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Assessment of alternatives for EPS fish boxes

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Responsibility

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Management summary

Background

Supply chains in the fish industry are among the most international and complex within the food industry. In these complex supply chains the role of single-use packaging is significant. Expanded polystyrene (EPS) is the most commonly used form of single-use packaging for fish. It is estimated an annual volume of 22 million EPS fish boxes is used in wild and farmed fisheries within the UK. Despite a number of significant advantages for EPS there are also some drawbacks. EPS is one of the top 10 most commonly found items on the coast and it is a known part of floating marine debris. Recovery rates for EPS are slowly increasing, but still at a relatively low overall level. Alternative materials for this application have been worked on for some time now by suppliers to the fish industry.

Points for attention within this research

The goal of this study was to map groups of alternative transport and storage solutions for fish. These alternatives have been assessed upon the characteristics of the packaging, its technical properties, availability on the market, relative environmental impact and lastly the suitability and readiness for large upscale to UK fish supply chains. Fish is a vulnerable product, especially fresh fish and fish fillets, and therefore the focus is on food safety and product integrity. The most critical characteristics of the single-use packaging is to maintain product integrity and to control temperatures below the prescribed levels for food safety reasons. Emphasis within this research was mainly on the choice of material and its consequences during the entire lifespan of the type of packaging.

Fish packaging alternatives

With existing alternatives to EPS that have entered the market, packaging for fish broadly be divided into five different material categories: (1) Single use plastic EPS, (2) single use plastic other (corrugated PP), (3) single use corrugated cardboard, (4) single use corrugated cardboard with liner (insulation panels) and (5) reusable solid plastic packaging. These alternatives have been examined for a fixed set of starting points and values via a life cycle assessment. The generalized results compared to the industry standard EPS are shown in the table below.

Broadly speaking, it can be said that the alternatives seem to score better in terms of overall CO2 footprint and environmental costs, especially for multiple use solutions. Production makes the largest contribution, while end-of-life processing methods make a relatively minor contribution. Presence of materials originating from fish boxes in nature and their effects on the environment are not included in these provisions. Many solutions focus on using potentially recyclable materials. However, the degree of success depends on the presence of a suitable (existing) collection structure for the waste that is released. In practice, there is often no suitable industrial route available for biodegradable or compostable materials.

Barriers and recommendations
Based on conversations with the players in the fisheries chain, it appears that behind the scenes more and more companies are actively looking at where in their supply chains alternative solutions for transport and storage could play a role. Important drivers are the desire to reduce plastic in packaging and increase the use of fully recyclable materials within their chains.
There are more and more examples where influential parties such as supermarkets force their suppliers to switch to alternatives, but smaller players also seem to embrace alternatives. However, the scale at which this occurs is still limited. Barriers that have emerged are technical packaging properties that cannot (yet) be matched, higher running costs, added packaging portfolio complexity and investments to adapt existing production lines to new packaging and case erecting facilities.

Table 0.1 Overview of fish packaging alternatives, compared to standard EPS packaging

Packaging system	Technological	Economical	Environmental
Corrugated PP	Insulation: - Weight: - Risk of damage: +/-	Investment: - Transport: + Scalability: +/- TRL: +/-	Production: + Transport: +/- EoL: + Collection system: +
Cardboard corrugated	Insulation: - Weight: - Risk of damage: -	Investment: - Transport: + Scalability: + TRL: +/-	Production: + Transport: +/- EoL: + or +/- Collection system: ++
Cardboard with insulation panels	Insulation: +/- Weight: - Risk of damage: -	Investment: - Transport: + Scalability: +/- TRL: +/-	Production: + Transport: +/- EoL: +/- Collection system: +/-
Reusable fish boxes	Insulation: - Weight: -- Risk of damage: +	Investment: -- Transport: + Scalability: +/- TRL: +/-	Production: -- Transport: +/- EoL: ++ Collection system: +

+ = better than EPS +/- similar to EPS   - worse than EPS

EoL = End of Life
TRL = Technology Readiness Level

Lastly, one other significant barrier that hinders implementation of packaging alternatives are the higher cost of the identified packaging alternatives. Many of the actors indicate that they only see a larger scale breakthrough of alternatives happening, when this ‘unprofitable peak’ will be eliminated by the introduction of a plastic tax on EPS transport packaging or ultimately a ban on EPS. However, it should be noted that there is not yet a fully-fledged alternative to EPS for all current applications. Multiple use solutions have proven te be both more environmentally friendly and more cost efficient is some cases.

Currently, there is still an absolute need for companies to target alternatives. This means that real changes will only occur if more powerful parties such as supermarkets or wholesalers take the lead. A well-organized supply chain such as that for Scottish salmon aquaculture is in a good position to make a contribution in the right direction and accelerate a transition towards less EPS based packaging, especially for inland deliveries.

1 Introduction

To date expanded polystyrene (EPS) is the most commonly used form of single-use packaging for fish with an estimated annual volume of 22 million pieces fish boxes[1] used in wild and farmed fisheries within the UK. Despite some of the properties that make EPS very suitable as a means of cold chain transport of fish, there are also some important disadvantages especially from an environmental perspective. It is one of the top 10 most commonly found items on our coasts and a known part of floating marine debris. Over time, a number of alternatives to EPS have become available on the market, which in a number of cases also consist of plastic. There are also solutions that focus on cardboard, as a single material or in combination with insulating natural materials produced as waste or byproduct. These types of alternatives are central to this research.

1.1 Objective

Key objective of this research is to map alternative systems for storage and transport of fish products to assess:

1. Characteristics and technical properties
2. Availability for the market
3. Relative impact on the environment (taking into account the complete life cycle)
4. Suitability and readiness for large upscale to UK fish supply chains

In order to address the problems associated with EPS fish boxes by increasing the uptake of alternative systems, the alternative systems need to be understood clearly before they can be recommended for implementation across packaging supply chains to avoid regrettable substitution.

1.2 Reading guide

The selected approach for the assessment is described in Chapter 2. A brief introduction and description of the fishing industry in the UK in Chapter 3 highlights the major role of import and export of fish species. Chapter 4 provides an overview of EPS and four other categories of alternative solutions available for the storage and transport of fish. For each category a number of examples will be discussed in more detail. The production process of the materials used is briefly described as well as the end of life scenarios after the packaging has been disposed of. Approach and outcomes of an indicative Life Cycle Analysis (LCA) are described in Chapter 5. The main findings and discussions are summarized in Chapter 6.

[1] Healthy market growth as polystyrene fish box production expands to meet increased demand for fish and seafood in UK The BPF EPS Group

2 Research method

The starting point for this assessment was an initial extensive inventory that had already been initiated by Fidra itself. This existing overview has been further expanded on the basis of additional information gathering. Alternatives that have been identified were then grouped according to the most common types of solutions with corresponding characteristics for a mutual comparison on the different environmental effects and circularity. In addition to these aspects, possible opportunities and drawbacks for scaling up these selected alternatives are analysed.

2.1 Assessment of alternative packaging systems

A combination of different information sources was used to get a better understanding of the supply chain for the UK and relevant underlying facts to be able to assess the alternatives to EPS. Information was drawn from additional desk research (public data), data provided by suppliers and insights from different selected stakeholders from the fishing industry. These groups of stakeholders included producers of alternative packaging solutions, producer organisations, retailers and wholesalers both from the UK as well as some other European countries.

2.2 Assessment of relative impact on the environment

A compact indicative LCA study was applied for the complete life cycle of the identified categories of alternative solutions. The LCA methodology roughly follows the international ISO standard 14040. Processes and materials were retrieved from the most recent version of the Ecoinvent (3.6) database. Proxies have been used in case no information on the specific processes and materials could be found. Assumptions and input parameters have been based on available information, also from existing LCA studies on EPS and cardboard[2] [3].

The results are expressed in a shadow value, environmental costing based on 11 of the impact categories. Absolute and relative values for all 11 impact categories are displayed as an appendix to this report.

2.3 Possibilities for further upscaling in the UK fish supply chains

Without legislative changes such as a ban on EPS containers or restrictions on its use, solutions with less environmental impact will only be adopted by the market if they can be brought to scale at competitive costs and with similar performance to EPS. An overview will be generated with the most important parameters being compared in a qualitative way for the solutions discussed in this report. Based on the current scope and approach only estimates for the cost price for individual solution could be retrieved. Full generic costs involved for switching over cannot be given due to the lack of sufficient underlying information and the strong dependence on case specific cost items and composition and structure of assets.

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[2] Life Cycle Assessment of the Industrial Use of Expanded Polystyrene Packaging in Europe EUMEPS/PWC (2011)

[3] Comparative Life Cycle Assessment (LCA) Study of Fish Packages Made of Expanded Polystyrene or Corrugated Board LCA consulting (2018)

3 UK Seafood Industry

Supply chains in the fish industry are among the most international and complex in the food industry. Due to the import and export of fish, accurate records are kept of how much and which type of fish is traded across national borders[4]. The fish processing industry in the UK, which is large in size, has also been described several times in studies. The annual survey from Seafish provides a good picture of total employment and the distribution of jobs across the various regions within the UK[5]. The domestic flow of fish products between the various processors, middlemen and the ultimate customers, is a lot less transparent. It should also be noted that some fish is exported abroad for processing and then re-imported, possibly this is more advantageous from a cost perspective. This section outlines some characteristics of the current situation for the UK, because this picture contributes to the consideration of the possibilities for applying alternative packaging for EPS fish boxes.

3.1 UK Seafood Industry and supply chain

Although the seafood industry makes a limited contribution to the overall British economy, during its membership of the EU, the UK was one of the major fishing countries compared to other member states. The fish processing sector especially is relatively large and only second to that of France compared to other EU members. When looking at packaging materials it is important to first of all understand the size and structure of the market and associated flows of seafood between the different actors.

3.1.1 Production

The inputs and outputs of fish in the UK (2019) are summarized in Table 3.1. A more detailed summary of the UK fish market can be found in Annex *I.*

Table 3.1 Inputs and outputs of fish in the UK 2019

Flow of fish	Volume (tonnes)	Value (£, in millions)	Fish type
Direct landings by UK and foreign vessels	362,000	762	Demersal and pelagic fish and shellfish
Aquaculture farms	189,921	962	Pelagic fish (mostly salmon) and shellfish
Import	721,000	3,457	Pelagic fish and shellfish
Export	452,000	2,004	Demersal and pelagic fish and shellfish

Much of the catch landed in the UK is exported, while a lot of fish is imported for UK consumption and processing. The main species are mainly exported to the European market, with the exception of salmon where about half is transported outside Europe. Due to this incongruity, there are many fish and fish product trade flows within the UK fishing industry.

[4] H.M. Revenue and Customs

[5] Labour and Employment in UK seafood processing 2019 Annual Report Seafish

3.1.2 Routes

Once fish is brought ashore there are multiple routes possible depending on fish species, the degree to which the fish has already been processed and the intended sales channel. The shapes of the supply chains are influenced by (among other factors) the preferences of end markets and available supplies. Part of the freshly landed fish is sold via fish auctions, but the larger volume is sent to either wholesalers or directly to processing sites. In general, large processors supply national outlets in retail and food service with sizeable volumes of fresh, chilled and frozen fish mainly sourced through direct contracts. Mid-sized processors source material for regional outlets by direct contract, by supplies from fish markets like Hull and Grimsby (white fish) or both contract and market supply. Small processing firms cut material for local outlets and are almost entirely reliant on the fish markets[6].

3.1.3 Processing

The UK fish processing industry had a total turnover of £3.4bn in 2018 with 353 sites active in primary or secondary processing or a combination thereof[7]. Primary processing is slaughtering and gutting. Secondary processing is filleting, fillet trimming, portioning, producing different fresh cuts, smoking, marinating or breading[8]. Most of the regions within the UK have their own profile and specialism, with Humberside (pelagic, demersal) and Grampian (pelagic) accommodating the largest number of sites and with Highlands and Islands as main regions for salmon processing.

The UK processes most seafood types and mixed species factories are the most common. Shellfish processing happens all around the UK. Almost all of the salmon and pelagic (mackerel, herring) processing happens in Scotland. There are 96 sites doing primary processing only and over half of those sites have less than 10 employees. There are 48 sites doing secondary processing only. Six of these sites account for 72 % of FTE jobs[9].

3.1.4 Retail

The wholesale channel and processing sites provide consumers with fish for in-home (major retailers, minor retailers/fish mongers, local street stores) or out-of-home consumption (hotels and restaurants, major food chains, food service)[10]. Well-known physical wholesale markets are Billingsgate (London), New Smithfield Wholesale Market (Manchester) and Birmingham's Wholesale Market, but the actual volume sold here is relatively small.

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[6] Fresh Cod in the United Kingdom EUMOFA (2017)

[7] Cutting Edge issue 1 Seafish (2019)

[8] Salmon Farming Industry Handbook 2020 Mowi

[9] Seafish Seafood processing data and insight

[10] EVID4 Evidence Project Final Report UK fish wholesale market DEFRA (2011)

Overall seafood consumption was £8.48bn in 2018[11] of which 45 % was in-home and 55 % was commercial out-of-home. Retail data on sales of seafood within the UK confirms the dominance of the UK's large supermarkets, with five retailers holding just under 75 % of the overall UK seafood market share (the five are Tesco, Sainsbury's, Morrisons, Asda and Marks & Spencer)[12].

3.1.5 Logistics

In general the fish chain is very complex and there is limited public information available on the logistical fish trade flows to and from and within the UK. The method of transport depends on the country of origin and also whether it concerns chilled or frozen fish. It is crucial to maintain the cold chain throughout the supply chain although this is well organized within the UK. For more detailed distribution and transport by courier, the insulating effect of fish packaging is of greater importance. Examples of the larger volume supply chains are given below.

3.1.6 Hull/Grimsby - haddock and cod

Hull/Grimsby is a key trading hub for UK seafood supply in general, and cod and haddock in particular. The supply of cod and haddock to Hull/Grimsby follows two key supply chains. The fresh/chilled chain involves air freighted fillets (cod), and containerized head-on gutted fish (largely haddock). The frozen chain is largely composed of containerized fillets (largely cod).

The largest volume of fresh material is sourced from Iceland. These supplies are transported either by air-freight (directly for processing) or container ship (for sale through auction markets in case of whole (head-on gutted) fresh fish). Fresh supplies are dominated by head-on gutted haddock by container, and fresh cod fillets transported by air. These go directly to retail or foodservice customers or sometimes have a repacking step in the UK. Processors tend to obtain frozen supplies from further afield. In the main, these are fillets of cod and haddock transported by container. These include products frozen at sea, primarily fillets that are used for further processing in the UK (breaded, battered, ready meals etc.) or go directly to retail and foodservice[13].

3.1.7 Scotland - farmed salmon

In salmon processing there are two primary steps. First is the harvest and gutting, and then the filleting and secondary processing. Salmon are typically taken by wellboat to harvesting stations where they are then killed and gutted. Once harvested, they are generally moved to another plant for the secondary processing. It is expected that there will be more concentrated aquaculture hubs in the near future, but the situation now is that the next processing step takes place in plants that are in various locations across the Scottish mainland and islands.

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[11] UK-Seafish-Seafood Value Chain 2018 Seafish

[12] Percentage share of the UK seafood market by retailer Seafish (2015)

[13] Outlook for supplies of Icelandic cod and haddock to the UK Seafish (2010)

3.1.8 Larkhall DFDS Logistics centre - fish and shellfish

Nearly all processed fish ends up in the DFDS Logistics centre at Larkhall, where fish and shellfish from almost all producers is consolidated into shipments for different (distant) destinations. DFDS specialises in cold chain transport services, and is the largest provider of transportation solutions to the Scottish salmon and seafood industries. Its site in Larkhall has an annual intake of around 300,000 tonnes of fresh seafood products for storage and distribution[14].

More than 23,000 loads with boxes of frozen salmon were shipped in 2016 from Larkhall to local and global restaurants, supermarkets, processors and distributors. Currently, all processed products of finfish and shellfish are transported from processing plants to UK and most European markets by truck. That for more distant destinations is flown as airfreight, almost all leaving the UK from Heathrow. Air-freighted transport of aquaculture products taken by truck from Scotland to Heathrow was estimated at around 100 tonnes daily in 2016[15].

3.1.9 Sea freight - containers

For sea freight three types of containers are available; normal containers, insulated containers and temperature controlled containers (reefer containers). Usually a whole container is used for exporting fresh fish. A big advantage of sea freight in comparison to air freight is that there are few and relatively secure handover points regarding temperature control. Containers (refrigerated and non-refrigerated) are multimodal equipment, which generally allow goods to be switched between land and sea transport without the need of breaking up the cargo[16]. But when unloading imported fish in for example Immingham, the containers are opened up and the pallets reloaded onto trucks. It is more expensive to ship whole containers directly to the buyer, as these have to be shipped back. Inside of the containers fish can be packed in EPS, PP boxes or bins for larger whole fish. Within Europe some larger well-known shipping companies travel regular routes into the larger ports a few times a week.

3.1.10 Air freight - free standing pallets

Air transport has the big advantage that transport often only takes about 2 days, while for ships this may be a couple of days from Iceland to the UK and even longer from distant countries outside Europe. After truck transport to the airport there are loading and unloading steps from truck to plane and vice versa. The product is not as insulated as in a container, there is more direct handling, usually more storage stages and the product is stored on palettes which are free standing (not in a container). Intermediate storage stages are sometimes non-chilled and when a product is stored for a long time in non-chilled storage it can affect the product greatly by increasing temperature in the product itself. This obviously plays a greater role if the difference between the temperature in the box and the outside temperature in summer in warm countries is very large. The risk of disturbances in the temperature profile is therefore greater with this type of transport[17].

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[14] The logistics issues faced by the Scottish aquaculture industry Systa (2018)

[15] The logistics issues faced by the Scottish aquaculture industry Systa (2018)

[16] Optimized Sea Transport of Fresh Fillets and Loins Ásgeir Jónsson (2016)

[17] Compilation and Economic Analysis of the Process of Fresh Fish from Catch to Retailer University of Iceland (2010)

3.2 Packaging Requirements

EPS fish boxes are exclusively used in the business to business market. The main factors for design and characteristics for fish boxes are to maintain product integrity and, in combination with cooling aids, control temperature below the prescribed levels for food safety reasons. Especially for fresh fish, quality depends on characteristics and conditions during storage and transport. Factors like hygiene and handling during pre- and post-processing, physical damage, bacterial growth, enzyme activity, physical damage, dehydration, chemical reactions and contamination are the main causes of quality loss in fish. Ultimately, the value of the fish products is much higher than the costs incurred for packaging. This also applies to the contribution that loss of product would have on the overall carbon footprint[18].

There are different types of packaging in use in the fishing chain. It strongly depends on a player's place in the supply chain, the scale of his activities and the type of fish (species, fresh or frozen). Results from a study that was carried out in 2011 clearly reflect this diversity, shown in Table 3.2.

Table 3.2 Packaging used throughout the UK fisheries supply chain (adopted)[19] [Resource Maps for Fish across Retail and Wholesale Supply Chains]

	EPS boxes	Card board boxes	Plastic trays	Plastic bags	Plastic liners & strapping	Ice / gel packs	Re-usable plastic boxes (<70 L)	Re-usable plastic tubs (<600 L)	Foil bags
Imports (chilled)	Yes	Yes	Yes	Yes	Yes	Yes			
Imports (frozen)		Yes		Yes	Yes				
UK landings (chilled)							Yes	Yes	Yes
UK landings (frozen)		Yes		Yes	Yes				
Processors & wholesale	Yes	Yes	Yes	Yes	Yes	Yes	Yes		
Retail (transport packaging on material received)	Yes	Yes	Yes	Yes	Yes	Yes			

[18] Guidelines for precooling of fresh fish during processing and choice of packaging with respect to temperature control in cold chains Matís (2010)

[19] Resource maps for fish across retail and wholesale supply chains WRAP (2010)

When purchasing their fish boxes, users such as fish processing companies and fish traders mainly consider aspects like costs, strength, durability, weight of the empty packaging, dimensions (sufficient headspace to fit ice or ice-packs, compact pack for easy storage) and possibilities for disposal at end of use. An important constraint as well is whether their production lines and handling systems are able to handle a specific design or box size. This is especially the case with large-scale automated production lines. Another important factor is that the staff must be instructed and willing to work with possible alternative solutions to make them accepted[20].

Use of EPS is limited to chilled fish and appears to be absent for UK landings of fish vessels, reusable plastic boxes are the norm here[21]. Frozen fish has long since been transported as frozen blocks in liner bags inside cardboard boxes.

In the same study, companies were asked to what extent a type of packaging was in use by them. This concerns somewhat outdated data, but such an in-depth investigation has not been carried out more recently. Moreover, it may be expected that mutual shifts may have taken place because for example one type of transport has become more important compared to another, but in general the picture will still broadly correspond with what is happening today.

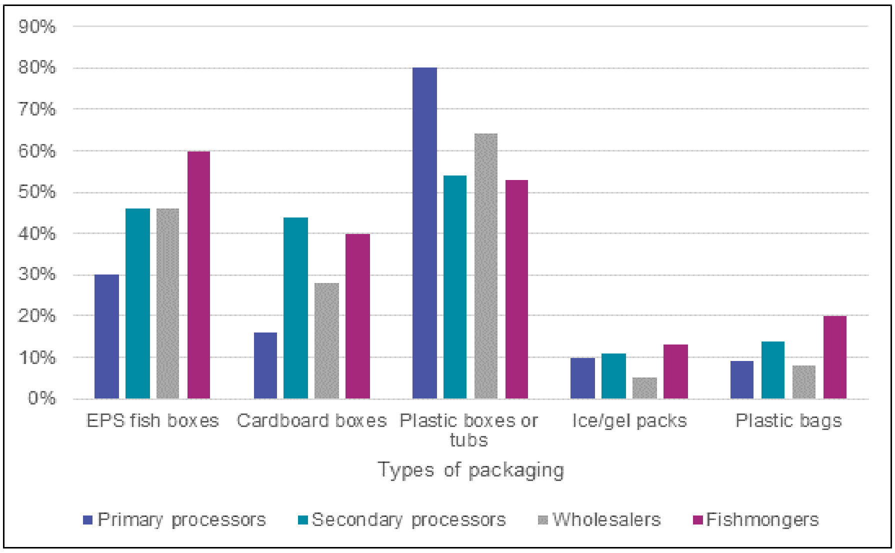

Figure 3.1 the proportion of the UK fisheries supply chain members using common types of packaging for raw materials (adopted) [22]

This data shows that further down the chain the relative use of reusable plastic crates decreases and the share of single use packaging such as EPS and cardboard increases.

Cooling

The aim of cooling is to reduce quality degradation and microbial growth, which both increase with increasing temperature. Strict food safety requirements are set for monitoring the correct temperature limits during transport.

[20] Fresh Fish Wholesale Packaging Seafish

[21] Study of the largest loopholes within the flow of packaging material BiPRO GmbH (2013)

[22] Resource Maps for Fish across Retail and Wholesale Supply Chains WRAP (2010)

By processing fish before transport a low product storage temperature can be achieved using e.g. one or a combination of the following precooling methods; combined blast and contact cooling (CBCC), liquid cooling (LC) or slurry ice cooling (SIC). Some processors apply extra cooling media immediately before packaging in the form of ice/gel-packs, dry ice or water ice[23]. For the (further) cooling of fish in boxes on pallets, it is an advantage if the heat transfer coefficient of the primary packaging material is low.

The most common cooling media are dry ice, ice- or gel packs and water ice. The choice of cooling media depends upon the required product temperature and duration of storage and shipment and sometimes a combination of cooling media is used, such as dry ice in addition to ice packs. Water ice is solely used in land and containerised sea transport where the ice has a clear way out of the packaging after melting to prevent deterioration of the product.

Ice and gel packs are available in numerous variants. Some of them are ready to use and do not need precooling before they can be applied. Other types are bags that contain powder to which water needs to be added to form a gel structure. Not all gels are water based and sometimes specific chemicals are added to control the melting point of the packs. There is a distinction between gel packs for single and multiple use. There will certainly be examples of large-scale reuse, but as a rule it is one-off use. For many of the water-based gels it is said that they can be emptied into the sink and the plastic container can be disposed of with the plastic waste. However, many will end up unsorted as residual waste. The gel beads in ice packs are usually made of sodium polyacrylate, which can be irritating if swallowed. Some early reusable ice packs contained toxic substances such as diethylene glycol or ethylene glycol (antifreeze).
These types of ice packs have been recalled and are generally no longer available.

Dry ice is usually spread over a plastic film covering the fillets in order to lower the temperature of the fresh fish after it is placed in the packaging, just before the lid is put on. Sometimes companies do this only in summer. Direct contact between the dry ice and fish needs to be avoided to not damage the fish[24].

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[23] Guidelines for precooling of fresh fish during processing and choice of packaging with respect to temperature control in cold chains Matís (2010)

[24] Guidelines for precooling of fresh fish during processing and choice of packaging with respect to temperature control in cold chains Matís (2010)

4 Analysis of EPS fish boxes and alternative solutions

For fresh fish and fish fillets, EPS has long been the standard solution for many in the fishing industry. Over time, a number of alternatives to EPS have also entered the market each with their own selection of materials and characteristics. With the increasing attention on plastics in society and also in legislation, awareness of problems with the use of EPS is also increasing. The popularity of home delivery meals also plays a role, as these must be delivered refrigerated during final distribution. The reduction of less sustainable materials in the service provision is part of this customer group's considerations in choosing the right provider. This also seems to stimulate the development and supply of alternatives.

Overall, fish and seafood packaging systems can be broadly broken down into five different categories:

- Single use plastic EPS
- Single use plastic other (corrugated polypropylene)
- Single use corrugated cardboard
- Single use corrugated cardboard with liner (insulation panels)
- Reusable plastic packaging

Examples of existing and available alternatives will be given for each of these categories. The aim is not to provide an exhaustive overview of all available solutions, but rather to give an idea of which sustainability aspects alternatives focus on. A brief description will be given of the production processes and materials used, as well as what the end of life scenario looks like. Included in the consideration of non-plastic products is the presence of coatings containing chemicals such as Per- or Poly-Fluorinated Alkyl Substances (PFAS) which are of major environmental concern.

4.1 EPS (industry standard)

EPS, recently also branded as airpop, is widely used in different applications due to its versatile material properties and cost effectiveness. The areas of application where EPS is consumed mostly are in buildings and construction work, as well as in packaging solutions. EPS consists of two percent polystyrene (PS) and 98 % air and it is therefore considered as lightweight material with a density in the range of 10 to 35 kg/m3. An EPS box varies in size and weight, a box carrying a 10 kg load of fish weighs 0.34 kg and a box for 20 kg of fish weighs 0.58 kg[25]. Having a thermal conductivity of around 0.034 W/m*K, EPS has good thermal insulation properties and is efficient as an insulator of perishable goods during transportation.

[25] Comparative Life Cycle Assessment (LCA) Study of Fish Packages Made of Expanded Polystyrene or Corrugated Board LCA consulting (2018)

Furthermore, mechanical properties of EPS also make it an obvious choice. Its good shock-absorbing characteristics are exploited in shipping processes to protect fragile goods and since it is not biodegradable the material does not deteriorate with age and has high durability.
The material is also water resistant and does not lose strength if exposed to damp conditions. High quality EPS is classified as safe for packaging food[26]. In distribution and processing of fish, EPS fish boxes are particularly used for transportation of fresh fish or processed fresh fish parts (e.g. fish fillet) in uncontrolled cooling chains, where the high insulative properties are needed. Transportation includes airfreight, and private transport to consumers for home delivery[27].
If separated from other plastic materials in waste collection, it is recyclable. Its versatility and favourable characteristics have made it the standard material used to package fresh fish for transportation and storage[28].

According to some of the largest exporting companies of fresh fillets and loins in Iceland and to the largest manufacturer and retailer of EPS-boxes, fish product is typically packed for sea transport as follows: EPS-box with two holes on each end, product placed in box with plastic sheet on top of product and ice, dry ice and/or ice or gel packs on top of the sheet. The boxes will be closed with a lid[29].

On a very limited scale, EPS is being replaced by biofoam produced from renewable sources. An example is the biomass-balanced Styropor® from BASF. There are no known examples that this already has a measurable share within the fishing industry. The carbon footprint of biofoam compared to fossil-based EPS is said to be up to 75 % lower, but details about the starting points are lacking[30].

4.1.1 Production process

EPS is made of fossil-based input materials, with the basic unit of polystyrene being styrene which is made out of ethylene and benzene. System boundary for some of the LCA studies that have been performed on EPS is the production and transport of small expandable polystyrene beads. In a three-stage conversion process these are pre-expanded to about 40 times their original size in a process using pentane as blowing agent. After maturing and stabilizing the beads are reheated with steam to form shape moulds. These moulds (both boxes and lids) are cooled with water before being shipped to a fish processing/repackaging entity[31]. There are variants that are completely closed as well as boxes with drain holes so that excess melt water can drain away during transport of fish with ice.

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[26] Adoption of Sustainable Packaging solutions for the Fish Industry KTH Royal institute of Technology (2020)

[27] Study of the largest loopholes within the flow of packaging material BiPRO GmbH (2013)

[28] Adoption of Sustainable Packaging solutions for the Fish Industry KTH Royal institute of Technology (2020)

[29] Optimized Sea Transport of Fresh Fillets and Loins Ásgeir Jónsson (2016)

[30] Styropor® BMB BASF website (consulted July 2021)

[31] Plastipedia Moulding Expanded Polystyrene (EPS) BPF website (consulted July 2021)

The EU market for EPS consists of 25 bead producers and over 1,000 converters which supplied an annual total of 1,800 kT (2018) of which 90 % is supplied to companies within the EU[32].
The share of packaging applications amounts to 20-25 % of this total[33] with insulated food grade packaging such as fish boxes accounting for 35-40 % (113,000 - 162,000 tonnes)[34]. This means that for most countries in Europe including the UK there are several production sites where EPS fish boxes can be produced. This is also necessary because transport of preformed boxes is relatively expensive because trucks are loaded to a volume limited far below their maximum payload.
Even though the boxes are light and easily stackable, once delivered to the fish processors, the preformed boxes take up a relatively large amount of space in their goods reception halls and factories. A number of larger fish processors even have an integrated business operation and shared facilities with producers of EPS fish boxes.

In the UK, EPS production for packaging is approximately 18,000 tonnes per year, with an additional 10,000 tonnes arriving in the UK as packaged goods. An estimated 24,000 tonnes of foamed polystyrene packaging waste is produced per year in the UK. The UK uses 22 million fish boxes (approximately 10,000 tonnes) every year for seafood storage and transport, protecting UK fish worth £900 million. EUMEPS commissioned PWC in 2011 to perform a LCA on EPS in comparison with corrugated PP and cardboard alternatives[35].

4.1.2 End of life

EPS can be recycled via two more common different routes: such as mechanical recycling, dissolution, physical and chemical recycling. (Annex V: System boundaries of the life cycle of EPS fish box packaging). With mechanical recycling the EPS is ground and sieved into small fractions. These fractions can then be added to the production of new EPS materials. Compacting (mechanical) and melting (physical) EPS is also an environmentally friendly way of recycling because of the benefits this brings to transportation. The compaction, or compression, of EPS is logistically interesting. This is because EPS consists of 98 % air and compression (50:1) reduces the volume of air that needs to be transported to a waste processing plant. Melting produces pallets of pure polystyrene that can be used again, for example to produce EPS. Physical and chemical recycling of EPS are types of processes that are currently still under development[36].

As soon as fish is unpacked after transport and storage the normal user life cycle phase ends since due to hygienic reasons EPS fish boxes are non-reusable. Fish box recycling is restricted due to the organic residues left after use . As a consequence material recycling of EPS waste from fish boxes is usually only for construction materials (e.g. EPS insulation boards) which seems more the norm in some other countries and less so in the UK itself[37].

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[32] EPS Recycling in Europe EUMEPS (2018)

[33] Seminar on eps recycling presentations EPRO (2016)

[34] EU Voluntary Pledge EUMEPS (2018)

[35] Life Cycle Assessment of the Industrial Use of Expanded Polystyrene Packaging in Europe EUMEPS/PWC (2011)

[36] EPS Recycling Beslisboom Stybenex (2021)

[37] Study of the largest loopholes within the flow of packaging material BiPRO GmbH (2013)

There are 28 recycling sites belonging to 24 companies across the UK recorded on the British Plastics Federation (BPF) EPS Group's website, although it is understood that some of these are no longer operational[38]. Compacted EPS is then exported in 23 tonne loads to Europe (Germany, Spain) for reprocessing as insulation boards.

In the EU EPS-SURE LIFE project (by a consortium including membership from the BPF EPS Group), an innovative initiative is being explored to demonstrate that EPS fish boxes can be collected and recycled to become new Polystyrene (PS) containers even for food applications[39].

Waste EPS fish boxes arise particularly at input and output stations of fish distribution, processing, commercialisation and consumption activities (e.g. landing of fish, preparing for processing, wholesale, retail and fish markets, consumption at home or in restaurants)[29]. Larger fish processing companies and locations where large volumes of fish are handled (auctions, fish markets) often have compacters on site to collect EPS and turn it into compressed blocks. Collection and processing seems to be guaranteed for these flows. With sufficient volume, the costs are also lower than if the waste is offered for energy from waste incineration. In some instances return transport is possible after deliveries of new boxes, with used boxes taken back to the producer for waste treatment. In general, however, there is a limited infrastructure for the collection of EPS waste, especially for smaller, specialized players operating at the finer ends of the supply chain.

Table 4.1 EPS produced and recycled - May 2020[40]

UK EPS Recycling rate	Updated 30 May 2020
Market structure	**Tonnes**
UK produced EPS Packaging	18,000
Exported with products	4,000
Imported with products	10,000
Disposed of in the UK	24,000
Recycled/collected	13,140
	55 %
Recycled in the UK	1,000
Exported to EU	12,140

Average numbers for end of life processing of EPS packaging in Europe (388 kT) in 2017 are 32.7 % for recycling, 35 % for recovery and 2.7 % for landfill. More specific numbers for Region Central, including UK, the Netherlands, Belgium, France, Germany and Austria, show an overall collection rate of 45 %. A total of 142 kT of packaging waste is processed, with 20 % via mechanical recycling to EPS, 24 % via mechanical recycling to PS, 46 % via energy recovery and 10 % via landfill.

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[38] Breaking down ocean polystyrene Fauna & Flora International (2020)

[39] LIFE EPS-SURE Project

[40] Recycling Roadmap BPF (2021)

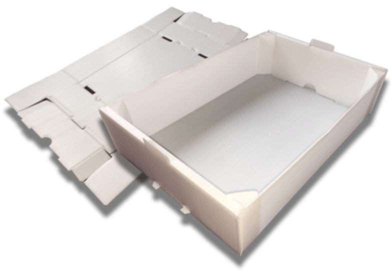
It must be noted that from this group the UK had the lowest level of recycling in comparison to the other countries that are considered leaders in the field of EPS recycling in Europe[41]. The BPF EPS Group states that 54 % of all EPS packaging in the UK is currently recycled[42]. It is difficult to substantiate these figures as there is very limited data available, but it seems likely that the 55 % is somewhat on the optimistic side of the expected range for the UK. Estimated amounts of EPS produced and recycled in the UK are shown in Table 4.1.

EUMEPS has pledged with the EU to increase the average recycling levels for EPS packaging and therefore fish boxes in Western Europe up to 50 % in 2025[43].

4.2 Single use plastic

Flexible plastic packaging alternatives to EPS fish boxes have been available since 2010. These boxes are made of extruded thin wall corrugated polypropylene (2-3.5 mm). Using a special technique to seal the corrugated edges, air is trapped inside the walls of the box to create a thermal barrier and at the same time make it waterproof and leakproof if desired. The material itself is approved for direct food contact. Heat sealing of the edges also eliminates bacterial contamination from entering open flutes. One of the advantages of sheets is that blanks can be die-cut in any dimension which offers the fallibility for customized sizes. In the case of product moulds like for EPS it would be more costly to divert from market standards. In the case of die-cutting losses need to be minimised to be able to get an optimum number of boxes from one mother sheet.

Table 4.2 Examples of commercially available polypropylene (PP) corrugated fish boxes

Producer	Material	Characteristics
CoolSeal boxes by TriPack	PP (corrugated)	
Karton	PP (corrugated)	

[41] EU Voluntary Pledge EUMEPS (2018)

[42] Breaking down ocean polystyrene Fauna & Flora International (2020)

[43] EUMEPS EU Voluntary Pledge

Polypropylene (PP) fish boxes are made out of virgin materials. Their performance is claimed to be similar to EPS with the exception of the thermal insulation properties, which are less. This is an advantage if pallets of fish boxes need to be frozen as significantly less time will be required. However, it does place higher demands on the cold chain for further transport and storage. PP is less able to absorb any fluctuations in external conditions if the chain is (temporarily) interrupted. In the case of air transport or distribution to Mediterranean countries, this can be an important factor, especially in warmer climatic conditions. For most of the current transport types in the UK an uninterrupted cold chain can be more or less guaranteed, making this risk for PP much lower.

The lightweight boxes are delivered as flat blanks, which gives the benefit that for transport of empty packaging to a fish processing plant 3-4 less truck transports are required and storage space upon arrival is limited. For the buyer of the PP boxes, this means that an extra box set-up step is added to the packaging process. This could adversely affect the line speed or require additional investments in an automated case erector to maintain plant capacity especially for large plants.

The thin walled PP boxes have smaller outer dimensions in comparison with EPS boxes and less headspace. With the same weight of fish and ice per box, more boxes can be stacked onto a single pallet and more weight can be shipped per kilometer. In some occasions a 20-40 % higher truck payload can be realized. Purchase costs for PP fish boxes can be 20-25 % higher than for EPS, but reduced transport costs for both empty and filled boxes can (partly) compensate for this.

It is not known what share of the fish packaging is already formed by the PP boxes, but it is known that there is growing interest in switching to this solution for some of the current EPS applications. One of the more known examples where a large European retailer has made the full switch to no longer use EPS is that of Makro. Coolseal Customers in Iceland, Norway and other countries are using leak-proof boxes to ship chilled fillets to supermarkets in the United Kingdom, France and elsewhere[44]. In the UK emphasis lies on wholesalers to switch to corrugated PP solutions. Species like white fish and salmon are packed in PP boxes. The box is also quite popular in the shellfish industry.

4.2.1 Production process

Corrugated PP is made of fossil-based input materials. Production of PP granules is the starting point to produce PP sheets. After mixing the raw materials are extruded into long sheets that undergo some calibration, form rolling, heating, coronaing and refrigeration steps. In the final stage the edges of the semifinished box are trimmed off and the sheets die cut into required dimensions. These die cut parts will be punched and the folding lines will be inserted to deliver the blanks for export to a fish processing/repackaging entity.

The corrugated PP solution has been part of the LCA study conducted by EUMEPS in 2011. No other public LCAs are known for this specific solution (Annex V1 System boundaries of the life cycle of PP fish box packaging).

[44] Environmentally Friendly CoolSeal Fish Boxes (2010)

There are around 10 major corrugated PP producers in Europe, of which some actively offer products for the fishing industry. Some producers have integrated production of sheets with that of blanks for boxes and lids. Other companies are more processors of sheet material that they buy from elsewhere in the world. Due to the still limited number of producers of PP fish boxes, the transport distances for delivering empty packaging to fish processors will be longer on average than for EPS boxes.

4.2.2 End of life

Corrugated PP plastics can easily be compacted in standard waste compaction equipment and are readily recycled after use. For a reliable picture, the degree of collection and recycling specifically of plastic industrial packaging waste is important, but data at this level of detail is not available for the UK. Therefore, the data is assumed for all packaging waste of which 50 % was recycled in 2020 and 86 % was used for recovery. The remainder is assumed to be landfilled (14 %)[45]. Together with PET and PE, PP belongs to the most frequently recycled plastic types.

The level of recycling and recovery is expected to further improve in the coming years due to the targets established in the UK Plastic Pact for 2025. By then 100 % of plastic packaging needs to be reusable, recyclable or compostable and 70 % needs to be effectively recycled or composted post use. An increase in the average amount of recycled content across all packaging can be expected to increase demand for secondary PP and therefore also its residual (positive) value[46].

Waste Management Option	LDPE & LLDPE (kg CO2eq per tonne material)	HDPE (kg CO2eq per tonne material)	PP (kg CO2eq per tonne material)	PVC (kg CO2eq per tonne material)	PS (kg CO2eq per tonne material)	PET (kg CO2eq per tonne material)	Average plastic film (kg CO2eq per tonne material)	Average plastic rigid (kg CO2eq per tonne material)	Average plastic (kg CO2eq per tonne material)
Waste Prevention	2,612	2,789	3,254	3,136	4,548	4,368	2,591	3,281	3,179
(Preparation for) Reuse									
Open Loop Recycling	620	620	620	620	1,957	620	620	620	714
Closed Loop Recycling	1,549	1,662	2,340	2,283	3,342	2,698	1,549	2,159	1,998
Energy Recovery (Combustion)	1,057	1,057	1,357	1,833	1,067	1,833	1,057	1,057	1,197
Energy Recovery (AD)									
Composting									
Landfill	34	34	34	34	34	34	34	34	34
Carbon Factor (Recycling V EfW)	-2,120	-2,183	-2,270	-2,686	-2,272	-3,503	-2,099	-2,179	-2,378
Carbon Factor (Recycling V Landfill)	-1,098	-1,1610	-948	-888	-1,240	-1,705	-1,076	-1,156	-1,215

Figure 4.1 Summary of carbon factors[47]

Zero Waste Scotland has developed a Scottish Carbon Metric that measures the carbon impacts of Scotland's waste (Figure 4.1)[48]. From this we can conclude that higher recovery and more recycling both have positive impact on the carbon footprint for processing of plastic waste streams. The values in this overview are self-contained and cannot be directly linked to the results of the comparison between alternatives in this study.

For the production of corrugated PP post manufacturing waste can be applied, but post consumer waste is currently not used for food contact applications. Used PP fish boxes can therefore be used in new products via open loop recycling, but not in a similar application for fish.

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[45] Recycling Roadmap BPF (2021)

[46] WRAP UK Plastics Pact Annual Report (2020)

[47] Plastic Surgery Managing Waste Plastic_Reality Check Biffa (2019)

[48] Carbon Metric Publications Zero Waste Scotland

4.3 Single use cardboard

A second category of alternatives to EPS consists of cardboard boxes. A distinction can be made between solutions that are entirely based on cardboard and a group that uses insulating liner materials in addition to the cardboard outer box. The fully cardboard variants are described in this section. Some examples are shown in Table 4.3.

The use of cardboard bulk packaging for fish is certainly not new, because within the frozen fish supply chain a lot of work is already being done with cardboard, with or without a separate plastic liner. The application of cardboard for fresh fish has developed more and more over the past years. Some of the larger board producers in Europe have launched designs that are also suitable for storage and transport of fresh fish.

The cardboard solutions share some of their benefits with corrugated PP. The blanks can be transported flat and in higher capacity per pallet to the end users, reducing the number of transports required for delivery. Boxes can hold more fish and more boxes can be stacked on the same pallet, so more fish can be transported in the same space. Thermal properties are not as good as for EPS and an uninterrupted cold chain is seen as a prerequisite. Users need to set up these boxes themselves, either manually of via case erectors.

Table 4.3 Examples of commercially available cardboard fish boxes

Producer	Material	Characteristics
EcoFishBox™ (Stora Enso)	Corrugated board with PET coating	
Thermobox (Smurfitkappa) EnviroCool® (Hydropac)	Hexacomb and kraft board	
Solidus	Solid board	

Producer	Material	Characteristics
Chiller Pack (Cepac)	Corrugated board	

Several single use cardboard products exist, often using liners and/or waterproof coatings. Examples are the EcoFishBox™ developed by StoraEnso, the Thermobox developed by Smurfitkappa. the Solidus solid board box and Cepac UK's Chiller Pack cardboard box (Annex II: Single use cardboard examples).

4.3.1 Production process

Cardboard is made of mainly renewable input materials. For corrugated board (kraft) liners are used between which a fluting layer is formed via steam preheating rollers and corrugating rollers. In the gluing station starch is added consecutively to both liners (double backer). After curing of the glue and application of protective speciality coating liner, a slitter-scorer trims the cardboard and cuts it into large sheets called box blanks. Boxes can be formed in the same plant as the corrugator. Such plants are known as integrated plants. Part of the scoring and cutting takes place in-line on the corrugator. Alternatively, sheets of corrugated board may be sent to a different manufacturing facility for box fabrication; these are sometimes called sheet plants or converters[49].

Solid board consists of two liners glued to a grey inner core (recovered paper) that can be made water resistant using additives. These are mostly wax or PE. Paper products used for food packaging are sometimes treated with PFAS for water and grease resistance. In previous testing, sandwich wrappers, french-fry boxes, and bakery bags have all been found to contain PFAS[50]. It is unknown whether it is applied in fish boxes.

In the UK, numbers from the Confederation of Paper Industries (CPI) indicate that 69 % of paper making used recovered paper in 2019. Woodpulp and other fibre had a share of, respectively 25 % and 1 %, with the last 5 % being additives. The proportion of recycled fibre is even higher for corrugated boxes. The UK consumption of boxes is almost exclusively from domestic supply[51]. The average energy mix for making paper and cardboard was 71 % Natural Gas and 29 % Biomass in the UK[52].

Some of the producers indicate that they use solely FSC certified virgin fibres for food contact applications, but the non contact areas can be made from recycled fibres or can be covered with coatings to provide the right barrier properties.

[49] How it is made Corrugated Cardboard

[50] Forever chemicals in the food aisle Fidra (2020)

[51] CPI Annual Review 2019

[52] CPI Zero Carbon Feb (2021)

In the case of fish boxes, these are often cartons and design variants which, even though these are usually produced by multinational companies with several production sites in the various countries, are manufactured on specially equipped production lines. This means that in practice there is often a limited number of supply points for these alternatives and production often also takes place outside the UK. It can be expected that with further upscaling these options will become wider and that there will be shorter supply channels and transport distances for the blanks. In some cases the hand products for making the cardboard have to be supplied from different locations, for example in the case of combinations of kraft paper, test liner and the fluting. Producers indicate that in the current market conditions, fibre prices have risen significantly which makes it more difficult and expensive to source the right (secondary) input materials to their processes.

4.3.2 End of life

Fibres from paper and cardboard are among the most recycled materials in our society (Annex V: System boundary and life cycle phases of an EcoFishBox™). Paper and board packaging tends to get recycled into new packaging, however fibres last only a limited number of cycles before they become unsuitable for making new cardboard. Virgin fibres will therefore always be added to meet the quality requirements of cardboard. In the UK 68 % of all the paper and cardboard that is collected is recycled. Of the remainder, 22 % cannot be recovered and 10 % is disposed of by other means. About 43 % is processed domestically. The majority of the volume is transported abroad for reprocessing into fibres, mainly outside Europe (50 %)[53].

Not every type of cardboard is recyclable, guidelines have been drawn up by the sector itself as to which cardboard can be processed into new cardboard. Specialty cardboard types sometimes consist of combinations with other (composite) materials, so that this is not always possible.
If cardboard contains too high levels of coatings or films, the material is not always accepted for reprocessing or it can cause interruptions or reduced yields in the regular recycling process.
The guidelines state that designers should target non-paper laminate content at a maximum of 5 % of pack weight. In the case of fish boxes, producers ensure that the cardboard has water-resistant properties or is water-resistant. Typically LDPE or PET coatings will be used for this.
The industry has no preference for biodegradable or conventional plastics since all plastic waste from the paper machine is rejected and sent for disposal unless separately collected and processed by specialist operators. Traditional waxed papers can be harmful to production in a paper mill and should be avoided. Other formulations such as micro-crystalline waxes may be acceptable. Moisture resistant papers can be dealt with by mill systems but are not preferred feedstock and may not be fully recycled[54].

Recently, a lot of attention has also been paid to the presence of PFAS in cardboard products to aid water repellency. In this study it has not become clear whether PFAS is a topic that is also relevant to the alternative cardboard solutions that are being discussed. It should be clear that the possible presence of this kind of perpetual chemical should be seen as a major disadvantage since they may pose a barrier to the recyclability of food packaging in the framework of a circular economy. In addition there is a high possibility that PFAS will be banned from use in food packaging materials in the EU and UK.

[53] CPI Annual Review 2019

[54] CPI Recyclability Guidelines Revision 1 (2020)

4.4 Single use cardboard with liner

A second group of cardboard solutions apply liners with insulation properties that can be inserted around the fish to be transported. These variants were conceived in particular to make the thermal properties for transport even more comparable to those of EPS and to make use of residual waste material flows that are available in abundance. Many of these applications seem to be initially conceived for other uses, for example the delivery of meals at home or more courier-like services. The step towards industrial production levels which would be required for fish boxes is in some cases not yet foreseen in the short term.

In general these types of solutions consist of a cardboard box in which inserts filled with insulating materials are used around the product in combination with cool or gelpacks. For the inserts plastic food grade liner wraps are used to prevent direct contact between the insulating materials and the product.

Landbox®

Landpack in Germany offers Landbox® cardboard boxes with straw or hemp based wrap liners (Table 4.4). Straw is a harvest waste by-product that arises from the grain harvest and does not compete with food production. This material is hardly used so far and the claim is made that up to 30 % of the world's straw reserves can be used for industrial purposes without any ecological disadvantages. Using just 0.3 % of the annual straw produced could completely replace styrofoam. For the straw-based liner a four step heating, de-moisturizing, pressing and packaging process scheme is used[55]. No adhesives or additives are used in the production process. Production of the liners is presented as being climate neutral using only renewable energy sources[56]. During production a much lower amount of primary energy is required than for EPS (it is unclear if the cardboard production is included in this comparison). Straw has moisture-regulating properties. The wrap liner can be made of compostable bio-fleece (starch-based) which makes the complete liner compostable (DIN EN 13432 certified) in organic waste or a thin polyethylene (PE) coating. The latter requires separate disposal of straw core and wrapping or both will be residual waste[57].

The cooling capacity and shock absorption of this solution appears quite comparable to EPS, but insulation depends on outside temperature, the number of cooling elements applied and avoidance of voids within the pack. Space savings are less then with full cardboard alternatives but still significant at up to 60 %[55]. Straw is sourced locally by farmers who receive significantly more for their material, namely 150 instead of the usual 80 euros per ton[58]. Landboxes® are sold just below the average price of EPS, but apparently at much higher profit margin levels. Current annual production of 250,000 boxes per year will be increased to 2 million boxes[59].

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[55] Revolutionizing the packaging industry with a patented treatment to lignin fibres StrawToGold (2018)

[56] Onepager kobotschaften Stroh 0820 Landpack

[57] Landbox® Straw the efficient and environmentally friendly insulted packaging Landpack website (consulted July 2021)

[58] This is how straw became an innovation

[59] Revolutionizing the packaging industry with a patented treatment to lignin fibres StrawToGold (2018)

Woolcool

Woolcool offers cardboard boxes with wool fleece-based wrap liners. Wool is a byproduct of raising sheep, where the cost of necessary shearing of sheep is higher than the yield of the wool. There is a surplus of wool on the market but with no direct intended use. After being sheared, all of the wool is washed and scoured in the UK to ISO standards, heat-treated and no harsh cleaning chemicals are used. This process results in wool that is clean and does not carry any toxins or chemicals, suitable to use with food and pharmaceutical products. Wool fibres are hygroscopic, absorbing moisture and condensation in the box. After their use the liners can potentially be re-used. In case users want to dispose of the packaging, wool can be separated into the organic bin for composting.

Table 4.4. Examples of commercially available cardboard fish boxes with liner materials

Producer	Material	Characteristics
Landbox® Straw or Hemp (Landpack)	Corrugated board with straw or hemp in plastic wrap liner	
Woolcool (Woolcool) Puffin Packaging (Puffin Packaging) Cool-wool (Cool-wool) WoolPack (Planet Protector Packaging)	Cardboard with wool in plastic liner	
ClimaCell® (TemperPack)	Cardboard with plant-based cells in kraft paper liner	

Producer	Material	Characteristics
Vericool®	Corrugated cardboard with compostable film and starch based insulation	

The protective liner bag is made from recyclable MDPE[60] and LDPE[61] produced in the UK. At end of use the plastic liner needs to be removed and can be put in with the standard plastic recycling. Then the wool liner is put either into a compost bin (if available) or some local authorities will accept the wool in household garden wastebins. Woolcool can be used in non-cold chain or broken cold chain systems and maintains the 0-5 degrees Celsius comfort zone for at least 24 hours and longer. It also works for frozen products
Thermal performance of boxes with wool insulation is claimed to be comparable to EPS.

Puffin Packaging

Puffin Packaging has a similar design to Woolcool that also uses a food grade PE liner around the wool insert. Both the Cool Wool and the Wool Pack solution use PLA[62] liners instead which are claimed to be biodegradable. Cool Wool intends to use a (bio)ORMOCER® coating developed by the German Frauenhofer institute to keep the box water-resistant. The coating combines several properties into a single thin layer of material, which lowers the amount of non-fibres in the recycling phase of cardboard, and is a combination of organic and non-organic materials itself.

ClimaCell®

TemperPack from the USA offers a cardboard box with paper-based liners filled with porous plant material. The complete solution is claimed to be bio-based. It is not known which material the liner will be filled with. Thermal performance of ClimaCell® is on a par with EPS for chilled and frozen applications, and moisture absorption is better. According to their own calculations, the emissions for production of their products are 93 % lower than for EPS, however no validation information is publicly available. Their product is also offered to the UK market by Hydropac Ltd and DS Smith[63]. For proper transportation a package consists of a double walled box, ClimaCell® A and B piece inserts, gel packs at the bottom and the top separated via a corrugated board layer from the actual products[64].

[60] WoolCool website (consulted July 2021)

[61] WoolCool website (consulted July 2021)

[62] PuffinPackaging website (consulted July 2021)

[63] Temperpack website (consulted July 2021)

[64] DS Smith ePack website (consulted July 2021)

4.4.1 End of life

It is important to realize that this series of alternatives requires the user to go through a number of separation steps at the end of use.

Cardboard should be kept separate for collection of paper and cardboard. Sufficiently clean paper and cardboard streams can be suitable for composting, but in reality they often contain substances which are difficult to remove (ink and plastic liner) and may harm the quality of compost. Moreover, not all types degrade sufficiently quickly in compost facilities[65].
Defra has highlighted that recycling paper back into new paper products is the preferred option, as it is the most environmentally sustainable[66].
The insulating components like wool, straw and porous plant materials can usually be kept separate for composting, whether or not with food waste. Whilst wool is fully biodegradable, this process takes a relatively long time[67]. For industrial composting with relatively short residence times this might not be beneficial. The natural properties of wool can have benefits with respect to functionality of compost.

It is very important to remove the plastic liner before material is actually offered for composting. In some cases the claim is made that the entire insert is compostable. However, what is still a point of attention to date is that biobased plastics may cause problems during processing in industrial composting installations. Much of the UK organics recycling infrastructure is not set up to fully treat the compostable plastics that they receive and will remove it as contamination along with other plastics. There is a significant challenge in being able to distinguish between compostable plastics and conventional plastics. In fact most compostable plastics are also viewed as a source of potential contamination when these materials enter the conventional fossil-based plastics recycling loop[68]. When PE wrap liners are used, these can be collected for recycling with usual plastic waste streams.

So besides the fact that it is important whether materials are technically recyclable, it must also be taken into account whether an adequate waste collection structure is available and how likely it is that a waste stream will actually be delivered in the necessary sub-streams for further processing.

4.5 Reusable plastic packaging

In addition to the discussed packaging intended for single use, there are also alternatives available that are designed for multiple use. This section focuses on plastic crates and bins. Around eight billion crates of goods are transported from producers to stores all over Europe each year. Reusable plastic crates (RPCs) are designed for the transportation of fresh food products, especially fruit and vegetables, but also for meat and fish products with a predominant use in the large-scale retail trade. They are usually manufactured via injection molding from either PP or HPDE or a combination of the two[69]. Some designs allow the crates to be nested for their empty return journey or crates can be folded to reduce their transport volume.

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[65] AfOR's message to local authorities regarding paper and cardboard Oceanics Recycling Group (2011)

[66] Guidance on applying the Waste Hierarchy, Defra (June 2011)

[67] The use of wool in compost & other alternative applications Farming Connect (2020)

[68] The UK Plastic Pact Considerations for compostable plastic packaging WRAP (2020)

[69] Life Cycle Assessment of Reusable Plastic Crates (RPCs) MDPI (2019)

Wild fisheries have long used reusable plastic crates (RPCs) to store freshly caught fish on board of their ships. The use of EPS in this part of the chain has been virtually minimized or is limited to small-scale fishing. Fish auctions and markets also frequently use RPCs for sorting fish according to the correct quality class and size. There are different service models in place for RPCs or bins. In most cases these packaging types are managed based on pooling systems. Ownership of the container is maintained by a rental service provider that is responsible for the integral process of delivery to the user companies, manages their return, inspection, and cleaning for another re-use, and their final treatment of recycling[58]. Companies can also decide to invest in their own reusable packaging containers and only outsource the other services.

RPCs and tubs can be used both on land and at sea. In general the size of reusable containers reduces further down the supply chain. Larger containers like iTUBs are used for bulkier transports between some of the main fishing and fish production areas in ports in Europe. Usage is roughly evenly split between fish on-board, fish export and fish processing. The insulated tubs come in many shapes and sizes, with the most common size being 460 L PE tubs. This product can be used for both fresh fish and fillets and/or loins packed in slurry ice that is put in the tub first. The product is then either packed in basic plastic bags that are closed with a knot or a strap or the product is packed in a vacuumed bag[70]. Currently about 50,000 units are part of an open pooling system. Rental locations in the UK are in Grimsby and Peterhead. A type 20' foot container can host 24 tubs, a 40' footer container 48 tubs and 40' High Cube container up to 80 tubs (in a stack of 4). As with (uncrushed) EPS boxes, the post use transport volume empty is identical to full. A concept using twin containers is in development that allows for better volume utilization in sea containers fully loaded and takes 40-50 % less space during back freight[71].

Table 4.5 Examples of commercially available reusable fish boxes

Producer	Material	Characteristics
Reusable Plastic Crates (PPS UK)	HDPE	
iTUB Insulated Containers (Sæplast)	PE/PE or PE/PUR	

[70] Optimized Sea Transport of Fresh Fillets and Loins Ásgeir Jónsson (2016)

[71] Presentation iTUB presentation TAUW (2021)

RPCs are used both in export applications for fresh fish and fillets and for shipment from importing seaport areas towards primary and secondary processing facilities. The UK's main import volumes in reusable containers arrive from Iceland and Norway. Size ranges vary between 50 kg units upon grading of the fish to 15 to 10 kg crates for fillets. Fresh salmon is transported in 25 kg RPCs. Companies that offer reusable packaging solutions claim that handling of fish is minimized and that no secondary packaging needs to be applied. Purchase prices for RPCs are 2-3 times higher than for EPS boxes. For transport of salmon from Iceland to the UK relatively more boxes can be stacked per pallet due to the slightly shorter height of the reusable boxes versus EPS[72].

In the UK there are examples of retailers who have switched to reusable bins for the supply of fish from Scottish salmon farms. Salmon is delivered in reusable bulk bins to Marks & Spencer from Scottish Sea Farms and to Sainsbury's from Mowi. A study by the Caledonian Environment Centre at Glasgow Caledonian University whose results are not public showed that this solution not only reduces plastic use, but also significantly reduces CO_2 footprint across the life cycle[73].
The seafood processor Aquascot have put in place the financial investment and project plans to move away from EPS within their supply chain. This has required a redesign of infrastructure, procedures, and engagement with supply companies. They are working on reusable plastic HDPE bins for their salmon supply to the retailer Waitrose.

Lerøy from Norway use a reusable system within the supply chain from one of their 3 companies dealing with farmed salmon, Lerøy Midt, a factory with high volume and high flow between factory and consumer companies. By processing fish on site, instead of transporting whole salmon, they increase the amount of fish products which can be transported in one truck. In addition, by using reusable boxes, without ice due to the effectiveness of the cold chain lorries, they can transport more than double the fish product in the same lorry. The reusable boxes can be stored and cleaned, with just one truck able to return the number of boxes required for a volume of salmon products that previously required five trucks to return. Use of RPCs (the Maxinest stack) for some of Lerøy's transport is highlighted by Schoeller Allibert, a supplier of reusable plastic packaging[74].

In Norway the SeaPack innovation project has been carried out by SalMar, Norsk Lastebærer Pool, Nofima and others to look at reusable bins as a replacement for EPS for transportation of salmon. A LCA was part of this work and initial results claim that replacing EPS with recycling bins that can be reused between 100-150 times will provide major environmental benefits. Results are not publicly available yet[75].

4.5.1 Production process

Thermoplastic reusable crates and bins are produced from fossil-based food grade HDPE or PP pellets (Annex V: Figure V 4. System boundaries of the life cycle of RPCs). RPCs are usually produced via injection moulding, whereas the iTUBs are made via rotational moulding.
The double-walled iTUBs are constructed from a tough recyclable polyethylene (PE) shell and insulated with either a polyethylene or polyurethane (PUR) foam.

[72] New Icelandic salmon farm introduces PPS's reusable boxes Fishfarming Expert

[73] M&S rewards Scottish Sea Farms for polystyrene purge Fishfarming Expert

[74] Returnable Plastic Packaging Solutions Schoeller Allibert

[75] Nofima Seapack (2020)

The PE tubs are considered stronger and more durable then PUR tubs. PUR tubs are on the other hand are better insulated than the PE tubs[76]. For this study we concentrated on the PE version, since composite material combinations like PE with adhesive PUR are known the be very difficult to recycle. The bins feature rounded edges and surfaces for optimum wash down, and easy access from all sides. After use the bins can be recycled and the producer Sæplast claims that tubs have already been remanufactured from older tubs, including in the UK. The RPCs are also recyclable at end of life, but no recyclate can be used in the production of new crates. Both the iTUBs and the RPCs can be repaired in case of small damages.

4.5.2 Reuse and End of life

An essential part of a cycle of reusable packaging solutions is to recondition them. For single-use solutions at the end of use, transport for the collection and processing of waste is important, and for reusable systems the organization of the return transport is a key part of the life cycle process. The crux is to minimize the number of kilometers transported for empty return packaging. It is therefore of interest for pooling companies to either work with large customers, making full truckloads possible, or to be able to work with so-called milk rounds where several users can be served in a service area of limited radius. Another important parameter is the distance between users and the reconditioning site. For a comprehensive national network, it may be necessary in terms of CO_2 footprint and cost-effectiveness to offer several widespread options for reconditioning. Literature shows that longer distances tend to favour single-use packages[77].

After the first inspection, all the crates and bins are washed using disinfectant and detergent. The reconditioning process generates wastewater, which is sent to a chemical-physical treatment plant located in the same facility. Washing water tends to be reused as much as possible. Energy consumption for heating the washing water and the drying step is an important part of the footprint of the washing process itself. A study by MDPI mentions a scenario based on primary data collected at the two main poolers operating in the RPCs market in Italy where 0.055 m3 washing water, 2.48 kWh electric energy, 0.099 kg disinfectant and 0.523 kg detergent are used to recondition 100 crates with a capacity of 12 kg and a weight of 1.5 kg each[78].

There are two main points where losses occur in the pooling system. Crates or bins can get lost at some point in the process between the delivery of clean items at the user location and collection for reconditioning. Also during inspection packaging that no longer meets the quality criteria for example because of damage will fall out of the loop. Some studies mention damage and loss rates of 0.53 %[79] but numbers up to 1 % are also indicated. Average life span of RPCs is seven years[80]. User cycles of both 50 and 100 times have been used in other assessments. However, the turning point was often already reached with only a limited number of user cycles.

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[76] Optimized Sea Transport of Fresh Fillets and Loins Ásgeir Jónsson (2016)

[77] Life Cycle Assessment of Reusable Plastic Crates (RPCs) MDPI (2019)

[78] Life Cycle Assessment of Reusable Plastic Crates (RPCs) MDPI (2019)

[79] Carbon Footprint von Verpackungssystemen für Obst- und Gemüsetransporte in Europa Fraunhofer-Institut für Bauphysik (2018)

[80] PPS Sustainability Week: Group Managing Director Joanne Lee talks All Things Environmental (2020)

5 LCA analysis

An indicative life cycle analysis was done on four of the categories discussed above. The LCA focusses on EPS, corrugated PP, corrugated cardboard and reusable HDPE bin packaging systems. For each packaging system the following two functional units were defined:
1. Distributing 300 kg of fish by truck over a distance of 100 km, 1 cycle
2. Distributing 300 kg of fish by truck over a distance of 100 km, 50 cycles

Functional unit 2 is included to take into account the impact of reuse over single-use.

The following phases are considered within the scope:
- Production of the packaging materials
- Transportation of empty boxes to a fish processing facility (100 km)
- Chilled transportation of full boxes from fish processing facility to customer (100 km)
- End of life scenarios (recycling, waste to energy, landfill)

These phases are left out of the scope:
- Production and use of fish
- Production of ice
- Transport of gel packs instead of ice
- Collection of packaging waste post use
- Use of wash water, infectants and detergents during reconditioning of reusable bins

The impact of both the production and use of fish and ice is considered identical for all four categories. The differences in environmental impact for the four categories arise from the differences in materials, weights and the number of empty and full boxes to be transported per truck and their end of life processing routes.

The following end of life scenarios were assumed:

Table 5.1 End of life scenarios for fish box alternatives

End of Life scenario	EPS [81] **	HDPE [82] ***	PP [83]	Cardboard [84]
Reused	0 %	99 %	0 %	0 %
Recycled	40 %	0.025 %	50 %	68 %
Incinerated (Waste to Energy)	46 %	0.001 %	46 %	22 %
Landfilled	14 %	0.001 %	4 %	10 %

** Numbers for region central from EUMEPS were modified to reflect lower suspected level of recycling for the UK

*** Actual end of life after *n* times reuse are similar to the PP scenario

All transport distances were set to 100 km (empty packaging and full boxes) and it was assumed that one box for packing 20 kg of fish needs 5 kg of ice or 1 kg gel pack. Further assumptions can be viewed in Annex III.

[81] EPS Recycling in Europe EUMEPS (2018)

[82] UK Statistics on Waste DEFRA (2021)

[83] UK Statistics on Waste DEFRA (2021)

[84] CPI Annual Review 2019

Main outcomes of the LCA are presented here. All other results including the analysis for CO_2 can be viewed in Annex III. The results are expressed in an aggregated number: the shadow price (EUR). This is an aggregation of the emissions that were calculated for the following impact categories (characterized with CML-IA characterization factors):

1. Abiotic depletion, non fuel (AD)
2. Abiotic depletion, fuel (AD)
3. Global warming (GWP)
4. Ozone layer depletion (ODP)
5. Photochemical oxidation (POCP)
6. Acidification (AP)
7. Eutrophication (EP)
8. Human toxicity (HT)
9. Ecotoxicity, fresh water (FAETP)
10. Ecotoxicity, marine water (MAETP)
11. Ecotoxicity, terrestrial (TETP)

5.1 Functional Unit 1: Distributing 300 kg fish; 1 cycle

Results for the different types for a single cycle show that the production phase is predominant in the total impact. The HDPE bin is the most heavy weight alternative since its design takes into account multiple uses.

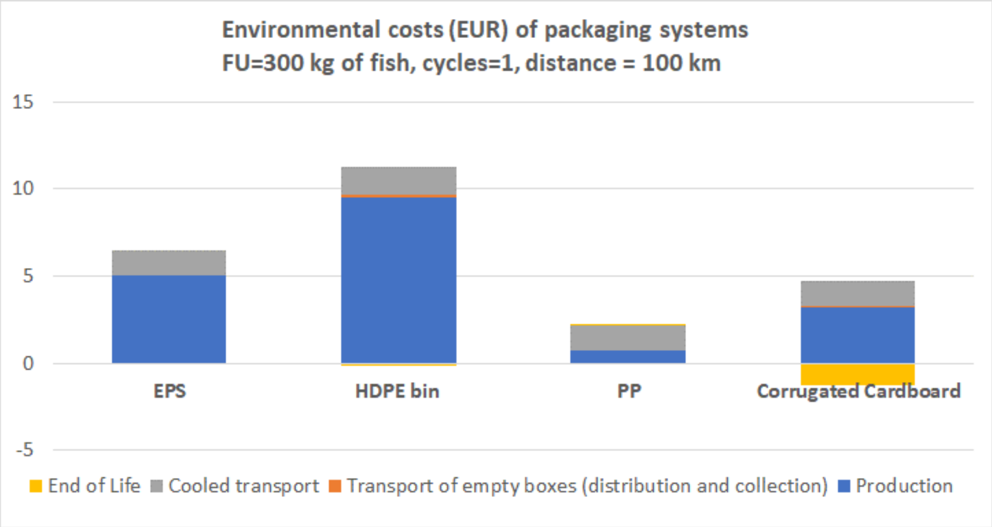

Figure 5.1. Environmental costs (EUR) to transport 300 kg of fish, 1 cycle

The packaging system with the lowest impact when looking at a single cycle of use is corrugated PP. The negative end of life value can be explained by the way the LCA method takes into account the saved environmental impact due to recovery of materials. Cardboard is heavy and has a high recycling rate and thus replaces the greatest amount of virgin material in relative terms.

Table 5.2. Environmental costs (EUR) to transport 300 kg of fish, 1 cycle

Phase	EPS	HDPE	PP	Corrugated Cardboard
Production	€ 5,00	€ 9,50	€ 0,70	€ 3,20
Transport of empty boxes (distribution and collection)	€ 0,00	€ 0,20	€ 0,00	€ 0,10
Cooled transport	€ 1,40	€ 1,60	€ 1,40	€ 1,40
End of Life	- € 0,10	- € 0,20	€ 0,00	- € 1,30
Total environmental costs (EUR)	**€ 6,40**	**€ 11,10**	**€ 2,20**	**€ 3,50**

5.2 Functional Unit 2: Distributing 300 kg fish; 50 cycles

In this scenario all alternatives but the HDPE bin are used only once and replaced by new packaging for each next transport. The HDPE bin is used throughout all of the 50 cycles.

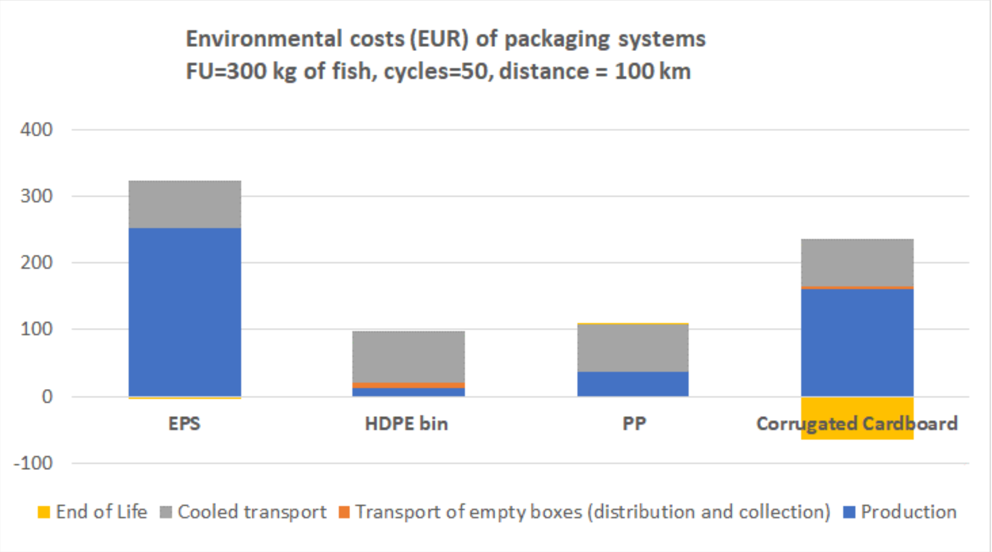

Figure 5.2 Environmental costs (EUR) to transport 300 kg of fish, 50 cycles

When distribution of 300 kg of fish is done 50 times, the total impact of reusable HDPE is lowest. This can be explained by the fact that there is (almost) no need for production of new packaging materials. The impact of transport is still high because it is a heavy product and it is assumed that the product travels 100 km empty and filled in every cycle. The empty cycle corresponds to the transport from the user back to the reconditioning facility and to the fish processor.

Table 5.3 Environmental costs (EUR) to transport 300 kg of fish, 50 cycles

Phase	EPS	PE	PP	Corrugated Cardboard
Production	€ 252	€ 12	€ 37	€ 161
Transport of empty boxes (distribution and collection)	€ 1	€ 8	€ 0	€ 3
Cooled transport	€ 70	€ 79	€ 70	€ 73
End of Life	- € 3	€ 0	€ 2	- € 64
Total environmental costs (EUR)	**€ 320**	**€ 99**	**€ 110**	**€ 173**

EPS has the highest impact which is explained by the high environmental impact of the production phase and the fact that more boxes with product can be loaded into a full truck for PP and cardboard.

6 Discussion and conclusions

The fisheries sector uses a number of different packaging solutions for the storage and transportation of fish to meet the specific requirements and needs related to food safety and seafood quality. The general conclusions of each packaging type are shown in Table 6.1. Between the actual landing of fish in ports and the final consumption stage a fish often undergoes several handling and possible value-added treatments steps. For fresh fish and fish fillets in particular, EPS appears to be an institutionalized solution within the fish industry. This means that entire logistics systems and processing factories for seafood products are set up on EPS as standard packaging, whereby the production of EPS boxes at some locations is even fully integrated with fish processing. With the increasing attention of the problems surrounding single use plastics, attention in society and changes in, for example, the policy of retailers, more and more companies are looking at their supply chains to see where alternative materials for fish boxes can be used. Although this is not yet happening on a large scale, momentum seems to be growing.

Change actors

The playing field within the UK fishing industry is very diverse and the number of companies involved in seafood, although decreasing in number, is still very large. If you look at where in the chain there are opportunities to drive change, a number of actors seem to be in a more appropriate position to do so. Looking at indigenous consumption, it is clear that retailers are an important power block towards the suppliers. As part of their plastic reduction strategies in their chains, a number of supermarkets already have a ban on EPS (Iceland, Lidl). You can also see that a transition to reusable bins is already visible from other retailers (Marks & Spencer, Sainsbury's, Waitrose). It often concerns large contracts between retailers and the larger fish processors that are established for a number of years and where long-term relationships exist between them. This is an excellent starting point for making retroactive agreements from the end of the chain about making transport packaging for fish more sustainable and a proportional distribution of the costs for such a transition.

There is also a manageable number of players on the production side, particularly among Scottish producers of aquaculture salmon, who can accelerate a meaningful transition to less EPS based on their market share and the corresponding volumes. This certainly applies to integrated companies that are also active in the fish processing itself. In doing so, the costs for change in their optimized and highly automated operations can be significant, but they may also be better able to bear these costs in part because of their better margins, of course also in coordination with the rest of the chain. The Scottish Salmon Producers Organisation indicated that many of their member are already evaluating switching to reusable alternatives. Other parties indicate that the salmon industry is the most difficult to move to make this transition.

Cold chain dependence

A barrier to switching to alternative solutions is that often extensive and expensive tests are necessary to compare the temperature profile and quality of the fish upon receipt with the initial situation. This will play an even greater role for smaller companies. Within an existing cold chain, alternatives may sometimes appear to give slightly less performance, but well within what is required. Truly greater risks only arise if there is a real risk that the cold chain will be interrupted and fish boxes may be exposed to varying ambient temperatures. Current alternatives do provide sufficient guarantees for the last mile deliveries of seafood, as this concerns short lead times from storage to the end customer. For domestic transport in the UK, this is an argument that should be less likely to play a role in the transition to alternative materials and some of the current conservatism is unfounded. It goes without saying that the packaging solution is always of secondary importance with regard to fish as a product. Seafood waste has a greater impact on the environment than the packaging itself.

Alternative packaging systems

Compared to EPS, each packaging system has its own benefits and drawbacks. This research focused on the technological, economical and environmental characteristics and compared these to EPS. This is summarized in Table 6.1.

Table 6.1 Summarizing table of characteristics of alternative packaging systems for fish

Packaging system	Technological	Economical	Environmental
Corrugated PP	Insulation: - Weight: - Risk of damage: +/-	Investment: - Transport: + Scalabilty: +/- TRL: +/-	Production: + Transport: +/- EoL: + Collection system: +
Cardboard corrugated	Insulation: - Weight: - Risk of damage: -	Investment: - Transport: + Scalabilty: + TRL: +/-	Production: + Transport: +/- EoL: + or +/- Collection system: ++
Cardboard with insulation panels	Insulation: -+ Weight: - Risk of damage: -	Investment: - Transport: + Scalabilty: +/- TRL: +/-	Production: + Transport: +/- EoL: +/- Collection system: +/-
Reusable fish boxes	Insulation: - Weight: -- Risk of damage: +	Investment: -- Transport: + Scalabilty: +/- TRL: +/-	Production: -- Transport: +/- EoL: ++ Collection system: +

+ = better than EPS +/- similar to EPS - worse than EPS

EoL = End of Life

TRL = Technology Readiness Level[85]

[85] TRL Scale in Horizon Europe and ERC Enspire.science

Corrugated PP fish boxes
The use of corrugated PP is already a common alternative, even in exports from Iceland to the UK. This makes it a proven solution that is also scalable. Compared to EPS, this is still a single use plastic made from non-renewable material. The collection structure for PP is more widely available to companies, including the smaller ones. In addition, there is less risk of damage or breakage of loose parts that could end up in the environment. This means that the impact of PP appears to be lower than that of EPS. However, it is important to further stimulate the actual recycled volume of PP from industrial waste and the use of recyclate, in line with the objectives of the UK Plastics Pact.

Cardboard fish boxes
For the cardboard alternatives to EPS, in which renewable fibres are used, an existing collection structure is used by companies, with high recycling percentages. Producers are able to reuse these fibres in equivalent, non-food, applications. Due to the specific requirements for fish products and the required water resistance of cardboard due to contact with ice and melt water or moisture on the outside, performance coatings are often used. If this proportion of non-cardboard materials is too high, specific requirements may have to be imposed on the repulping process, as there is a risk of contamination of cardboard due to the presence of interfering substances or that the yield of usable fibres decreases. From a circular perspective, cardboard is satisfactory in many respects, the impact of cardboard production is lower than for EPS, but high compared to PP and reusable HDPE bins.

Recently, a lot of attention has also been paid to the presence of PFAS in cardboard products to aid water repellency. In this study it has not become clear whether PFAS is a topic that is also relevant to the alternative cardboard solutions that are being discussed. It should be clear that the possible presence of this kind of perpetual chemicals should be seen as a major disadvantage since they pose a barrier to the recyclability of food packaging in the framework of a circular economy.

Cardboard fish boxes with insulation panels
Trying to match thermal properties of EPS by adding elements such as wool or straw insulation panels in cardboard boxes involves using a combination of different materials. Through a careful selection of renewable residual materials that currently have a low (functional) value and for which there are currently limited applications, the circular economy is done justice on the design side. Keeping cardboard separate after use can be expected as this is a common waste stream for most companies.

For application in environments with large packaging volumes, the question is whether the insulation panels and the plastic liner around them are also separated in separate collection systems. In practice, there is a risk that the entire panel ends up in the residual waste or that it, including the liner, ends up in the organic waste. The presence of plastic, even if certified compostable, in industrial installations is undesirable. This higher degree of complexity at the front is therefore no guarantee of success at the rear. Use for homemade meal deliveries or courier medicine transports seems more appropriate for this type of solutions.

In the specific case of straw, there seems to be a clear cost advantage over EPS, which could make it interesting for companies to switch.

Reusable fish boxes

The use of reusable alternatives for fresh foods is very common, and is also true in the fish industry. There is often a transfer moment somewhere in the chain where reusable packaging is replaced by smaller EPS fish boxes, often after landing and sorting out the fish. Various LCA analyzes have shown that reusable alternatives often result in a lower environmental impact after just a few cycles. It is important, however, that the distances for return transport remain limited and that sufficient facilities must be nearby for the reconditioning of crates and bins.

The average lifespan of reusable packaging such as RPCs and bins ensures that a large number of cycles can be realized before they eventually have to be discarded. In the case of fish, fossil-based non-renewable hard plastic materials are used. These materials are recyclable at the end of their lifespan and there is a collection structure that can be used, especially since the packaging often remains the property of pooling companies that achieve sufficiently large volumes and are often already working to reduce the share of recyclate in their solutions.

In many cases, switching to reusable solutions within the supply chain also leads to lower overall costs.

This makes this a solution of which upscaling can make a significant contribution to the reduction of (one-off) EPS within the UK. This type of solution is particularly evident with sufficiently frequent deliveries, steady supplier relationships and sufficient trade volume (scale).

Barriers for change

The solutions based on corrugated PP, cardboard and also collapsible RPCs have the advantage that less transport is required for the supply of the empty packaging to the fishermen. The LCA shows that the contribution to the total impact of empty transport is limited. Increasing the load factor of full trucks is a noticeable advantage. For companies that have automated production lines, the use of blanks will lead to a reduction in the line speed due to manual set-up of boxes or require a one-time investment in a case erector. This can have serious consequences for the site layout and amounts in the order of 50-150 kEUR per machine. This means that decision-making whether a company switches will not be taken lightly.

For many companies it will also apply that having different packaging solutions side by side is undesirable due to the increasing complexity of their own business operations. For the larger companies this will require that they want to do this in coordination with their largest customers, while for smaller companies with a clearer business management it may be a transition that can be realized more easily.

Obviously, there are no solutions that are better for all cases. This remains highly dependent on the size and position in the chain. In an international environment such as fisheries, there is a worldwide supply of products with sometimes opaque chains of (intermediate) traders. By no means will a buyer of products be able to impose requirements on its suppliers in all cases.

Where this can be, therefore, proper alternatives are already available. In addition, there is a continuous development of new alternatives to EPS, although these are not always aimed at industrial volumes and applications.

Market incentives

The share of EPS is still dominant in the market. The alternatives are often more expensive than EPS, also because they do not yet have sufficient scale for further cost reduction optimisations. Many of the interviewed parties indicate that they only see a larger-scale breakthrough of alternatives happening when this unprofitable peak is eliminated by the introduction of a plastic tax also on EPS transport packaging. A requirement for the reuse of a mandatory percentage of plastic recyclate per type of plastic can also contribute to this, as this is not yet possible for EPS, certainly within the UK. A ban on EPS has also often been discussed, but an adequate alternative is not yet available for all applications.

Annexes

Annex I	**Figures**
Annex II	**Examples cardboard**
Annex III	**Assumptions LCA calculations**
Annex IV	**Results LCA calculation**
Annex V	**LCA System boundaries other studies**

Annex I - Figures

Fish enter the UK market fresh via direct landings by both UK and foreign vessels into one of the 14 major landings ports in Britain (Table I.1 UK landings by UK fleet in 2019). For different types of seafood a distinction is often made between demersal fish types, pelagic fish types and shellfish. Key ports for landings are located in Scotland (Peterhead, Lerwick and Fraserburgh) and some smaller ports in the UK (Newlyn, Brixham) where the total volume from UK landings for Peterhead (153,600 tonnes in 2018)[86] outweighs the combined volume landed at other key UK ports.
The landed volume of 362,000 tonnes represents a value of £762m (2019).[87]

Other supply of fresh fish is from the aquaculture farms which is mainly salmon. This sector still sees an annual growth and takes place almost exclusively in Scotland (volume 189,921 tonnes and value of £962m in 2018.)[76]

The UK is a net importer of fish. In 2019 a total of 721,000 tonnes of fish and fish preparations were imported (£3,457m).[88] Main import countries for fish into the UK are China (10.2 %), Iceland (8.1 %), Germany (8.1 %) Sweden (6.0 %) and Norway (5.1 %).

Main export countries for fish from the UK are France (20.7 %), the Netherlands (12.8 %), Ireland (11.4 %), USA (8.9 %) and Spain (8.3 %) (Annex I *Table I.2 UK exports of fish and fish preparations 2019*).

Table I.1 UK landings by UK fleet in 2019

Species	Volume (tonnes)	Share
Mackerel	61,527	16 %
Herring	34,560	9 %
Nephrops	33,970	9 %
Haddock	33,471	9 %
Crabs	29,348	8 %
Scallops	27,948	7 %
Cod	22,051	6 %

[86] UK-Sea Fisheries Statistics 2018 Seafish

[87] UK Sea Fisheries Statistics 2019 Seafish

Table I.2 UK imports of fish and fish preparations 2019

Species	Volume (tonnes)	Share	Countries of origin	Volumes (tonnes)	Share
Tuna	110,297	15.3 %	Mauritius	15,416	14.0 %
			Seychelles	13,904	12.6 %
			Spain	11,514	10.4 %
Cod	105,500	14.6 %	China	25,088	23.8 %
			Iceland	24,722	23.4 %
			Norway	14,834	14.1 %
Salmon	90,600	12.6 %	Sweden	36,934	40.8 %
			Faroe Islands	24,454	27.0 %
Shrimps and Prawns	78,200	10.8 %	Vietnam	18,784	24.0 %
			India	13,497	17.3 %
			Denmark	7,478	9.6 %
Haddock	51,100	7.1 %	Iceland	14,893	29.2 %
			Norway	13,574	26.6 %
Other	285,229	39.6 %			
Total	**720,952**				

Table I.3 UK exports of fish and fish preparations 2019

Species	Volume (tonnes)	Share	Countries of origin	Volumes (tonnes)	Share
Salmon	124,880	27.6 %	France	39,023	31.2 %
			USA	32,179	25.8 %
			China	9,442	7.6 %
			Ireland	6,943	5.6 %
Mackerel	62,186	13.8 %	The Netherlands	18,789	30.2 %
			France	7,675	12.3 %
			Ireland	4,485	7.2 %
Herring	34,699	7.7 %	The Netherlands	14,958	43.1 %
			Germany	7,752	22.3 %
Crabs	16,906	3.7 %	France	4,368	25.8 %
			Spain	4,332	25.6 %
			China	4,188	24.8 %
Other	213,459	47.2 %			
Total	**452,131**				

Annex II - Examples cardboard

Single use cardboard examples:

EcoFishBox™
StoraEnso developed their EcoFishBox™ cardboard solution in 2019. The box is a fully waterproof three-layered corrugated cardboard box with two liners and one corrugated medium produced by both virgin and recycled material. Both the inner and outer line is coated with a plastic film, while the corrugated medium is constructed of a fibre-based paper line. The inner liner is constructed of a paper line coated with a polyethene terephthalate (PET) film and the outer liner is a paper line coated with a polyethene (PE) film. These liners constructed of both paper and plastics work as a barrier against moist and water.

After use the boxes can be flat packed, rinsed, dried and offered for recycling under certain conditions. Not all recycling mills can handle laminated materials, although this does not appear to be a major problem in Scandinavia. Most of the early adopters of the EcoFishBox™ are situated in the Nordic countries. Finland has the biggest level of EcoFishBox™ use, but companies in Sweden and Norway are also looking into this alternative. Known users of these boxes are Kesko/K-store, COOP Sweden, Kalaneuvos and their sister company Nordic Trout and Tuomaan Kalatukku.

Thermobox
On the initiative of one of their customers Smurfitkappa developed a cardboard fish box with honeycomb structure panels that provide both strength and acts as a thermal barrier. The corrugated cardboard box solution contains part kraft and part testliner. Kraftliner is made with virgin fibres and testliner with recycled fibres. Kraft paper on the outside of the honeycomb is important because of moisture that can come during transport. It is a closed box design and no drain holes are present. The honeycomb panels, that are normally produced for industrial protective packaging, must not come into direct contact with the fish, as these are not certified for direct food contact. A plastic liner bag has to be used. Costs for this solution are somewhat higher than for EPS, but for companies that use medium to smaller quantities cost can be comparable or even slightly lower. There are relatively fewer producers of honeycomb cardboard, which means that delivery routes can be longer and possibilities for upscaling can require a longer lead time than for pure corrugated board solutions. The box is used for fresh fish as well as for shellfish products.

Solidus
The Solidus solid board box is made from their PACKLINE board line, a fibre-based board. Solid board consists of a grey inner layer that has been made from recycled paper and cardboard. An additive in the grey layer prevents water from entering the board. This is called a moisture-resistant Sapino® coating with a PE finish layer also to keep box water-resistant.

Fish can be packed both fresh and frozen and it can also be used for a variety of species including round fish, salmon and shellfish. Compared to corrugated cardboard even more blanks can be fitted onto a pallet for transport of empty packaging to the fish processing companies.

Chiller Pack

Cepac UK has a design of a cardboard box that can be used in combination with fresh ice. The difference in their design lies in the presence of a sling (bridged structure) that keeps any melting water separate from the fish and rest of the ice. The corrugated cardboard is partly made from FSC certified fibres and uses a PET coating to achieve waterproofing on the inside of the box. Starting point is that the use of ice is a lot cheaper for companies than the use of gel packs, especially at higher production volumes. Initial use is foreseen for packing products for Scottish Shellfish who supply mussels and oysters to restaurants, retailers, and wholesalers across the UK. Absence of a water repellant coating on the outside of the box requires the products to be processed in dry parts of the production environment. Design can also be adopted for heavier products like fresh salmon, but is less forgiving with respect to rough handling in comparison with EPS boxes. However, this applies in general to almost all cardboard solutions. Supply of blanks outside of the UK is not considered to be cost-effective.

Annex III - Assumptions LCA calculations

Table III.1 Assumptions LCA

Production	EPS	Reusable container (PE)	PP	Cardboard with PE liner	Unit
Weight fish per box size (kg)	21	300	20	20	kg
Weight packaging (kg)	0,526	51	0,209	1,271	kg
Weight packaging at Functional Unit (300 kg fish)	7,5	51,0	3,1	19,1	kg
Kg of ice per box	5,0		5,0	5,0	kg
Kg of ice for FU (300 kg fish)	71,4	75,0	75,0	75,0	kg
Total weight (incl fish, packaging, ice) FU	378,9	426,0	378,1	394,1	kg

Table III.2 Assumptions sensitivity analysis

Upscaling (to 50.000 kg fish)	EPS	PE, Itub container	PP	Cardboard with PE liner	Unit
Amount of km needed for distribution of empty boxes for packing 50 tons of fish	472	167	71	78	km
tonkm for transporting empty boxes for packing 50 tons of fish (distance =100 km)	125	850	52	318	tonkm
Amount of km for transporting 50 tons of fish	575	355	417	453	km
tonkm for transporting 50 tons of fish	6.316	7.100	6302	6568	tonkm
Weight of fish in 1 truck	8.694	14.085	12.000	11.040	kg
Total weight per truck (incl fish,packaging, ice) (kg)	10.982	20.000	15.125	14.502	kg
tonkm of 1 truck filled with empty boxes distance = 100 km	125	850	52	318	tonkm
tonkm of 1 truck with full boxes distance if 100 km	6.316	7.100	6.302	6.568	tonkm
With collection of empty boxes	250	1.700	105	636	tonkm

Annex IV - Results LCA calculations

Figure IV.1 Results TAUW LCA calculations alternatives for fish boxes

Annex V - LCA System boundaries other studies

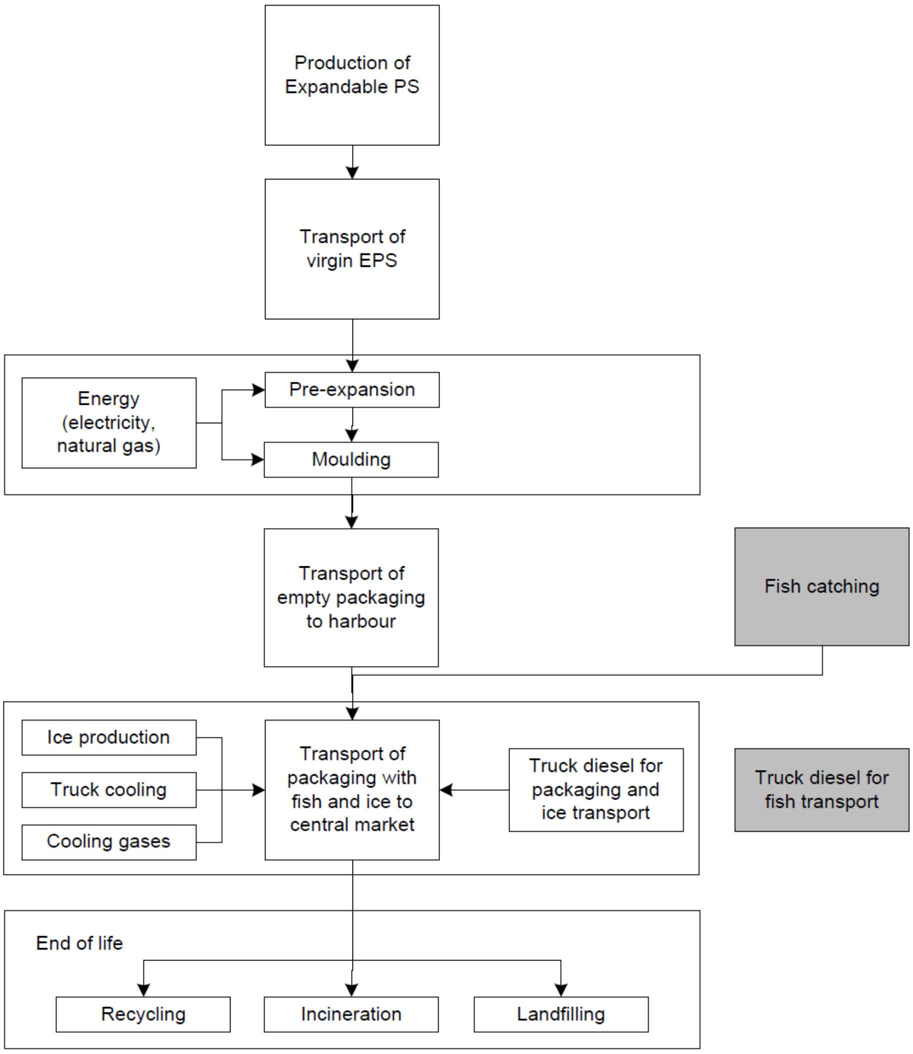

Figure V.1 System boundaries of the life cycle of EPS fish box packaging[89]

[89] Life Cycle Assessment of the Industrial Use of Expanded Polystyrene Packaging in Europe EUMEPS/PWC (2011)

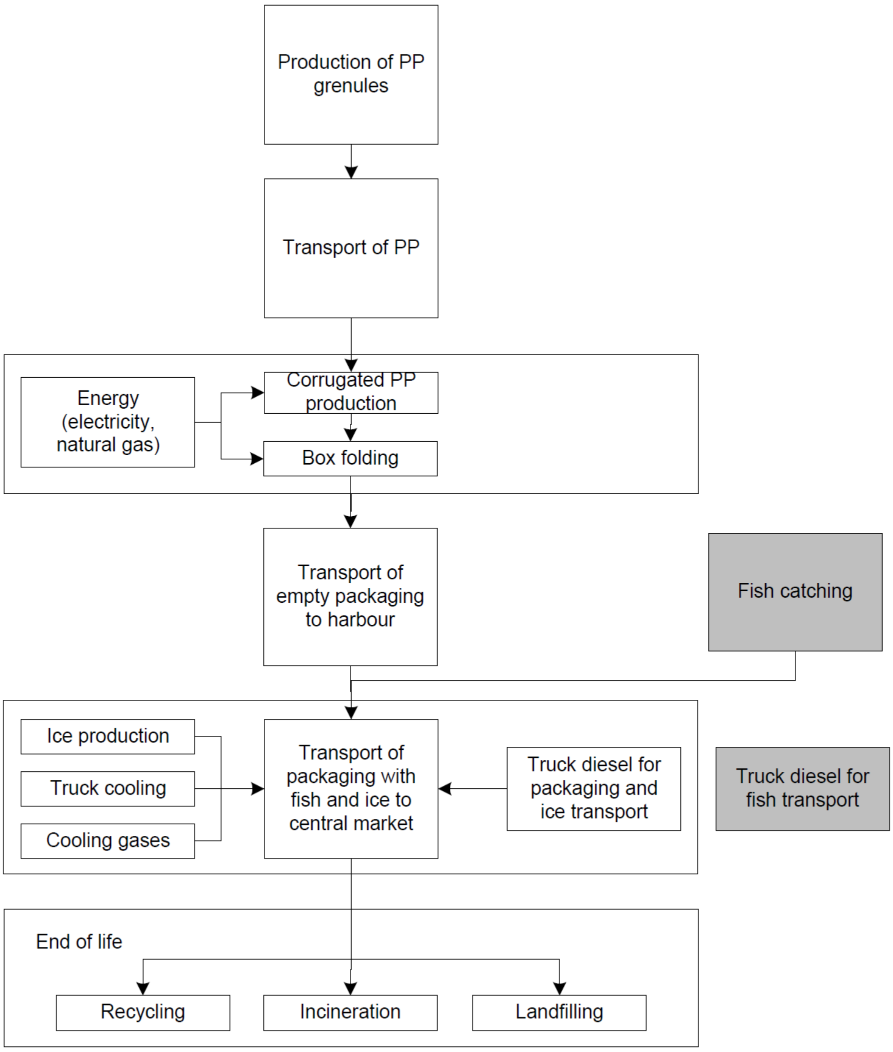

Figure V.2 System boundary and life cycle phases of a corrugated PP fish box[90]

[90] Comparative Life Cycle Assessment (LCA) Study of Fish Packages Made of Expanded Polystyrene or Corrugated Board LCA consulting (2018)

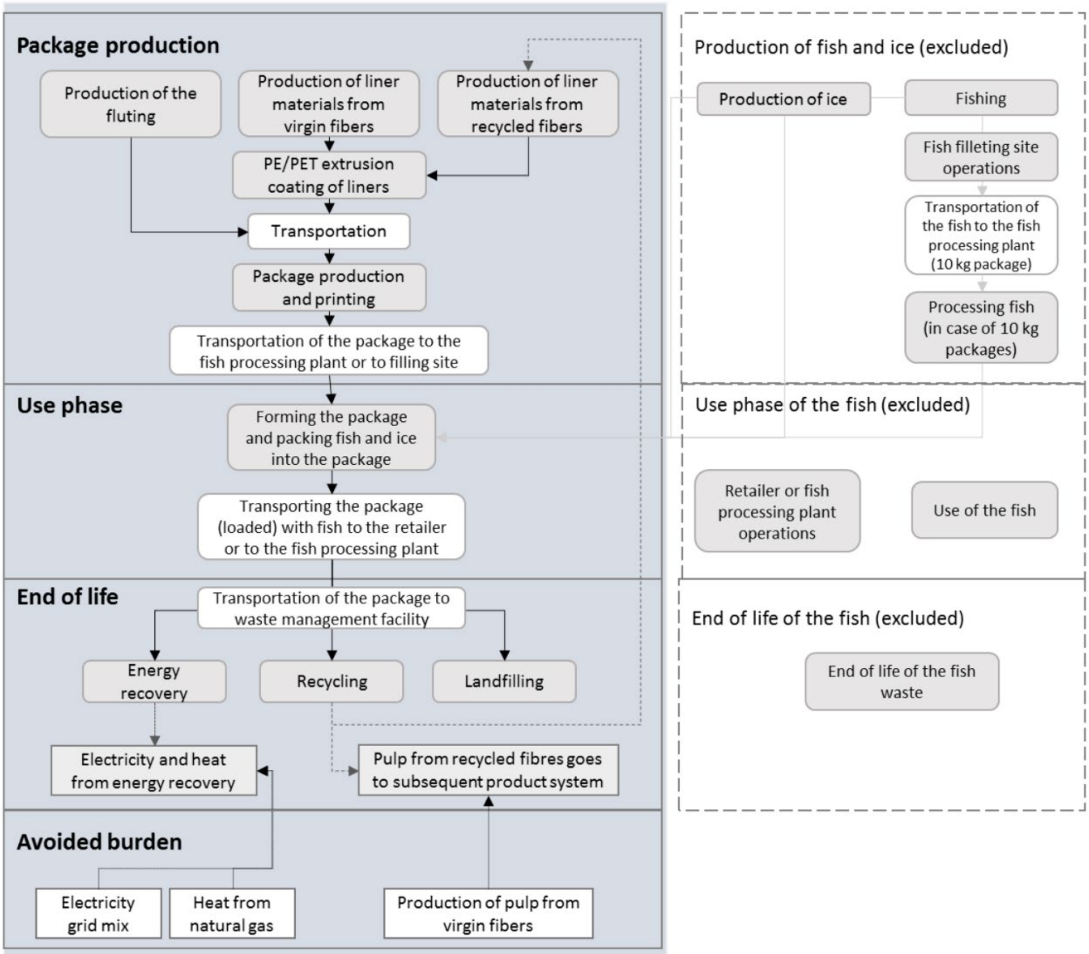

Figure V.3 System boundary and life cycle phases of an EcoFishBox™ [91]

[91] Comparative Life Cycle Assessment (LCA) Study of Fish Packages Made of Expanded Polystyrene or Corrugated Board LCA consulting (2018)

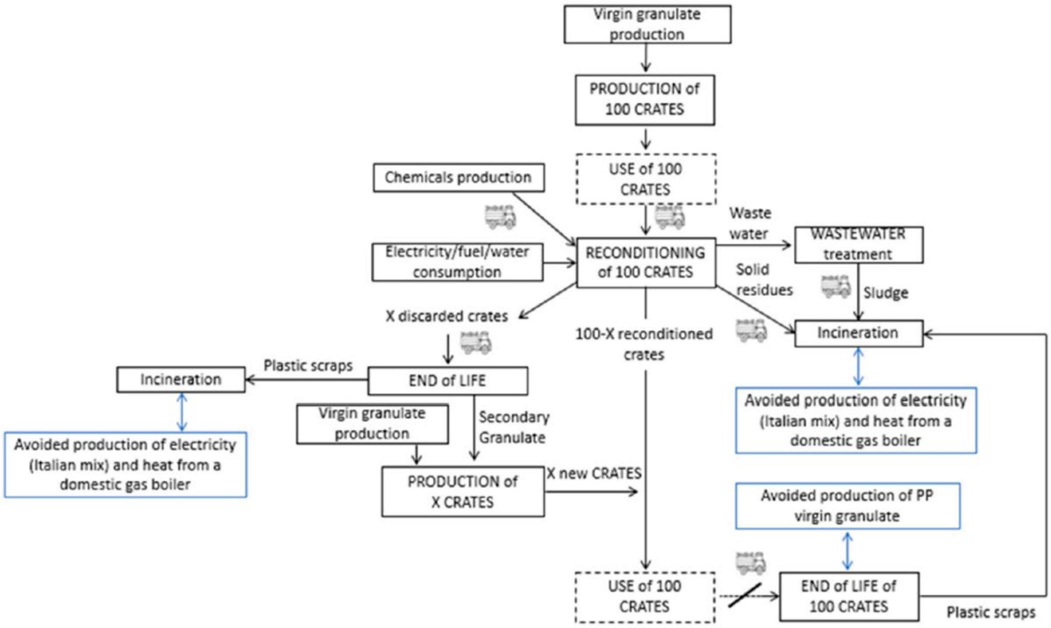

Figure V.4 System boundaries of the life cycle of RPCs[92]

[92] Life Cycle Assessment of Reusable Plastic Crates (RPCs) MDPI (2019)