also GHG (e.g., mainly carbon dioxide (CO_2) as well as nitrous oxide (N_2O), oxides of nitrogen (NO_x), and ammonia (NH_3) to the atmosphere and its use should be reduced as much as possible.

Biodegradable packaging. When packaging is biodegradable, it means that it is prepared to decompose naturally, with the help of microorganisms (e.g., fungi and bacteria). The temperature, light, humidity and existing microorganisms in the composting place will determine the ability of these packages to degrade. After being used, they can be disposed and sent to the correct waste bin for treatment (e.g., plant-based plastics are meant to break down more easily than regular plastic and be safer for the environment).

Compostable packaging. Compostable packaging can be defined as those packages that biodegrade under specific conditions (domestic or industrial) in a place with lots of fungi and bacteria, high humidity, and the right temperature (e.g., packaging made of vegetable starch or bamboo). Both compostable and biodegradable packaging degrade through the action of microorganisms, but the main difference lies in the fact that biodegradable packaging refers to just any material which breaks down, while compostable packaging gives rise to a compost that can later be used as fertilizer (i.e., when they break down, they release valuable nutrients).
All compostable material is biodegradable, but not all biodegradable material is compostable (e.g., biodegradable plastic bags are not necessarily compostable and could still be made of plastic).

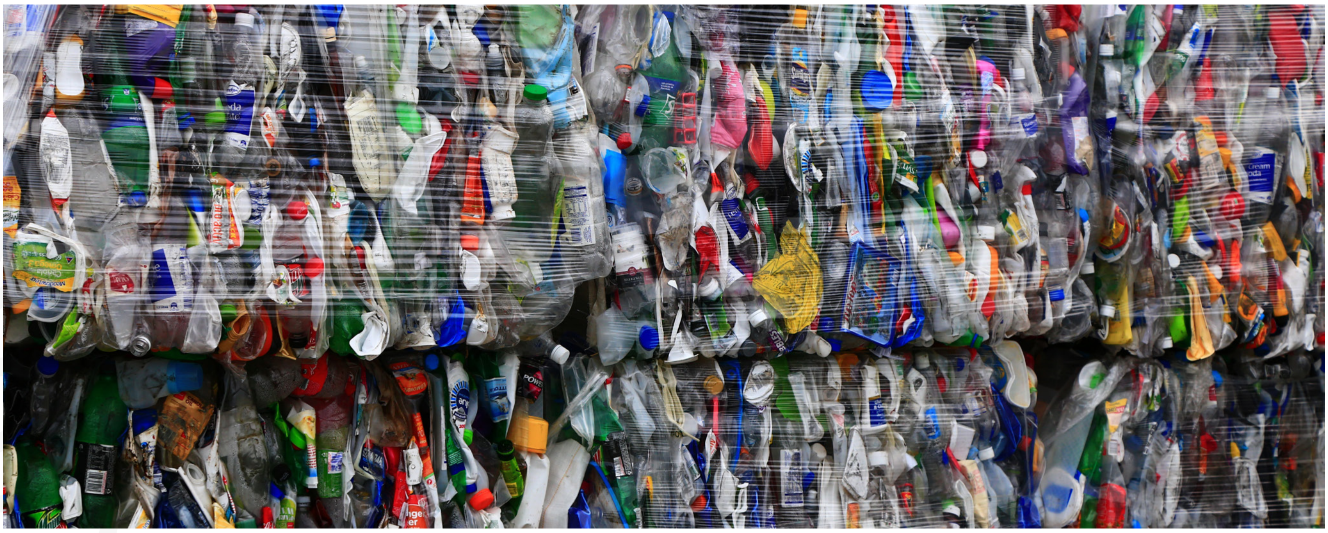
Recyclable packaging. Whether paper, cardboard, plastic, metal or glass, the recycling process allows recyclable packaging to gain a new purpose after their use. By placing them in the right recycling container, they will be taken to treatment plants and reused in materials that can give rise to new materials and save GHG in the production of new materials. It allows also to save water and energy, and reduce the contamination of soils, water courses and amount of pollution emitted by avoiding the extraction of new raw materials. Recycling also reduces the amount of waste placed in landfills or sent to incineration avoiding the environmental impacts from these operations.

Seafood packaging, as plastic bags or aluminium cans, should be placed in the recycling bin, even if they are dirty, as long as their contents have been drained, because they are washed during the recycling process.
Also, many seafood packaging are made of expanded polystyrene that should go to the recycling bin.

Re-using packaging. Re-use should be part of a circular economy strategy together with reducing and recycling. Some options to reuse the packaging could be:

· refills packs - consumers could be incentivised to choose the refill option through a lower retail price or promotion;

· returnable systems - returnable secondary and tertiary packaging is very common for fresh and chilled seafood transport boxes, pallets, and display crates, but can also exist when consumers return packaging which is cleaned and refilled as, for example, glass bottles (e.g. beverage and milk);



6. How do we make seafood packaging more 'sustainable'?

There is no one size fits all solution to sustainability and understanding the product is vital. The choices and strategies can be different and adapted for each product, user and context. In some cases, it can be important to reduce plastic consumption, in others can be switching to recyclable materials. A company can also decide to supply reusable containers as an effort to reduce the consumption of single use plastic packaging, but cannot be sure that a consumer is going to use it enough times that it will actually be better for the environment. Therefore, it is up to designers, producers, retailers, and researchers to work out the numbers as accurately as possible, and then share them with consumers to make a difference in more sustainable production and consumption, and to avoid any type of greenwashing.

There is no such thing as a truly 'sustainable' product, however a packaging can be better than what has come before. Lifecycle design strategies can help to identify the different phases were improvements can be made[3]:

1. Material impact
2. Material reduction
3. Production optimization
4. Distribution optimization
5. User optimization
6. Lifespan optimization
7. End-of-lie optimization

7. Recommendations from NEPTUNUS project

- The sum of climate and other environmental impacts of the seafood products should be assessed in its entire lifecycle, including packaging end-of-life options, recognizing both direct and indirect impacts, and incorporating all the impacts associated with each material choice.

- Sustainability of packaging materials varies by which sustainability elements are prioritized (e.g., food waste avoidance, waste reduction, recyclability, circularity, carbon footprint, or a combination of different elements). Companies in the seafood value chain need to understand the trade-offs across the different goals.

- Among end-of-life options, the reduction option should be the first choice whenever it is possible followed by re-use of packaging. A returnable system of seafood packaging could raise collection levels of packaging materials and motivate citizens to participate circular economy.

[3] https://www.sustainabledesignhandbook.com/

• Packaging can indicate clear disposal instructions, suggest creative options for packaging reuse, and state the recycled materials used.

• Despite fast advances in packaging materials, there are many challenges to overcome for the development of seafood packaging and their possible forms of recycling and/or reuse.
There is still some uncertainty in how packaging sustainability is interpreted and the assessment may change when considering different dimensions.

Interested in learning more?

Almeida C, Loubet P, da Costa TP, et al (2021)
Packaging environmental impact on seafood supply chains: A review of life cycle assessment studies.
J Ind Ecol 1–18. https://doi.org/10.1111/jiec.13189

Almeida C, Vaz S, Cabral H, Ziegler F (2014)
Environmental assessment of sardine (Sardina pilchardus) purse seine fishery in Portugal with LCA methodology including biological impact categories.
Int J Life Cycle Assess 19:297–306. https://doi.org/10.1007/s11367-013-0646-5

Antonopoulos I, Faraca G, Tonini D (2021)
Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers.
Waste Manag 126:694–705. https://doi.org/10.1016/j.wasman.2021.04.002

Beltran M, Tjahjono B, Bogush A, et al (2021)
Food Plastic Packaging Transition towards Circular Bioeconomy: A Systematic Review of Literature.
Sustainability 13:3896. https://doi.org/10.3390/su13073896

ECOEMBES (2021)
Tipos de plásticos. http://ecoembesdudasreciclaje.es/tipos-de-plasticos/
European Commission (2018) DIRECTIVE (EU) 2018/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018, Amending directive 94/62/EC on Packaging and Packaging Waste

European Commission (2020a) Circular economy action plan. In European Commission (Issue March)

European Commission (2020b) A new Circular Economy Action Plan. For a cleaner and more competitive Europe

European Environment Agency (2021a) Waste recycling in Europe

European Environment Agency (2021b) Linking cross-border shipments of waste in the EU with the circular economy
Eurostats (2022) Packaging waste statistics

Groh KJ, Backhaus T, Carney-Almroth B, et al (2019)
Overview of known plastic packaging-associated chemicals and their hazards.
Sci Total Environ 651:3253–3268. https://doi.org/10.1016/j.scitotenv.2018.10.015

Hamed I, Jakobsen AN, Lerfall J (2022)
Sustainable edible packaging systems based on active compounds from food processing byproducts: A review.
Compr Rev Food Sci Food Saf 21:198–226. https://doi.org/10.1111/1541-4337.12870

Laso J, Ruiz-Salmón I, Margallo M, et al (2022)
Achieving Sustainability of the Seafood Sector in the European Atlantic Area by Addressing Eco-Social Challenges: The NEP-TUNUS Project.
Sustain 14:. https://doi.org/10.3390/su14053054

Minos S (2021) Consumer Guide to Recycling Codes. United States

Molina-Besch K, Wikström F, Williams H (2019)
The environmental impact of packaging in food supply chains—does life cycle assessment of food provide the full picture?
Int J Life Cycle Assess 24:37–50. https://doi.org/10.1007/s11367-018-1500-6

Ncube LK, Ude AU, Ogunmuyiwa EN, et al (2020)
Environmental Impact of Food Packaging Materials: A Review of Contemporary Development from Conventional Plastics to Polylactic Acid Based Materials.
Materials (Basel) 13:4994. https://doi.org/10.3390/ma13214994

Ncube LK, Ude AU, Ogunmuyiwa EN, et al (2021)
An Overview of Plastic Waste Generation and Management in Food Packaging Industries.
Recycling 6:12. https://doi.org/10.3390/recycling6010012

Sasaki Y, Orikasa T, Nakamura N, et al (2021)
Life cycle assessment of peach transportation considering trade-off between food loss and environmental impact.
Int J Life Cycle Assess 26:822–837. https://doi.org/10.1007/s11367-020-01832-7

Shaikh S, Yaqoob M, Aggarwal P (2021)
An overview of biodegradable packaging in food industry.
Curr Res Food Sci 4:503–520. https://doi.org/10.1016/j.crfs.2021.07.005

Tallentire CW, Steubing B (2020)
The environmental benefits of improving packaging waste collection in Europe.
Waste Manag 103:426–436. https://doi.org/10.1016/j.wasman.2019.12.045

Wikström F, Verghese K, Auras R, et al (2019)
Packaging Strategies That Save Food: A Research Agenda for 2030.
J Ind Ecol 23:532–540. https://doi.org/10.1111/jiec.12769

Wikström F, Williams H, Verghese K, Clune S (2014)
The influence of packaging attributes on consumer behaviour in food-packaging life cycle assessment studies - A neglected topic.
J Clean Prod 73:100–108. https://doi.org/10.1016/j.jclepro.2013.10.042

Williams H, Wikström F (2011)
Environmental impact of packaging and food losses in a life cycle perspective: A comparative analysis of five food items.
J Clean Prod 19:43–48. https://doi.org/10.1016/j.jclepro.2010.08.008

Zhao X, Cornish K, Vodovotz Y (2020)
Narrowing the Gap for Bioplastic Use in Food Packaging: An Update.
Environ Sci Technol 54:4712–4732. https://doi.org/10.1021/acs.est.9b03755

Authors

Cheila Almeida[1], Jara Laso[3], Sandra Ceballos[3], David Alonso[4], Diego Mendez[4], Andrei Briones-Hidrovo[5], Paula Quinteiro[5], Ana Dias[5], Ronan Cooney[6,7], Eoghan Clifford[6,7], Maria Leonor Nunes[2], António Marques[1,2]

[1]**IPMA** - Instituto Português do Mar e da Atmosfera, Lisboa, Portugal
[2]**CIIMAR** - Centro Interdisciplinar de Investigação Marinha e Ambiental, Matosinhos, Portugal
[3]**Departamento de Ingenierías Química y Biomolecular**, Universidad de Cantabria, Santander, Spain
[4]**ANFACO-CECOPESCA**, Vigo, Spain
[5]**Centre for Environmental and Marine Studies (CESAM) & Department of Environment and Planning,** University of Aveiro, Aveiro, Portugal

NEPTUNUS

PROJECT