Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

Markus Elsheim

Designing sustainable fish boxes for distribution of fish.

Master's thesis in Industrial Design
Supervisor: Jon Herman Rismoen
June 2022

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Forord

Denne rapporten er skrevet i forbindelse med min avsluttende masteroppgave i studieprogrammet 2-årig master i Industriell design ved NTNU Trondheim vår 2022.

Jeg vil gjerne uttrykke en stor takk til Håvard Wollan og Anja Wollan fra Aqualoop AS og Gerrit Wakker fra Sekkingstad AS for å introdusere meg for oppgaven og bistå med deres ekspertise. De har også bistått meg med fordypningsoppgaven min høst 2021, jeg er veldig takknemlig for at vi har opprettholdt samarbeidet.

Jeg vil også takke min veileder fra NTNU, Jon Herman Rismoen for å dele sine kunnskaper og veilede meg gjennom arbeidet med masteroppgaven og fordypningsoppgaven.

Til slutt vil jeg takke min kjære samboer Susann for å gi meg støtte og omsorg, både i medgang og motgang. Ser frem til alt vi skal oppleve sammen etter endt studie!

NTNU
Fakultet for arkitektur og design
Institutt for design

Masteroppgave for student Markus Elsheim

Tittel Design av bærekraftige fiskekasser for distribusjon av fisk.
Title Designing sustainable fish boxes for distribution of fish.

Masteroppgaven er en videreføring av samarbeidet med bedrifter fra prosjektet gjennomført i emnet TPD4500 Design 9 som omhandlet emballasjedesign for forbrukerinnpakket fersk fisk.

Prosjektet har som mål å utvikle et bærekraftig alternativ til fiskekassene som i dag benyttes for transport av fisk på is over lengre avstander. Dagens fiskekasser er vanligvis laget av ekspandert polystyren (ESP) og det er ønskelig å utvikle et mer bærekraftig produkt uten å miste de sentrale egenskapene ved fiskekasser laget av ESP.

I prosjektet vil miljøutfordringer innen emballasje tilknyttet norsk eksport av fisk, kartlegges. Mulighetene for å utvikle en fiskekasse som er resirkulerbar og/eller nedbrytbar vil bli utforsket.

Oppgaven utføres etter "Retningslinjer for masteroppgaver i Industriell design".

Ansvarlig faglærer (hovedveileder ID): Jon Herman Rismoen
Bedriftskontakt: Håvard Wollan fra Aqualoop AS

Utleveringsdato: 07.01.2022
Innleveringsfrist: 07.06.2022

Jon Herman Rismoen — Trondheim, NTNU, dato 07.01.22 — Sara Brinch

Jon Herman Rismoen
Ansvarlig faglærer

Sara Brinch
Instituttleder

Abstract

This report describes the work carried out by Markus Elsheim in his master's thesis in industrial design at the Norwegian University of Science and Technology (NTNU) spring 2022. The theme of the thesis is design of sustainable fish boxes for distribution of fish. The goal is to design a sustainable alternative to the industry standard EPS fish boxes used in the Norwegian fish export industry.

This thesis can be divided into three main parts, it starts with part 1 explaining the background for the thesis. Part 2 explores the theme, and part 3 describes the design process of a sustainable fish box.

In Part 2 I have performed a literature rewire to collect information. This part is divided into three chapters. Part 2, chapter 1 introduces the theme EPS fish boxes and discusses environmental issues concerning EPS fish boxes in the fish export industry. Part 2, chapter 2 presents available alternatives to EPS fish boxes. Part 2, chapter 3 discusses circular economy in packaging, the physical internet, the differences between one way and reusable packaging, environmental issues concerning the overproduction of plastics, and the use of bioplastics in packaging.

Part 3 describes a short design process where the findings from part 2 is used to solve the design assignment. In part 3 important functions and requirements for the fish box are established. Production techniques and materials are evaluated. Lastly the exploratory work during the design process is presented.

To be able to design a truly sustainable alternative to the EPS fish boxes it is also necessary to include a new logistical system which utilizes shared assets and reusable fish boxes. The system is based on the upcoming "physical internet" proposed by the EU. This will change the service life of a fish box from a linear to a circular lifespan, and ensure that resources contributed to the system will stay in circulation for ass log as possible.

Sammendrag

Denne rapporten beskriver arbeidet som er gjort i tilknytning Markus Elsheim sin masteroppgave i industriell design ved Norges Teknisk-naturvitenskapelige Universitet (NTNU) Trondheim vår 2022. Oppgavens tema er design av bærekraftige fiskekasser for distribusjon av fisk. Målet med oppgaven er å designe et bærekraftig alternativ til EPS fiskekassene som er industristandard i norsk fiskeeksportnæring.

Oppgaven kan deles opp i tre hoveddeler, den starter med del 1 som forklarer bakgrunnen for oppgaven. Del 2 utforsker tema og del 3 beskriver designprosessen.

I del 2 er det gjennomført en litteraturstudie for å samle informasjon om valgt tema. Denne delen er delt opp i tre kapitler. Del 2, kapittel 1 introduserer tema EPS fiskekasser og diskuterer miljøutfordringer tilknyttet EPS fiskekasser i fiskeeksport industrien. Del 2, kapittel 2 gir en oversikt over allerede tilgjengelige alternativer til EPS fiskekasser. Del 2, kapittel 3 diskuterer temaer som sirkulær økonomi i emballasjedesign, det fysiske internett, forskjeller mellom engang og gjenbrukbar emballasje samt miljøutfordringer tilknyttet overproduksjon av plast og bruk av bioplastikk i emballasje.

Del 3 beskriver en kort designprosess hvor funnene fra del 2 er brukt til å løse oppgaven. Her er viktige funksjoner og krav til fiskekassen bestemt. Produksjonsteknikker og materialer er evaluert og til slutt er det utforskende arbeidet tilknyttet designet av fiskekassen presentert.

For å kunne designe et bærekraftig alternativ til EPS fiskekasser er det nødvendig å inkludere et nytt logistikksystem som utnytter felles ressurser ved hjelp av delingsøkonomi og gjenbruk. Det nye logostikksystemet tar utgangspunkt i det fysiske internettet som skal innføres av EU. Dette forandrer livsløpet til fiskekassen fra et linjert til et sirkulært livsløp, med mål om å utnytte ressursene som er dedikert til emballasje så lenge som mulig.

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List of abbreviations

ALICE = Alliance for Logistics Innovation through Collaboration in Europe
B2B = Business-to-business
CO_2 = Carbon dioxide
CO_x = Carbon oxides
EFSA = European Food Safety Authority
EPS = Expanded polystyrene
EU = European Union
FDA = Food and Drug Administration
FHI = Norwegian Institute of Public Health (Folkehelseinstituttet)
HDPE = High-density Polyethylene
LCA = Life Cycle Assessment
NHO = Confederation of Norwegian enterprise (Næringslivets hovedorginisasjon)
NLF = Norwegian truck owner's association (Norges lastebileier-forbund)
NOx = Nitrogen oxides
NRI = Near infra-red
NRK = Norwegian Broadcasting Corporation (Norsk Rikskringkasting)
PE = Polyethylene
PET = Polyethylene terephthalate
PLA = Polylactic Acid
PP = Polypropylene
PS = Polystyrene
SOx = Sulphur oxides
SDG = Sustainable Development Goals
SSB = Statistics Norway (Statistisk Sentralbyrå)
UN = United Nations
VNR = Voluntary National Review
WFP = World Food Program
WWF = World Wildlife Fund
XPS = Extruded polystyrene

PART 1.
BACKGROUND

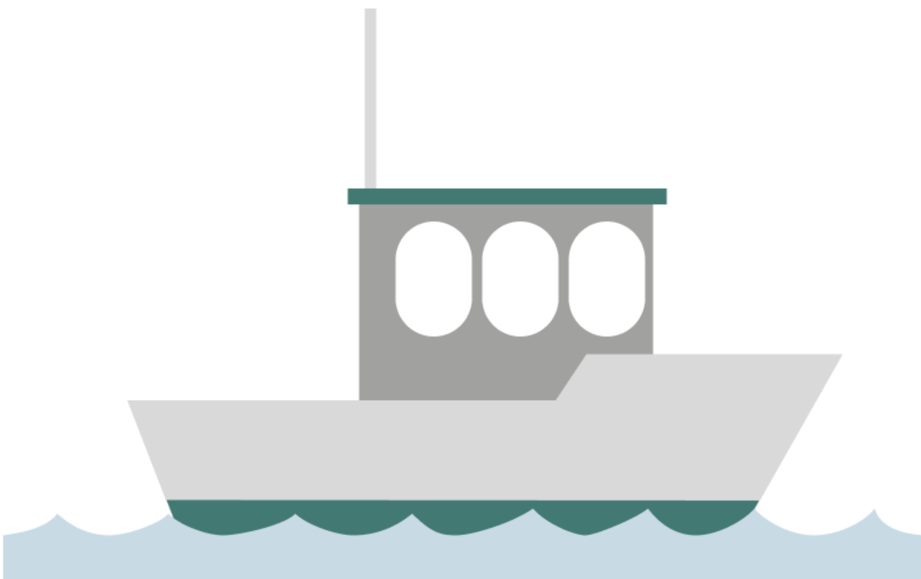


FIGURE 1. BOAT

1.1 Introduction to The Norwegian fish export industry

Norway has historically been a nation relying on fishing as a source of food and have had a long tradition for exporting fish products. Fish is one of Norway's oldest exports and Statistics Norway started their documentation of Norwegian fish exports back in 1830. Back then dried and salted fish was the most important type of fish export in Norway (Gram Dokka, 2020).

According to an article published at Statistics Norway (Statistisk Sentralbyrå, SSB) web page, The Norwegian fish farming industry started in the 1970's when the first entrepreneurs, many farmers, and fishermen, managed to successfully farm salmon and rainbow trout in floating net cages in the sea. The fish farming industry first started by farming rainbow trout, but the species quickly became less favourable as salmon turned out to be easier to sell on an international market. By 1977 salmon was produced in greater numbers than rainbow trout. By 1999 the first-hand value of farmed fish surpassed the traditionally caught fish (A. Steinset, 2017).

An article from the Norwegian Broadcasting Corporation (Norsk Rikskringkasting, NRK) reports that in 2021 Norway exported a total 3.1 million tons of seafood worth about 120 billion Norwegian kroners according to "Norges Sjømatsråd". The biggest export is still salmon which accounts for about 70% of the total export, most of the fish is exported to the EU and the country importing the most seafood from Norway is Poland (export value 12,6 billion NOK) mostly because it is a processing market which distributes the fish. The second largest import country is Denmark (export value 10.4 billion NOK) because they are a transit market mainly to the EU (NRK, 2022). Most of the salmon exported from Norway is gutted with head still attached, and this trend seems to continue into the future (Ellingsen, Emanuelsson, Skontorp Hognes, Ziegler, & Winter, 2009).

Norway is the biggest exporter of Atlantic salmon in the world accounting for over half of the world's production. Where the countries ten biggest seafood companies constitute for 70% of the production of farmed fish in Norway. It is not uncommon that the Norwegian salmon is exported to other countries to be packaged and redistributed. For example, Germany imports a lot of Norwegian salmon that has been packaged in Poland, Denmark, and the Nederland's. Statistics from 2014 reveal that China is the biggest producer of farmed fish, producing 45,5 million tons for human consumption almost three quarters of all production in the world. Norway was ranked as number 6 in the world producing 1,3 million tons of fish the same year, and 1,26 million tons of the Norwegian production was Atlantic salmon (A. Steinset, 2017).

According to the Food and Agriculture Organization of the United Nations, fish farming has been dominated by Asia in the last 20 years, whereas Asia has produced 89 prosect of the total global volume. Since 1991 China has produced more aquatic food than the rest of the world put together, but their share in the world's aquaculture production has been decreasing and are expected to decrease further in the coming years. In the last 20 years the shares for worldwide global production of farmed fish have increased in Africa and the Americas while it has dropped in slightly in Europe and Oceania. However, the largest producers of fish including Norway have strengthened their shares by varying degree (FAO, 2020).

FIGURE 2. SOUTH NORWAY ROADTRIP SEPTEMBER 2018, PUBLISHED 2020 BY TIM STRULIK. HTTPS://UNSPLASH.COM/PHOTOS/IKMDADNPPAY

1.2 Boundaries

This is a packaging design project; the theme is industrial packaging in the Norwegian fish export industry, specifically the design of sustainable fish boxes aimed to transport fresh, whole, gutted fish. In this project I will be investigating:

- Norwegian fish export markets.
- Environmental challenges related to industrial packaging in the fish export industry.
- The current transport packaging practices.
- Future transport packaging trends.
- Circular economy of transport packaging.
- Single use vs. reusable packaging systems.
- The necessity for plastics in transport packaging.

The knowledge gained from the investigation is intended to be used to suggest a sustainable alternative to the current Norwegian industry standard EPS fish boxes. These boxes are used to transport fish from Norway to domestic and European destinations. The suggested solution is adapted, but not limited, to operate within the European market. This is because, as uncovered in this thesis, the European market is the most relevant market for Norwegian fish exsport industry. Likewise, the solution is adapted to fulfill the current industry needs.

1.3 Problem statement

Investigate industrial packaging design within the fish exsport industry and based on the knowledge gained through research, propose a sustainable alternative to the industry standard EPS fish boxes that are in service today. These boxes are used for transportation of fresh, whole, gutted fish over long distances. The proposed solution must be sustainable and should fulfil the industry needs in the current market. Furthermore, research and discuss, the necessity of plastics and single use packaging, emerging packaging trends in the seafood industry and how industrial packaging design effects the environment.

1.4 Disclaimer

This report is a part of a master's project preformed at NTNU spring 2022 and are strictly intended for vetting in mentioned subject. The described project is not subsidized by any corporation or organisation. Any mention of company names or products is not intended to undermine their value but simply for research purposes only. Shareholders from the fish farming industry have participated with information and guidance through regular conversations, but they have no commercial interest in the result. The project is performed in accordance with NTNU's GDPR guidelines.

1.5 Method

The aim of this thesis is to design a sustainable alternative to the industry standard EPS fish boxes used today to transport fish over long distances, used by the Norwegian fish export industry to export fish to other European countries. The findings included in this thesis has mainly been gathered through a literature review. During the writhing of the thesis, I have had regular meetings with my collaborators in the fish farming industry from Sekkingstad AS and Aqualoop AS. They have provided me with valuable information, suggestions on future research and feedback on my work. I have also received counselling from my designated NTNU supervisor.

NTNU's digital library Oria has been used to find relevant research articles. I have also used other internet resources belonging to environmental organisations, interest organisations, shareholders in the fish farming and export industry, and packaging producers. I have read related newsletters and information published by the Norwegian government and the EU. The literature has mainly discussed the themes packaging, waste disposal/management and related environmental concerns. A wide variety of sources have been reviewed to gain a deeper understanding of how the industry works, what trends are emerging and to create deeper understanding of the environmental issues facing Norwegian fish export and fish boxes. During the exploratory design process of the fish box I explored solutions through sketching, 3D modelling and 3D-printing.

FIGURE 3. EPS FISKEKASSE MED FISK, BRØDR. SUNDE, 2022. HTTPS://WWW.SUNDOLITT.CO.UK/NO/OM-OSS/NYHETER/FISKEKASSER-RESIRKULERES/#

1.6 Why this project is important

Norway has committed itself to fulfilling the United Nations (UN) Sustainable Development Goals (SDGs). The Norwegian government published its second Voluntary National Review (VNR) in 2021. In the VNR opening statement by the prime minister of the time Erna Solberg reports:

“The COVID-19 pandemic has posed new challenges to our efforts to reach the Sustainable Development Goals. Progress on some goals has slowed and there have been setbacks on others. This presents us with a choice: we can choose to sit back, or we can view the challenges as a call to action. The enormous effort needed to bring life back to normal also provides an opportunity to build back better” (Norwegian Government, 2021, s. 4).

The VNR is a grate tool to gain useful information about Norway’s efforts towards fulfilling their obligation towards the SDGs. It also provides proof that there is a willingness for change in the society stating that; 8 out of 10 consumers in Norway wish to contribute to the sustainable development, furthermore, 73 per cent of the largest companies in Norway now prioritize the SDGs by including them in their business strategi (Norwegian Government, 2021).

The SDGs address huge global challenges some of which are poverty, inequality, environmental challenges, and world peace. “Goal 12: Responsible consumption and production” is important for this project because it involves reducing food loss in the supply chain, reducing the generation of waste while encouraging reduction, recycling, and reuse, all of which are essential when working with developing a sustainable fish box.

“Goal 12.6” is of special importance for all projects with the intention of creating sustainable product solutions and practices, because it directly affects companies’ willingness to prioritize innovation. The goal is formulated as follows:

“12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle” (UN, 2022).

According to the Norwegian government's web page "goal 12" highlights issues that are essential in Norway's efforts to combat climate change. The government is working towards introducing circular economy and sustainability, reducing food waste and dangerous chemicals. The Nordic countries has agreed to cooperate to increase sustainability in production and consumption. Norway is acting against global pollution trough working with chemical conventions (Norwegian Government, 2018).

Till now the plastic production has been spiraling out of control, there is produced more plastic in the world than ever before, and the production is expected to double in the coming 10 to 15 years. Half of all consumer plastics are single use, and 91% of plastics is not recycled, relying extensively on virgin materials in production. Plastics has become an integral part of the modern food packaging and are now the biggest consumer of plastics (Healey, 2019). There is currently a lot of attention towards the overproduction of plastics, waste generation and the environmental impact of plastics (European Commission, 2022). The EU and Norway is now acting towards limiting their plastic consumption trough regulatory changes, including bans on certain plastic products (Norwegian Government, 2021). The resent attention towards plastics rises the need to discuss the necessity of plastics in all industries involved with plastics.

An industry that involved with plastics through their EPS packaging, which happens to also be the theme of this thesis, is the Norwegian fish export industry. Norway is now the world's largest producer and exporter of Atlantic salmon and rainbow trout, whereof fish has become Norway's second largest export. Because of this the Norwegian government argues that Norway has become an important contributor to the production of sustainable foods globally (Norwegian Government, 2021). With that argument in mind, and while considering the sheer size of the fish farming industry in Norway it can contribute greatly to reducing Norway's climate footprint in the world if they are willing to challenge their traditional practices and encourage innovation. This argument will become evident later in the thesis when environmental issues related to disposal of used EPS fish boxes and the consequences of improper waste management, the overproduction of plastics and single use packaging, and safety issues like leakage on public roads – all concerning the fish export industry is presented and discussed in further detail.

PART 2. RESEARCHING THE INDUSTRY STANDARD EPS FISH BOXES

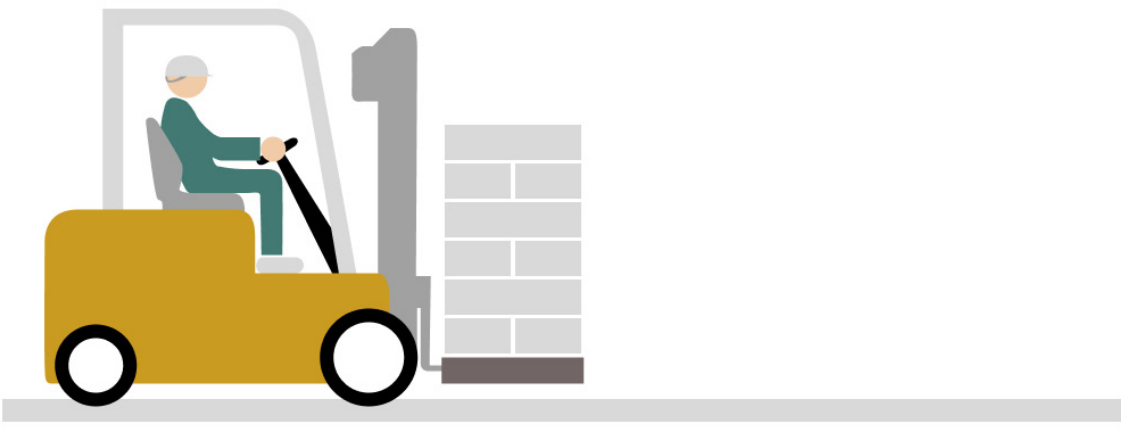


FIGURE 4. FORKLIFT LIFTING FISH BOXES

Part 2, chapter 1 introduction to the industry standard EPS fish box

2.1 What is industrial packaging

Packaging is typically divided into three categories primary, secondary and tertiary packaging (Chung, Ma, & Chan, 2016).

- Primary packaging, also referred to as consumer or retail packaging is used to contain and protect the product, until the product is consumed. Examples of primary packaging are drink bottles and food containers. This type of packaging also serves as an important marketing tool to the consumer (Verghese & Lewis, 2007).

- Secondary packaging is additional packaging used to protect the primary packaging, prevent theft, and facilitate self-service sales. This type of packaging can also be used for advertising and generally thrown away after the product is opened. Examples of secondary packaging can be cardboard boxes and cartons (Verghese & Lewis, 2007).

- Tertiary packaging is packaging used to facilitate buck handling of the product in warehousing and transport. This type of packaging affects the logistics in the supply chain and determine the requirements for handling equipment and transport vehicles. Products will usually be packed with different types of tertiary packaging to protect the product and tighten them together to ease handling. Examples of tertiary packaging is plastic films, polystyrene foam, boxes and nets (Chung, Ma, & Chan, 2016).

To increase the accuracy when discussing packaging there is made a distinction between the packaging that is commonly encountered by the consumer, and the packaging that remain in the supply chain - referred to as industrial packaging. This type of packaging includes those used for transport and industrial products. Consumer packaging is often far more important for marketing than industrial packaging. Consumer packaging is more often subjected to greater scrutiny for its environmental performance by environmental groups and regulators, with particular emphasis on its recyclability, than industrial packaging (Verghese & Lewis, 2007).

2.2 What is EPS

Expanded polystyrene (EPS) is a petroleum based plastic foam made from Polystyrene (PS) a substance belonging to the styrene family for polymers (Lefteri, 2014). PS is also used to make the foam Extruded polystyrene (XPS), both foams are known for their insolating properties (ChemicalSafetyFacts.org, 2022). EPS is a thermoplastic, meaning it can be softened and shaped when applying heat. It is produced by applying hot steam on solid beads of polystyrene, the gas inside the beads will then expand resulting in a foam known as EPS. The Polystyrene beads will expand approximately 40 times from its original volume and can be customized to fill different applications and desired shapes (British Plastics Federation, 2022).

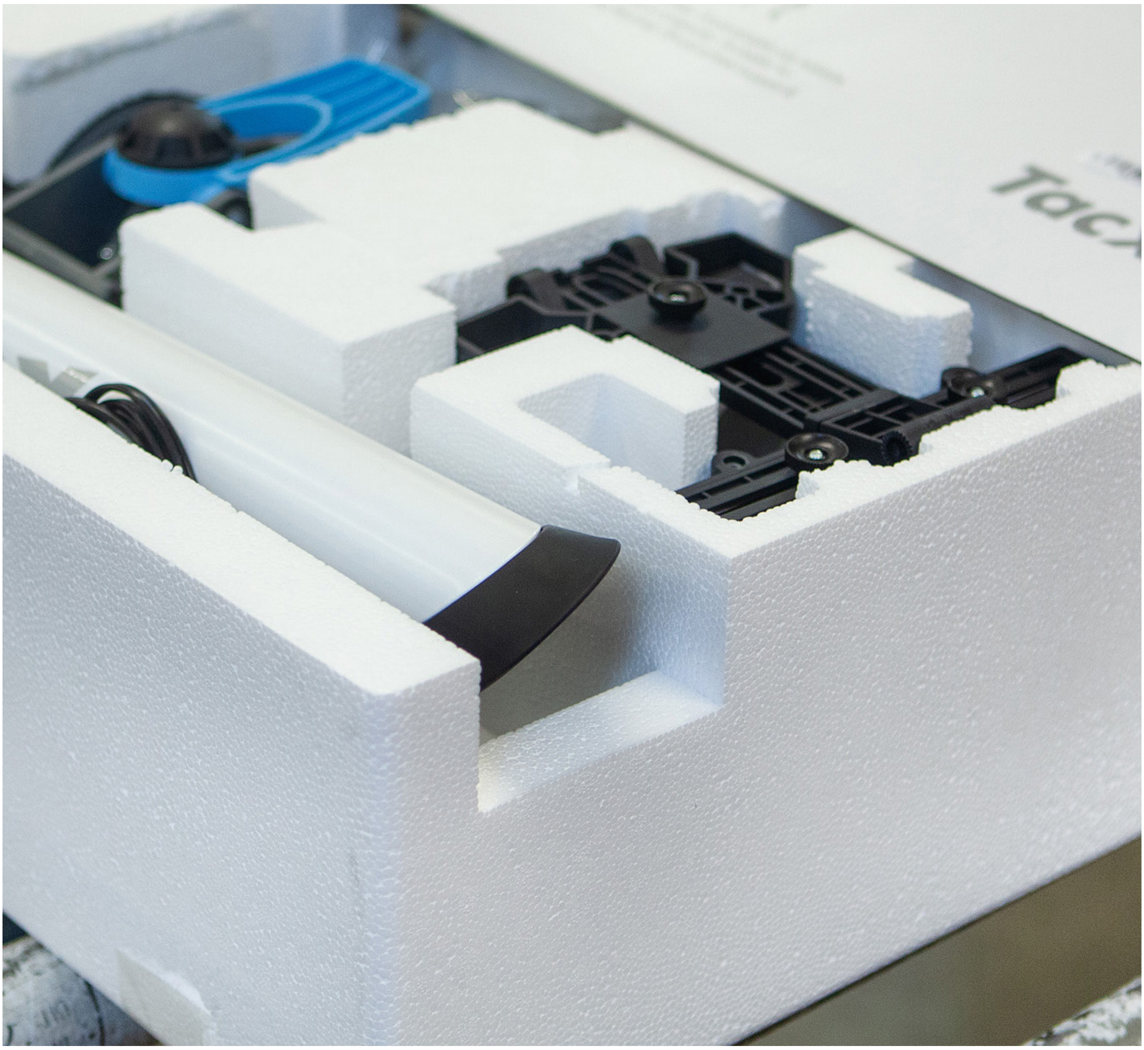


FIGURE 5. PRODUCT IN EPS PACKAGING, 2022, BEWI. HTTPS://BEWI.COM/SOLUTIONS-INDUSTRIES/FISH-SEAFOOD/EPS-FISH-BOXES?LANG=NO

2.3 Applications of EPS

EPS has many different applications, it can be found in everyday products like cups, lids, and food containers – many of which are single use. EPS is also found in longer lasting products like helmets, surfboards, and insulation for housing. It can also be used for packaging where it is a popular method of protecting products like electronics and home appliances. In the food industry apart from protecting it is also used to keep the food at the right temperature. (OceanWise project, 2022). It is for example used in the agricultural sector to package fruits, vegetables, and seeds. EPS is also used in the fish industry to package chilled products (British Plastics Federation, 2022).

2.4 Properties of EPS

EPS contains 98% air, which makes it a lightweight material and consequently a suitable packaging material for transport because it adds little weight to the cargo. It can also withstand impact and protect products from physical damage. The thermal properties make EPS a popular packaging material in the food packaging industry. EPS packaging is used as an insulator and can keep products warm or cold depending on the application. It will also keep the food fresh and can prevent condensation through the distribution chain. EPS is an inexpensive material to produce and can be moulded into custom shapes. It is also chemically inert and non-toxic, meaning it is safe in contact with food, and bacteria and fungi cannot grow on it (British Plastics Federation, 2022).

2.5 The lifespan of EPS Fish boxes

A fish box life first starts by the manufacturing of EPS, the Australian national industry body “Expanded Polystyrene Australia” explains the process of EPS manufacturing trough following three stages, pre-expiation, conditioning, and moulding:

Pre-expansion. EPS is manufactured from styrene monomer, a derivative from ethaline and benzene. The first step in the production process is to make translucent spherical beads of polystyrene (PS), this is done through a process called polymerisation. To aid expansion, a pre foaming agent usually pentane gas, or other low boiling point hydrocarbons is added to the material during the polymerisation process. The resulting PS grains is about the size of sugar granules. When the PS grains is exposed to steam the pre-foaming agent starts to boil. The boiling pre-foaming agent will then cause the beads to expand about 40 to 50 times its original volume (Expanded Polystyrene Australia, 2022).

Conditioning. This is the part of the process after expiation where the beads undergo a maturing period. This is necessary for the EPS to reach an equilibrium temperature and pressure (Expanded Polystyrene Australia, 2022).

Moulding. The EPS can be moulded into desired shapes customized for a range of different applications. When moulding the already expanded beads are placed within the mould and heated again with steam, causing the beads to expand further, and filling the mould cavity and fusing them together. There are two types of EPS moulding; block moulding where EPS is moulded into large blocks and cut into shape and shape moulding where the moulding produces customized shapes and specifications (Expanded Polystyrene Australia, 2022).

The Norwegian industry association “EPS-foreningen” is a part of “Norsk indusrti” a federation in the overall Confederation of Norwegian enterprise (Næringslivets hovedorginisasjon, NHO). They write in an article that EPS fish boxes have a relatively short storage time. The boxes age will determine its quality as the boxes start to degrade under storage. It is therefore important to have a constant flow of boxes leaving the storage. Optimally the storage should be completely renewed every 14 days. The fish box is filled with fish and ice. It is important that the box is filled with the correct amount of fish and ice in relation to the size of the fish box, if not it will affect the performance of the box late on (Norsk Industri, 2022).

This thesis will focus on the most common fish box in Norwegian fish export industry, the industry standard 20 kg fish box (EPS-foreningen, 2019). The box itself ways about 600 grams and can contain about 20 to 22 kg of fish depending on the size and shape of the fish (Norsk Industri, 2022) and each box is packed with 5kg of ice (EPS-foreningen, 2019).

According to a report from SINTEF, most of the fish traveling from Norway to Europe is transported by trailer on country roads in fish boxes packed with ice. This type of transport causes an array of different environmental problems like the increased need for roads, car accidents, noise pollution, leakage of fluids from the fish boxes and greenhouse gas emotions (Ellingsen, Emanuelsson, Skontorp Hognes, Ziegler, & Winter, 2009).

The Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA) has declared virgin EPS as safe in contact with food (ChemicalSafetyFacts.org, 2022). Despite that, not all EPS are safe in contact with food. According to the Ocean Wise Projects, recycled EPS will never be suitable for food contact due to contamination (OceanWise project, 2022).

However, according to the media company “Packaging Europe”, this may change as there is now developed new mechanical recycling technology for PS by the company “Styrenics Circular Solutions” which has been submitted to the EFSA for authorisation. The goal is to contribute to the circular economy of polystyrene (PACKAGING EUROPE, 2020; Styrenics Circular Solutions, 2021).

Despite the technological breakthrough, so far the collected EPS waste is not recycled into new fishboxes. According to “EPS-foreningen” used EPS-fish boxes are instead turned into new products like for example building isolation for housing or coat hangers (Norsk Industri, 2022).

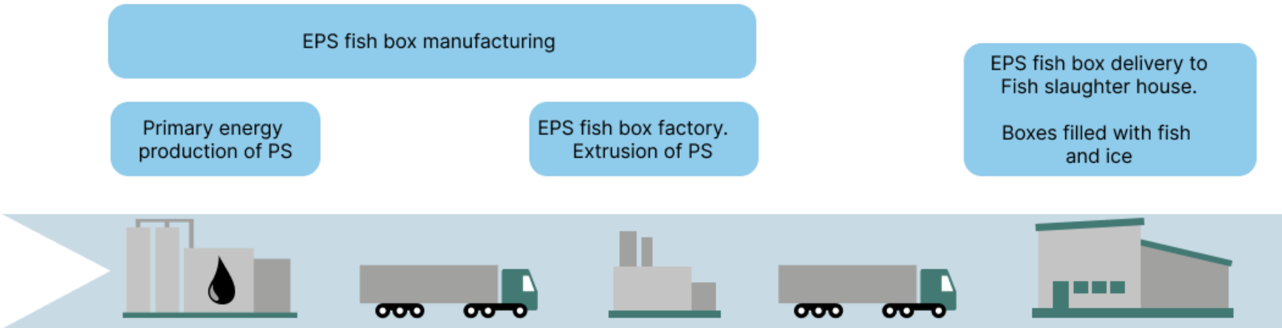
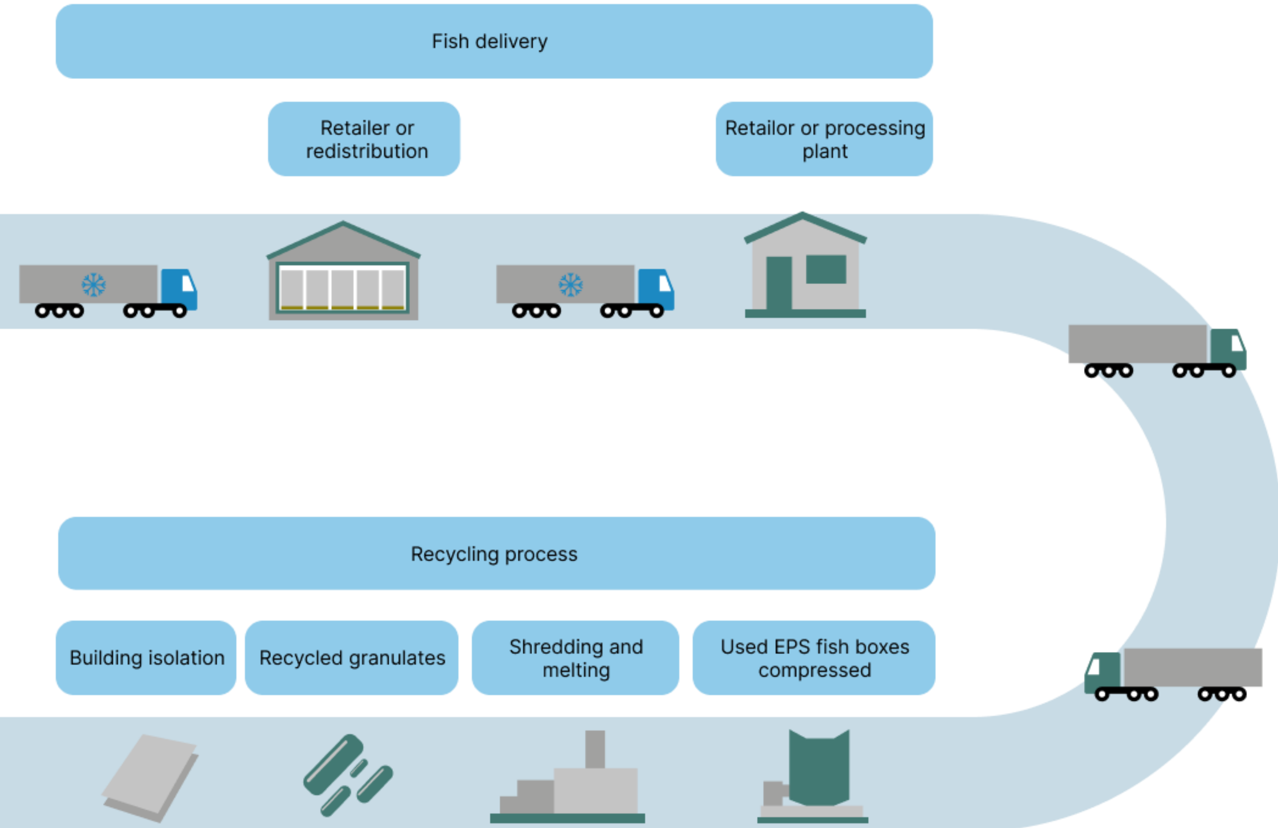


FIGURE 6. LIFESPAN OF A FISH BOX


Fish delivery
Retailer or redistribution
Retailor or processing plant
Recycling process
Building isolation
Recycled granulates
Shredding and melting
Used EPS fish boxes compressed

2.6 How to recycle EPS

Protecting the environment is important, and proper management of our materials is therefore crucial and an important step in protecting the environment from EPS waste is recycling (Norsk Industri, 2022). In theory EPS is fully recyclable on the premise that is has not been contaminated or soiled by other materials. If so, it can be recycled into crystal PS which can be used to make new EPS or other products (OceanWise project, 2022).

EPS can be recycled trough mechanical recycling, chemical recycling processes, and dissolution process (D. Gil-Jasso, et al., 2022). Mechanical recycling is a process where plastic is turned into secondary raw materials. Mechanical recycling does not significantly change the chemical structure of the material. Chemical recycling converts the plastic into monomers or changes the chemical structure into new raw materials. Dissolution is not considered to be chemical recycling but rather a physical reaction. For something to be called a chemical reaction it must produce a new substance, while a physical reaction does not (Altnau, 2020).

Dissolution processes include the use of organic solvents, and their negative effects on the environment and human health is commonly known. If the solvents were to be discharged into the soil, then it can cause contamination of underground water and pose a threat to nearby organisms. Protective equipment is necessary when handling solvents, if misused then solvents can pose a serious risk to human health (D. Gil-Jasso, et al., 2022). Exposure to organic solvents have been found to cause brain damage and mental impairment (FHI, 2019). This is explained in further detail in the section “Health issues related to poor EPS waste management”.

Commonly used methods of EPS waste treatment used in recycle plants are granulation, compacting and densifying. Granulation is a process where lighter density polystyrene foam passes through a machine called the granulator. The machine will separate the beads and mix them with new unused beads of expanded polystyrene. This process will not weaken the capabilities of the new EPS. Compacting is used for denser foams of polystyrene. The compacter will press the material together to form a dens bale of pure polystyrene. The bales can then be shredded into new general purpose polystyrene pellets. A less commonly used technique is densifying, the EPS will be feed into a machine called the densifier. The machine will expose the EPS to heat and pressure, which will melt it down to a paste and then cool it into a solid block of polystyrene, extracting the air from the material. The blocks of polystyrene can be shredded into general purpose polystyrene pallets (Plastic expert , 2022).

When there is large accumulation of plastic waste a common method of waste treatment is incineration. This process involves combusting waste, and the heat can be used for energy recovery. Energy recovery trough technologies like incineration and gasification operate on similar principles. Incineration is a high temperature process, while gasification rely on combustible gases. Incineration produces a large volume of CO_2 (Carbon dioxide) and the plastic waste release toxic gasses like CO_x (Carbon oxides), NOx (Nitrogen oxides) and SO_x (Sulphur oxides), etc. into the environment. Incineration is used for energy recovery of plastic waste and can produce heat that can be used in urban areas and in industry (Gupta, Kumar, & Sinhamahapatra, 2021).

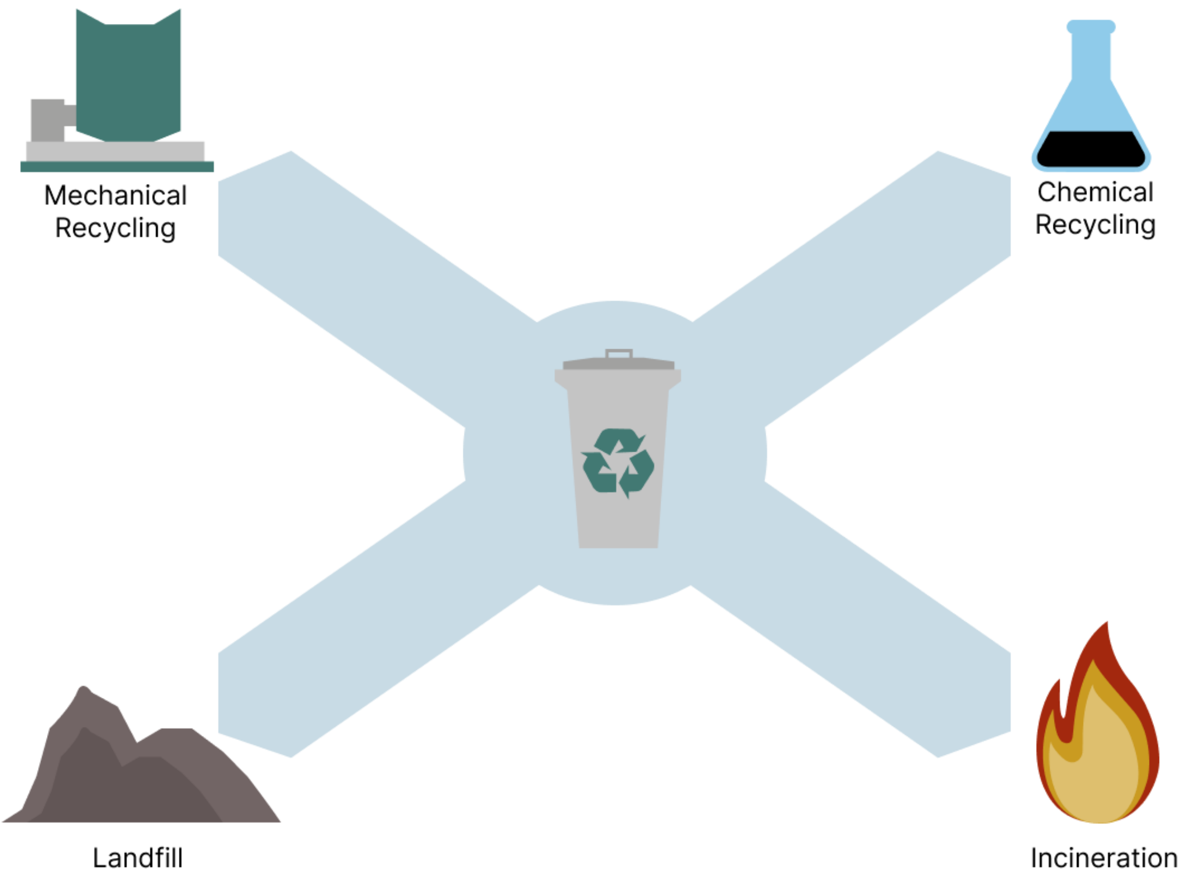


FIGURE 7. RECYCLING

FIGURE 8. WASTE IN OPEN LANDFILL, PUBLISHED 2021 BY VIANET RAMOS. HTTPS://UNSPLASH.COM/PHOTOS/AISJU_WYJPM

2.7 Health issues related to poor EPS waste management

Even though EPS is recyclable it is not recycled all over the world. The increase in EPS production the last years has caused the amount of waste to increase accordingly (Uttaravalli , Srikanta, & Bhanu Radhika, 2020). According to statistics published on “Statista” web site, a market leading online portal providing business data, the production capacity of EPS on a worldwide scale is expected to reach 10.6 million tons by 2024 (Statista, 2021). In developing countries that is lacking proper waste management systems their EPS waste will often end up in open landfills or burned in incinerators. Poor EPS waste management has become a significant global concern, as disposal and burning of EPS causes harmful chemicals to be released into the environment. Styrene has in recent years been linked to cancer, and to be toxic to the gastrointestinal tract, kidney, and respiratory system. It is therefore important to pay attention to how synthetic polymer waste is recycled to avoid reuse of cheap and abundant waste products (Uttaravalli , Srikanta, & Bhanu Radhika, 2020). According to the Norwegian Institute of Public Health (Folkehelseinstituttet, FHI) human made chemicals can pose a risk to our health and environment if not properly regulated trough, production, use and disposal. Trough examinations carried out in the last 20 -30 years they have found a correlation between people being exposed to organic solvents over a long-time span, typically trough work, diffuse organic brain damage and mental impairment (toxic encephalopathy). They further list styrene as one of the suspected toxins (FHI, 2019).

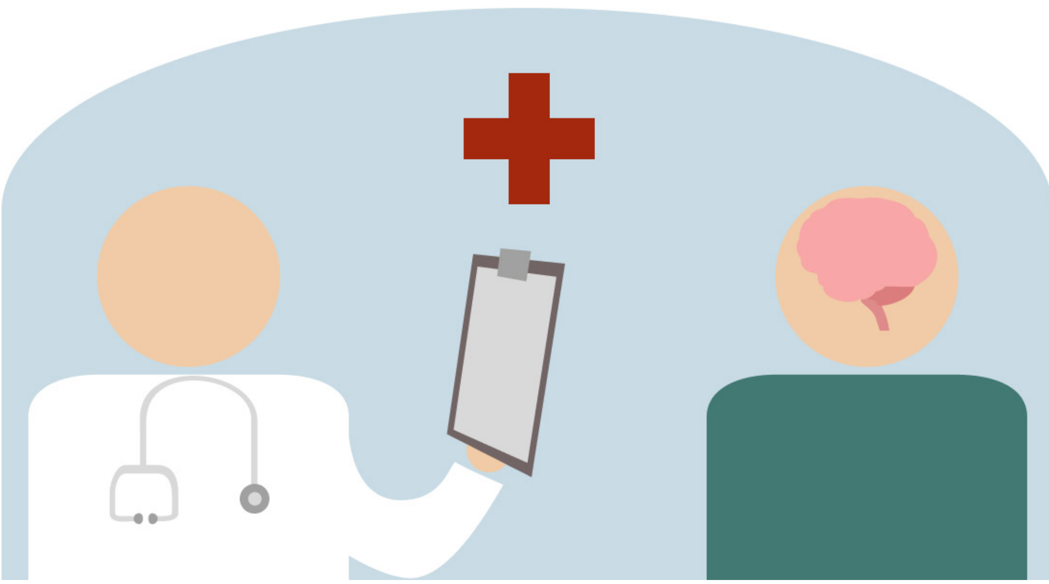


FIGURE 9. BRAIN RESEARCH

2.8 EPS in Norway

Unfortunately, far from all plastic that are in use in Norway are recycled into new material. An article published on “Handelens Miljøfond” web page, Norway’s largest private environmental fund, states that only 30% of all plastic packaging is recycled. If all plastic waste is included then only 25% of the plastic waste is recycled (Jensen, 2020). According to “Avfall Norge” about 70 000 tons of EPS is used every year in Norway. The two biggest means of use are the export of fish boxes which accounts for about 35 000 tons and building isolation for construction which accounts for 30 000 tons, the remaining material is used for packaging furniture and other appliances. In Norway the collection of fish boxes and other packaging is provided by the non-profit organisation “Grønt Punkt”. A lot of the biggest EPS users returns their waste for recycling while households and small users fall behind. “Avfall Norge” states that the biggest challenge when it comes to recycling EPS in Norway is the low dead weight which makes the cost of transport high, but the dead weight of EPS can increase up to 40 times after compression. They further state that the key to a circular economy is delivering the waste material efficiently to a compressor (Avfall Norge, 2022). “Grønt Punkt” writes in a news article on their web page that there has been a significant increase in EPS collection from 2018 to 2019. In 2019 there was collected 5353 tons, that is a 1000 ton increase from the previous year (Grønt Punkt Norge, 2020). In an article published at “Norsirk” web pages, an extended producer responsibility partner in Norway, it is written that most of the EPS collected in municipal recycling stations are burned together with residual waste. They endorse the procurement of compactors in the Norwegian municipalities, claiming that he environmental gains for the municipalities and for those with large holdings of EPS would be huge (Norsirk, 2022).

2.9 Plane, truck and sea transport and standards

For freshly caught fish to reach the plates of hungry consumers, it must first be transported, either by sea, land, or air and there are different requirements that must be taken into account when handling the fish boxes.
After the fish boxes are filled with fish and ice they need to be held together by straps. EPS boxes usually need a minimum of two straps, unless it is traveling by plane, then it will usually need a minimum of three. The terminals can have different demands deciding how many straps needed and their correct dimension. It is not uncommon to use vacuum lifting at the terminals, which needs to be minded when applying the straps. Before the fish boxes can be transported, they need to be placed on pallets. It is very important that the boxes are placed correctly to ensure safety trough the supply chain. The weight of the boxes needs to be distributed equally, therefore most transport companies in Norway only allow a height of nine fish boxes per pallet. There will be twenty-seven fish boxes on each pallet. The same rules apply at the terminals where the pallets are reloaded for further transport. “EPS-foreningen” uses the following pictures on their webpage to explain correct loading of fish boxes on a truck (Norsk Industri, 2022).

FIGURE 10. STACKING FISH BOXES IN TRAILER, 2022, EPS-FORENINGEN. HTTPS://WWW.NORSKINDUSTRI.NO/KAMPANJESIDER/EPS-GRUPPEN/AKTUELT/HANDTERING-AV-FISK/

2.10 Leakage on public roads

Leakage of fluids from fish boxes onto public roads when transported by truck has gained media attention recent years. NRK has published several articles concerning the issue, where it has been described as a traffic hazard that has caused several accidents resulting in majors injures and even death.

In an article from 2017 NRK report that The Norwegian Public Roads Administration (Statens Vegvesen) has been addressing the problem towards both the transport industry and fish farming industry, but there has not been any significant change (NRK, 2017). Five years and several articles later in 2022 NRK can again report that there has not been any significant change and there is an ongoing disagreement between the transport industry and the fish farming industry whether who bears the responsibility. In the meantime, hundreds of trailers are stopped in traffic controls every year and many of them have been banned from driving because of the leakage (NRK, 2022).

Leakage will occur when the temperature inside the fish boxes becomes too high causing the ice to melt and a mixture of blood and water to leak onto the roads. In the winter the fluids will freeze endangering motorists, it can also cause dangerously slippery roads in summer times, especially for motorcyclists. A representative from The Norwegian Public Roads Administration confirms that it is an environmental problem as well as a traffic hazard (NRK, 2022). Hundreds of trailers loaded with fish travels on the roads every day in Norway destined for domestic and European destinations. One trailer carrying 20 tons of fish can in a 36-hour journey spill about 3000 liters of fluids from its cargo (Kyst.no, 2020). The slippery leakage is not spread equally onto a road, but often when the trailer is going uphill causing the trailer to tilt and the fluids to leak out from the backdoor. It is a problem for other people traveling on the road because they often don’t expect the sudden loss of traction (NRK, 2017).

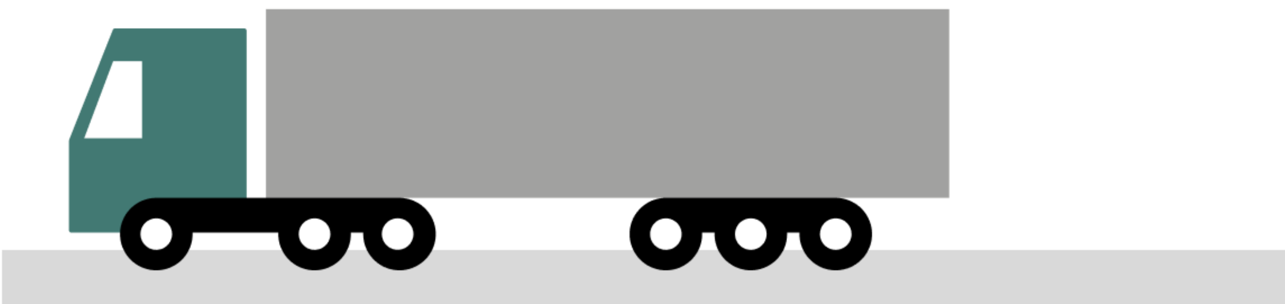


FIGURE 11. ROAD

The previous Minister of Transport in Norway Ketil Solvik-Olsen replied trough the Norwegian parliaments webpage to a written question on whether the leakage is illegal. In his reply Solvik- Olsen refers to the Norwegian regulations on the use of vehicles § 3-2 and the Road Traffic Act § 3 and confirms that the leakage is illegal (Stortinget, 2018).

In the Norwegian Regulations on the use of vehicles § 3-2 it is written: «Gods skal være sikret slik at det ikke utgjør en trussel for helse, eiendom eller miljøet …» (Lovdata, 2022).

In the Road Traffic Act § 3 it is written: "Enhver skal ferdes hensynsfullt og være aktpågivende og varsom så det ikke kan oppstå fare eller voldes skade og slik at annen trafikk ikke unødig blir hindret eller forstyrret. Vegfarende skal også vise hensyn mot dem som bor eller oppholder seg ved vegen» (Lovdata, 2022).

Solvik-Olsen further replies that it is the transporters responsibility to secure their cargo in accordance with the law, and it is expected that they take the matter seriously (Stortinget, 2018). There has been suggested several measures to prevent to the leakage problem and the Norwegian truck owner's association (Norges lastebileier-forbund, NLF) in corporation with the seafood industry are pushing to introduce a statutory industry standard for fish transport. The statutory industry standard includes implementation of electronic consignment note including information about the cargo, and its core temperature at departure. There will also be implemented mandatory temperature logs through the whole transit. They have a high expectation towards the industry to provide innovative and competitive solutions that will contribute to the development of leak-proof packaging and sustainable fish boxes (Kyst.no, 2020).

Part 2, chapter 2- Currently available alternatives to EPS fish boxes

There are many different sustainable alternatives to EPS fish boxes already available on the market, this chapter is intended to explain some available alternatives and what future trends are emerging. When the fish industry chooses which boxes they are going to implement into their production line they mainly consider aspects like costs, strength, durability, weight, dimensions including the space inside for ice or icepacks, compacting for storage, disposal and end of life treatment (TAUW, 2021).

2.11 Corrugated board

From a cost-effective and environmental point of view a transport packaging needs to be lightweight and strong, and it should also be recyclable. Corrugated board is all those things, which makes it a vastly popular option in the transport packaging market (Nordstrand, 2013).

More and more fibre-based fish box alternatives are becoming available on the market. In an article published in the newspaper "ilaks" representatives from the multinational packaging company "Ds Smith" endorse the use of corrugated board packaging as an alternative to EPS. They explain that the fishing industry is often conservative towards new packaging practises and that it will take time for them to change, but they are confident that corrugated board packaging is the future (iLaks, 2018). In a press realise "Smurfit Kappa" Europe's leading corrugated packaging company is announcing that they are also supplying their own fish box made from corrugated board able to keep fish cool up to 48 hours (Smurfit Kappa, 2021). The seafood company "Domstein" announced at their webpage that they are testing a new recyclable fish box named EcoFishBox made from corrugated board, which they expect to replace the EPS fish box in the Norwegian grocery and catering market (Domstein, 2018).

An article published in the Journal of Food Engineering about two experiments measuring the fish quality and the packaging thermal resistance (R-value) after the fish was subjected to temperature changes, and packaged with and without ice, in different types of box-in-box corrugated board packaging and commercial EPS- packaging suggest that although the R-value was lower with the corrugated board boxes, they may still be suitable for transport. According to the article there was not measured any difference in quality of the fish packaged in corrugated board boxes or EPS, but further research is needed. They point out that the corrugated board may limit the packaging folding and manufacturability (Navaranjan, C. Fletcher, Summers, Parr, & Anderson, 2013).

2.11.1 Construction of corrugated board

A corrugated board consists of two outer sheets of paper called liners glued to an inner layer called a flute. The following picture is from the webpage belonging to the non-profit interest organisation "The European Federation of Corrugated Board Manufacturer", the picture illustrates how a "single wall corrugated board" is assembled. Double and Trippel walled corrugated board is also available on the market (FEFCO, 2022).

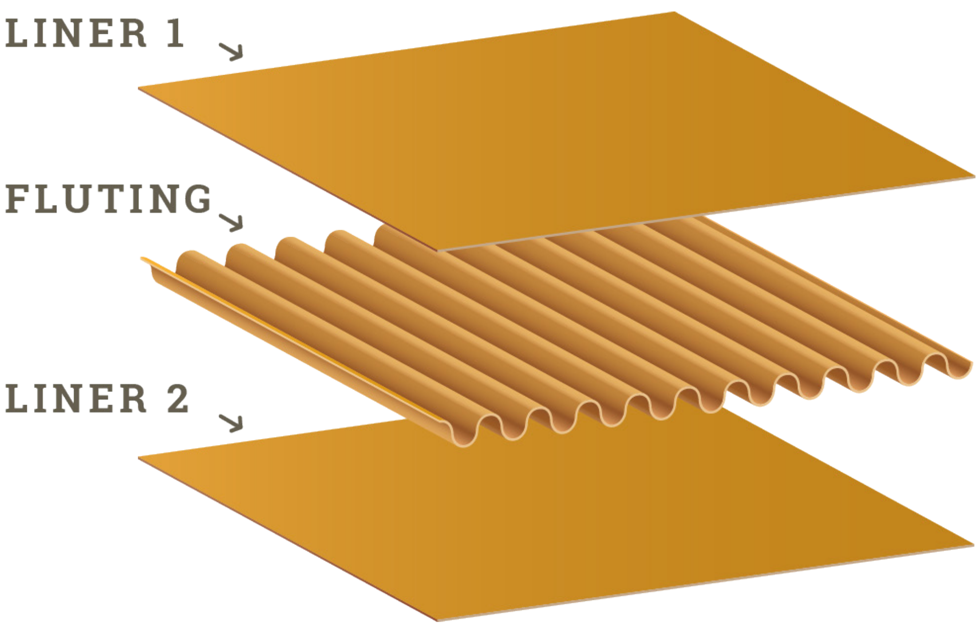


FIGURE 12. CORRUGATED BOARD ASSEMBLY, 2022, FEFCO. HTTPS://WWW.FEFCO.ORG/ABOUT-FEFCO/WHAT-IS-CORRUGATED

2.11.2 Corrugated board example – EcoFishBox

EcoFishBox is a fibre-based fish box made by the company Stora Enso, this box comes in different sizes and are made to transport all types of seafood. Stora Enso make renewable products like packaging, biomaterials, wooden construction, and paper. They are also one of the largest private forest owners in the world (Stora Enso, 2022). EcoFishBox primary purpose is to deliver fish to grocery stores and restaurants, but it is suitable for export as well. The boxes laminated with a thin layer of Polyethylene terephthalate (PET) on the inside and folded in a way that makes them waterproof (Skala, 2022). Stora Enso claim that because the boxes can be delivered and stored as a flat pack, they take up seven times less space than EPS boxes. They also claim that according to their LCA (life cycle assessment) study the boxes achieve 40 – 73% less carbon emissions than EPS and due to their reduced volume, 20% more fish boxes can be loaded onto the same vehicle (Stora Enso, 2022).

FIGURE 13. PICTURE OF ECOFISHBOX , 2022, STORA ENSO. HTTPS://WWW.STORAENSO.COM/EN/PRODUCTS/CORRUGATED-PACKAGING-SOLUTIONS/ECOFISHBOX

2.11.3 Recycling of corrugated boards

Corrugated board is a commonly recycled material, and the fibres can be recycled into new corrugated boards and paper products, but there are some limitations. Fibres can only be recycled a limited number of cycles before it is unsuitable for recycling, usually six to eight times before the fibres are worn out (Fretex Norge, 2022). Because of this limitation virgin fibres will always be needed to meet quality standards of corrugated boards. Furthermore, not all corrugated boards are suitable for recycling. Corrugated boards that are combined with other composite materials like coatings or films may also not be accepted for recycling. The general guideline in the fibre industry is that the designers should reduce the amount of non-paper laminated content to a maximum of 5% of the total weight of the packaging. Corrugated board packaging can be suitable for composting if the material is clean, but packaging made from corrugated board often contain other materials like plastic liners and ink which will make them less compostable (TAUW, 2021).

2.11.4 Future predictions for Corrugated boards

The market research company "Fact.MR" reports a massive decline in the demand of corrugated fish boxes due to the Covid-19 pandemic, but the market started to recover in 2021 as major companies are recuperating their positions in the corrugated packaging. The demand for EPS fish boxes traditionally comes from its insolating abilities. However, growing environmental concerns are changing the costumers demands and paving the way for new eco-friendly packaging solutions. The demand for fish for human consumption is rising due to its health befits. "Fact.MR" forecasts a high demand for corrugated fish boxes the coming years (Fact.MR, 2022).

2.12 Corrugated plastic boxes

An alternative to EPS and fibre-based boxes are single use corrugated plastic boxes. These boxes are usually made from corrugated polypropylene (PP). Just like corrugated board these boxes can be delivered as flat blanks, which gives them an advantage when transporting and storing empty packaging. Also, like corrugated board boxes they have small pockets of air inside them which creates a thermal barrier. Using a special technique, the edges of the box can be sealed to make a waterproof and leakproof barrier. Except for the thermal barrier, which are less in corrugated plastic boxes, they offer the same qualities as EPS. The lower thermal barrier makes the corrugated boxes more susceptible to changes in temperature (TAUW, 2021).

According to an article published in the "International Journal of Refrigeration" describing an experiment measuring the thermal performance of EPS and corrugated plastic fish boxes containing whole fresh fish fillets, some packaged with ice packs and exposed to dynamic temperatures reveal: Ice packs provide efficient protection against temperature abuse. EPS boxes isolating abilities are far superior to the corrugated plastic boxes, the fish packaged in corrugated plastic is therefore less protected against temperature abuse regardless of use of icepacks. As a result of the lesser isolation, the temperature decreased faster in corrugated plastic boxes during the cooling period. The article suggest that less isolation can be favourable in some stages of the chill chains where the product temperature exceeds the ambient temperature (Margeirsson, Gospavic, Pálsson, Arason, & Popov, 2011).

2.12.1 Corrugated plastic box example - CoolSeal

CoolSela is a range of corrugated plastic boxes made by the company Tri-pack. The boxes made to cater different types of seafood, and come in different shapes and sizes, and can be customized to the costumers needs. All the boxes are made from polypropylene (PP) and every component on the box is recyclable, including the glue and ink. If required, the edges can be sealed by sealing all the open flutes, making it dirt and dust tight, the seal will also make it easier to clean and reuse. There are both waterproof and drained options depending on the customer requirements. The company claims to have superior insulation propertied over its competitors when in a complete cold chain, where the boxes will cool down products 12 hours faster than those packed in EPS boxes. The packaging is also lightweight and durable, able to withstand heavy loads without losing its shape or structure (Tri-pack Packaging Systems, 2022).

FIGURE 14. PICTURE OF COOLSEAL, 2022, TRI-PACK PACKAGING SYSTEMS. HTTPS://TRI-PACK.CO.UK/COOLSEAL/

2.12.2 Recycling of corrugated plastic boxes

Corrugated PP can be compacted and are one of the most commonly recycled materials (together with Polyethylene terephthalate (PET) and Polyethylene (PE)) in waste management systems. While post manufacturing waste can be used to produce new corrugated PP, post-consumer waste is currently not used for food contact applications. Meaning, used Corrugated PP fish boxes cannot be recycled into new fish boxes. They be recycled in an open loop recycling system for other non-food related purposes (TAUW, 2021).

2.13 Reusable plastic crates

An alternative to one-time use fish box solutions are reusable plastic fish boxes in the form of crates. These crates are usually made from PP or High-density Polyethylene (HDPE) and are specially made to transport fresh food products, mostly fruit and vegetables, but also meat and fish. The crates are predominately used in large-scale retailer trade. About eight billion crates filled with goods are transported from producers to stores in Europe every year. There are both stackable and foldable solutions that reduces return volume (TAUW, 2021).

2.13.1 The SeaPack project

SeaPack is an innovation project preformed in cooperation with “Nofima” and “Østfoldforskning” operating as independent research communities.
The project is funded by The Research Counsel of Norway (Forskningsrådet) and participating companies. The purpose of the project is to reduce the environmental impact related to food waste, material use, and transport caused by seafood.
According to an article in “Fiskeribladet” the Seapack project has showed promising results regarding the possibility of implementing reusable plastic fish boxes, made from PP. The results show that there is no significant difference in fish quality or bacterial growth when fish is transported in reusable boxes apart from EPS boxes, although the temperature is lower in the EPS box in the first period of storage. They further claim a similar result as the one found in the article from the “International journal of Refrigeration” that was exemplified when describing corrugated plastic, the insolating properties of EPS has become less important for transportation of fish due to implementation of cooling during transport, the insulation abilities of EPS can actuality hinder proper cooling if the fish is to hot when packaged (Fiskeribladet, 2019).

“Nofima” while referring to the SeaPack project claim on their webpage that there is a big environmental gain in replacing the EPS boxses with reusable boxes. Their argumentation is, reusable boxes can be used 100 to 150 times before they must be recycled, an EPS box on the other hand can only be used once. It is therefore needed far-less reusable boxes to transport the same amount of fish (Nofima, 2021).

2.13.2 Reusable plastic tub example – iTUB

iTUB is a company that rent plastic tubs made from Polyethylene (PE) to the fishing industry in Norway. The tubs are made to transport seafood for use at land and sea with options to rent both short and long term (iTUB, 2022). iTUB incorporates “sharing economy” and “circular economy” in their solution.
The sharing economy is an economic system based on the belief that one can increase the utilization of an asset by sharing it with others. The goal of shearing economy is to limit the need for businesses to produce new assets (iTUB, 2022).
When a customer returns a used tub they wash, inspect and do repairs before it is delivered to a new costumer. iTUB tries to keep their tubs in circulation as long as possible. When a tub eventually reaches its end of life where it no longer can function as required, then it will be recycled into PE granules and reused as raw material for new tubs (iTUB, 2022).

FIGURE 15. PICTURE OF ITUB, 2022, ITUB. HTTPS://ITUB-RENTAL.COM/SUSTAINABILITY/

2.13.3 Reusable plastic box example – PPS

PPS is a UK based company with a similar business model as iTUB. They do rental and pooling of crates, trays, pallets and more (PPS, 2022). PPS have been delivering fish boxes to the seafood industry for over 30 years and have developed their own reusable plastic fish box named "Re-Fresh box". The fish boxes are designed for distribution of fresh fish and seafood through a chilled supply chain, it is hygienic, leakproof and comes with a leakproof lid. The "25kg salmon fish box" can be seen in the following picture. The box is made from the material HDPE (PPS, 2022).

FIGURE 16. PICTURE OF 25KG SALMON FISH BOX, 2022, PPS. HTTPS://WWW.PPSEQUIPMENT.CO.UK/PRODUCTS/FISH-BOXES/

2.13.4 Plastic recycling

Plastic is recycled in many ways, and often categorized as either chemical or mechanical recycling. Some types of plastics can be mechanically recycled, PET, PE(LD/HD) and EPS are among those who are commonly recycled. When mechanically recycling plastic there will always be some material loss, usually about 20% after the materials is sorted. Generally plastic can only be mechanically recycled upwards of 6 times. On the other hand, there are no limit to how many times plastic can be chemically recycled, but this is more resource intensive. The environmental gain becomes greater when more plastic is recycled and for every time a monomer repeats the cycle. The biggest environmental gain is when recycled plastic can replace virgin plastic. Replacing virgin with recycled plastic is estimated to save the resources and energy equivalent of two kilograms of oil for every kilo recycled plastic. Recycling will also reduce the pollution associated with extraction and processing of oils and gas (Norges Naturvernforbund, 2006).

2.14 Corrugated board with liner

These boxes were made to enhance the insulating abilities of corrugated boxes. They consist of a corrugated board box with inserts filled with insulating material and a liner separating the food from the inserts. Many of the examples currently available on the market use of residual waste material for their inserts that are abundantly available (TAUW, 2021).

2.14.1 Corrugated board with liner example - Landbox

Landbox is a product range of packaging made by the company Landpack and are intended for food delivery. It has insolating abilities with performance characteristics similar to EPS. Landbox is available as a corrugated board with ether straw or hemp inner lining. The product portfolio also includes two types of cooling elements and a bag (Landpack, 2022).
“Landbox Straw” is a box made from corrugated board with inner lining made from straw. it is made to be disposable as both bio waste and residual waste, with the option of packing the straw in either compostable bio-fleece (Starch-based) or a thin plastic coating made from PE. The box is moisture regulated and shock absorbent. The straws are collected from local farmers in the region and there are not used any additives (Landpack, 2022).

FIGURE 17. PICTURE OF LANDBOX, 2022, LANDPACK. HTTPS://LANDPACK.DE/EN/FOOD/INSULATED-PACKAGING-MADE-OF-STRAW

2.14.2 Corrugated board with liner example – Woolcool

Woolcool is a company producing chilled packaging solutions for both food and pharmaceutical products. Their insulating solutions are made from sheep wool and do not require cooled delivery chains. Their solutions are supposedly re-useable and recyclable. The insolation can be recycled simply by separating the plastic liner from the wool and returning them to suitable recycling systems or home compost the wool (Woolcool, 2022).
The "Insulated Food Delivery Box Sets" are a rage of corrugated board boxes with inner liners made from wool. The boxes are optimized for delivering chilled food products. It is typically used to deliver meats, cheeses, fruit, vegetables, drinks, chocolate, and ice-cream. They claim that because of its strong construction and flexibility of the inner liners, the boxes can carry goods waying up to 30kg (Woolcool, 2022).

FIGURE 18. PICTURE OF WOOLCOOL, 2022, WOOLCOOL. HTTPS://WWW.WOOLCOOL.COM/FOOD/WOOLCOOL-FOOD-INSULATED-BOX-SETS/

2.14.3 Disposal of packaging in bio waste

It is important to note that some of the materials in the examples above may need to be collected separately and therefore some disassembly may be needed for these types of packaging to be sustainably discarded. Corrugated board should be recycled by itself in accordance with the description given in the earlier section “Corrugated board”. In some cases, the plastic liner must be separated from the content of the liner before recycling or composting.

In Norway there are rules for what can and cannot be collected in the food waste composting facilities. Food waste like eggshells, peals, bones, coffee grounds and leftover foods is accepted for composting in Food waste collection system. Compostable products are not accepted and should be treated as home composting, including compostable single use packaging, plates, and cutlery (Sortere.no, 2022).

According to “Avfall Norge” there has been an increasing amount of biobased compostable products. There has also been an increase in the number of bioplastics that is labeled as “food waste”. This type of labeling can cause problems in both food composting and recycling facilities. Most municipalities in Norway collect food waste and turns it into biogas and fertilizer during a short timespan (typically no more than month) using low temperatures. While biodegradable products often require composting facilities that subject the product to high temperatures (50-60°C) over a long timespan. The biodegradable products will therefore not be composted properly in the food waste system. “Avfall Norge” also claim that labeling products as biodegradable can wrongfully create an illusion that is convincing people into believing that the product can be safely discarded into the nature. Some bioplastics will not degrade properly, but instead dissolve into micro plastics that will stay in nature for a very long time (Avfall Norge, 2020).

Therefore, despite the fact that the product is technically biodegradable, there must also be a system that collects, and adequacy processes the material in order for it to be a sustainable solution.

2.15 Bio foams

Resent attention towards the environmental impact of EPS has inspired companies to develop biobased alternatives with similar properties. PLA has gained a lot of attention and is already used for a range of different commodity plastic applications. The innovations E-PLA, which can be made from commensally available PLA beads using CO_2 foaming technology. E-PLA has similar properties to EPS in both impact resistance, isolation, and top load strength, and it can be used to make products like insolation and packaging. E-PLA do not have the same problems associated with pentane blowing agents and do not contain Volatile Organic Compounds (Ali Ashter, 2016, ss. 255-258). An example of a company that supplies this type of service is “BEWI”. They produce a product called “BioFoam” made from PLA which is made from corn starch and sugarcanes. This product can be used for both molded and cut products, it is also used for ice trays and boxes for fresh fish and vegetables. They claim that their “BioFoam” can be recycled like EPS and are suitable for industrial composting (BEWI, 2022).

FIGURE 19. PICTURE OF BIOFOAM, 2022, BEWI. HTTPS://WWW.BEWI.COM/PRODUCTS/BIOFOAM/

2.16 Comparing packaging methods

The table rates the abilities of the different types of boxes based on the information provided in part 2 chapter 2:

	Industry standard EPS fish box	Corrugated board	Corrugated board with liner
Strength	Strong enough to hold to stack on pallets.	Can be affected by moisture, needs liner.	Can be affected by moisture, needs liner.
Leakproof	No, causing leeks on public roads.	Only with liner.	Only with liner.
Insulation	Can provide sufficient protection against temperature abuse during transit.	Less protection against temperature abuse than industry standard EPS fish box.	Can provide similar insulating abilities as EPS.
Cooling abilities in cold cain	Long cool down time.	Shorter cool down time than EPS.	Shorter cool down time than EPS.
Reusability	Single use.	Single use.	Single use.
Need for revers logistics	No need for revers logistics.	No need for revers logistics.	No need for revers logistics.
Recyclable	Recyclable.	Yes, but only recyclable if non-paper content is below 5%.	Yes, but liner needs to be separated from box before recycling.
Remanufacturing	Recycled EPS cannot be used for food contact.	Can be used to make other fibre products.	Depends on liner. Box can be used to make other fibre products.
Compostable	No.	Yes, if clean from other materials.	May need to separate box and liner. Home composting only in Norway.

	Corrugated plastic boxes	Reusable plastic crates	Bio foams
Strength	Strong enough to hold to stack on pallets.	Strong enough to hold to stack on pallets.	Strong enough to hold to stack on pallets.
Leakproof	Yes, edges can be sealed to make it leakproof.	Yes.	Not spesified, but has simular properties as EPS.
Insulation	Less protection against temperature abuse than industry standard EPS fish box.	Depends on type of reusable crate. Can have similar insulating abilities as EPS.	Similar insulating abilities as EPS.
Cooling abilities in cold cain	Shorter cool down time than EPS.	Can have shorter cool down time than EPS.	Similar cooling abilities as EPS.
Reusability	Single use.	Reusable.	Single use.
Need for revers logistics	No need for revers logistics.	Needs revers logistics.	No need for revers logistics.
Recyclable	Recyclable.	Recyclable.	Recyclable.
Remanufacturing	Cannot be used for food contact applications.	Can be used for remanufacturing.	Cannot be used for food contact applications.
Compostable	No.	No.	Industrial compostable, but not accepted in Norway.

Part 2, chapter 3- Discussion

2.17 Circular economy and industrial packaging design

Circular economy is a term used to describe the lifecycle of goods that can be turned into new resources after its service life. It is a different way of perceiving economic logic from our linear economy where we produce, use and dispose. The goal of circular economy is instead to close industrial loops and minimize waste by recycling the things that cannot be reused, repairing the things that are broken and remanufacture the things that cannot be repaired (R. Stahel, 2016). According to Karstensen, et al. The circular economy is a way of ensuring that the resources remain in circulation for as long as possible. Resources can remain in circulation longer trough a reduction in emissions, waste generation, raw material consumption, and energy consumption (Karstensen, Engelsen, & Kumar Saha, 2020).

Packaging is often mistakenly considered an economic and environmental cost when it should be considered as an opportunity for added value towards waste reduction. Packaging is an essential part of sustainable food consumption and vital to minimize the environmental footprint of packaged foods. Packaging can preserve the quality, protect, and maintain food safety while extending shelf life. An advantage of an extended shelf life is the potential reduction is food waste. Because, when food waste occurs it is not only the food product that is wasted, but the packaging is also discarded. Food waste will therefore lead to an additional environmental burden in both the loss of the food product and its packaging. When addressing the environmental issues in packaging and food system it is therefore necessary to view the system on the whole, not only the impact of packaging material by itself, but its contribution to the system (Guillard, et al., 2018).

Industrial packaging directly impacts a company's suitability performance, and it has the ability to enable efficient and sustainable logistics throughout the supply chain. Designing and developing of industrial packaging is a complex task and requires a holistic overview of the entire lifecycle of the product. Apart from choosing the right material with desired qualities, it is important to consider the handling of the product like activities in the warehouse and transportation. End of life treatment is an important consideration in industrial packaging design, but also a difficult one because of its ability to affect the environment when packaging turns to waste. Industrial packaging often travels long distances, and one way packaging is used extensively. Whether it should be one- way or returnable is debatable. One way packaging results in extensive cost and resource consumption, but returning packaging can also lead to additional impacts from the reverse logistics. The possibilities for recycling and reuse need to be taken into account, and solutions need to be optimized for the whole route (Silva & Pålsson, 2022).

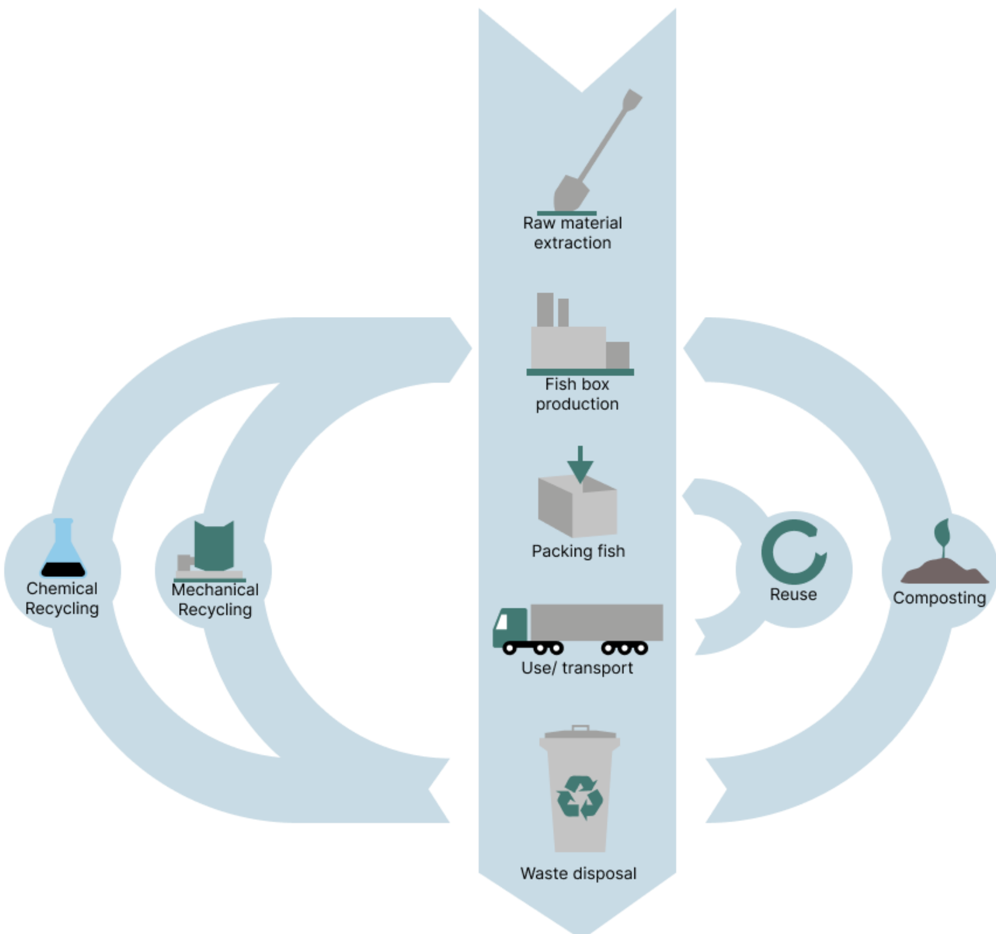


FIGURE 20. CIRCULAR ECONOMY

2.18 One-way single use packaging or returnable reusable packaging

Implementing reusable packaging solutions have some unique environmental advantages, but there are also limitations. This section will provide an overview of the environmental impact of returnable reusable packaging and discuss how it compares to the more common method one-way single use packaging.

One of the most obvious advantages of reusable packaging is the reduction in the overall amount of packaging waste. By reducing the amount of packaging waste going through the recycling and waste management systems it will also reduce the workload and energy consumption within these systems (Long, Ceschin, Mansour, & Harrison, 2020).

For reusable packaging, the greatest environmental impacts are in relation to its service life, mainly those connected to transportation and washing (Albrecht, et al., 2013). Hence, a significant drawback of reusable packaging is related to the environmental impacts of reverse logistics, in this case the transportation distances is important factor when evaluating the environmental gain of reusable packaging (Silva & Pålsson, 2022). Reusable packaging systems will also require washing operations, which causes additional water and energy consumption, and wastewater emissions (Long, Ceschin, Mansour, & Harrison, 2020; Albrecht, et al., 2013). The reusable system becomes more beneficial compared to the single use system for every time it is reused, because the energy demand and emissions of reverse logistics and washing increase in a slower rate compared to the decreasing energy demand and emission in packaging production caused by reduced need for packaging production (Albrecht, et al., 2013).

As far as the transportation and reverse logistics is concerned, some research indicates that returnable reusable packaging performs best in short distance supply chains, where the emission from transportation is less significant (Albrecht, et al., 2013; Battini, Calzavara, Persona, & Sgarbossa, 2016). Reusable plastic crates, which is a common reusable solution usually way more than its single use counterpart, resulting in higher fuel consumption and more emissions during transport (Albrecht, et al., 2013). An increased use of electric vehicles and more fuel-efficient engines will contribute to reduce the emissions related to transportation activities (Battini, Calzavara, Persona, & Sgarbossa, 2016). Furthermore, In the end-of-life stage, reusable packaging made from recyclable plastics can benefit from the material recovery in recycling, because secondary granulates can be used to make new packaging in a closed loop, or similar applications (Albrecht, et al., 2013).

2.19 The physical internet

Reusable packaging can be beneficial in both business-to-business (B2B) segments and business-to-consumer segments. In the business-to-consumer segments, achieving an effective reusable packaging systems is more challenging, but it could include purchasing targeted applications like reusable bags to limit plastic bag consumption. Reusable B2B packaging has the potential to enable cost savings through collaborative pooling systems. An advanced form of reusable B2B packaging pooling systems is what's referred to as the "Physical internet" - a system that enables logistics trough shared assets across industries, a system where the packaging is standardized and modularized (World Economic Forum, 2016). It builds on similar principals as the digital internet, but instead of a digital delivery like an email traveling through a network of servers until it reaches its destination – it allows transport and logistics companies to access a network of routes connected by hubs. The flow of goods can be streamlined through accessing a network of different routes and transportation methods (Ceurstemont, 2021). If the fragmented logistic market is converted into a shared pooling system built on the idea of the physical internet on a global scale, it will have the potential to significantly improve asset utilization and global material flows (World Economic Forum, 2016; Ceurstemont, 2021).

Traditionally freight carriers have been operating enormous distribution centers and transportation fleets solely for maintaining their own distribution systems. Because of these practices some degree of empty running, where vehicles travel empty or partly empty, is unavoidable. In 2012 almost a quarter of the kilometers traveled by heavy goods vehicles in the EU involved an empty vehicle (Simmer, Pfoser, Grabner, Schauer, & Putz, 2017), and when loaded they are typically not loaded to their full capacity, averaging only 50% full (Ceurstemont, 2021). This means that the current transportation system is insufficient, inflexible, and not environmentally friendly, causing high fuel consumption and CO_2 emissions and avoidable costs (Ceurstemont, 2021; Simmer, Pfoser, Grabner, Schauer, & Putz, 2017).

To make all parts of the physical internet work together seamlessly, a digitalization of all available information is needed. The idea is that every element included in the physical internet will have a digital twin providing updated information. The information will be fed into a centralized algorithm able to establish the optimal route for each delivery (Ceurstemont, 2021) The ICONET project has the objective to create a cloud-based framework and platform for the physical internet while Increasing connectivity, visibility, and collaboration. ICONET offer solutions that will make logistics work more effectively by enabling real time visibility, reducing overall lead-times, errors, and costs (ETP ALICE, 2020). During the ICONET project it was found that that the network could help companies find the optimal route depending on their requirements. While some may want their goods to be delivered as quickly as possible, others may be more concerned with reliability, in both cases the network could find an optimized route. Furthermore, during the MODALUSCA project, an EU funded project on the physical internet, it was found that standardization of the boxes can improve cost savings due to increased fill rates on crates and pallets. Because cargo from different companies may come in different shapes and sizes, it can be hard to sufficiently pack them into a truck while maintaining the best possible fill rate. It was discovered that standardization could improve the fill rate by 15% for manufacturers and up to 50% for retailers (Ceurstemont, 2021).

As decided trough the “European Green Deal”, the ambition for the EU is to make Europe the first climate neutral continent in the world by 2050, including a reduction of net greenhouse gases by at least 55% by 2030, compared to 1990 levels (European Commission, 2022). As a contribution to reach those goals work has begun to transition into the physical internet in the EU. The Alliance for Logistics Innovation through Collaboration in Europe (ALICE), which receives funding through the EU, has released a “Roadmap To The Physical Internet”, a document that are outlining the path towards the physical internet from 2020 to 2040. It includes important milestones, required technologies and fist implementation opportunities for the physical internet. They expect that an advanced pilot implementation of the physical internet will be operational and common industry practice by 2030. This implementation will supposedly contribute to a 30% reduction in emissions, energy consumption and congestion caused by the transport industry. They further predict that a forecasted 300% increase in transport demand can be meet with only a 50% increase in assets, in the event where all identified efficiencies are achieved. This implies that environmental sustainability is achievable in an economically and socially feasible way (ALICE, 2020).

2.20 Comparing reusable packaging versus one-way single use packaging

The table rates the abilities of the different types of boxes based on the information provided in part 2 chapter 2 and 3:

	Pros	Cons
Reusable pacaging in a shared asset sysem	• Less waste. • Less material usage. • Less energy needed for overall packaging production. • Can be recycled into new boxes. • Shared transport costs. • Environmental benefit from shared transport. • Enables the use of shared information platforms.	• Emissions related to reverse logistics. • Emissions related to washing. • Possibly higher Weight (Higher fuel consumption).
One-way single use packaging	• No reverse logistics. • Cheap packaging.	• High amount of waste. • High material usage. • Not always recycled sufficiently. • Avoidable transport cost (could be sheard). • Emissions from inefficient transport (Low fill rate and empty vehicles).

2.21 Discussing the necessity for plastics

There is currently a lot of attention towards the overproduction of plastics, waste generation and the environmental implications associated with it, especially marine pollution. The European Union (EU) is now acting towards limiting the effects of plastic pollution and marine litter as well as accelerating the transitioning to circular economy. The EU wants to protect human health and environment through introducing a new policy on plastics. The plastic policy also aims to change the way plastics are being designed, used and recycled as well as supporting sustainable and safer consumption (European Commission, 2022).

Norway among other countries is taking steps towards limiting their plastic consumption trough regulatory changes. Norway is complying to the EUs “directive on the reduction of the impact of certain plastic products on the environment” which was adopted 5. June 2019. This in accordance with article 1, which is supposed to limit the environmental impact of certain plastic products and promote development of circular economy. Norway is now restricting fishing equipment and several single use items like cotton swabs, cutlery, plates, and straws. They are now illegal to sell if they are made of or partly made of plastics, including food and drink containers made from EPS and items made from bioplastics (Norwegian Government, 2021).

It is fair to assume that most Norwegians are somewhat aware of the environmental implications associated with plastics. But is eliminating plastics always the answer? Are there some applications where plastics are unavoidable? This section aims to discuss the need for plastic packaging in the food industry.

There are many legitimate purposes for using plastics, but the fact of the matter is that humans have become over reliant on single use and disposable plastics. For many of which there are full-fledged alternatives to plastics. Plastics pose a serious threat to both the environment and human health, but still the plastic production is spiraling out of control worldwide, so much so that the amount of plastic produced every year is roughly the same as the weight of the entire human population. In 2018 alone there where produced an estimated 360 million tons of plastic, and these numbers are expecting to double the next 10-15 years. By the year of 2025 it is predicted that production will reach a staggering 500 million tons. Sadly, 91% of plastic waste is not recycled. Furthermore, 50% of all consumer plastics are single use. To put the amount of plastic waste produced every year into perspective, it could circle the earth four times (Healey, 2019).

Plastic packaging has become an integral part of modern food packaging because it is cheap, light, durable, flexible, and rigid, but most of all it is a usable material that can serve multiple purposes. Packaging is the biggest consumer of plastic (Healey, 2019). Plastic is used in all types of food packaging and extensively used in single use applications (Wohner, Pauer, Heinrich, & Tacker, 2019; Healey, 2019). In packaging there is also used an excessive amount of virgin material, while there is a limited capacity to recycle it (Healey, 2019).

However, plastics have many attributes when it comes to protecting food products, especially fresh produce which is also a common source of food waste. Plastics can prevent spoilage trough acting as a barrier towards oxygen and moisture, prohibiting contamination and protecting against physical damage, all while adding convenience for the consumer. When removing plastics there is a trade-off that needs to be considered, which is the potential loss of shelf life and probability of food waste (White & Lockyer, 2020).

Food packaging, including the ones made from plastics, main purpose is to protect the foods, as well as extend shelf life, facilitate handling, and communicate information (Wohner, Pauer, Heinrich, & Tacker, 2019). According to the United Nations environment program, roughly one-third of the food that is produced for human consumption in the world every year is lost or wasted (UN Environment Programme, 2022). Almost 14% of the food is lost before it even reaches the retailers (UN, 2022). About 30% of all cereals, 40-50% of root crops, fruits, and vegetables, 20% of oilseeds, meat, and dairy, and 30% present fish goes to waste every year (UN Environment Programme, 2022). There are differences in where the main source of food waste occurs in developing and developed countries, but a common ground is that better packaging practices can help both. In developing countries, the biggest source of food waste occur early in the supply chain before the food reaches the consumer. The losses can be linked to limitations in harvesting, storing and cooling facilities. In these countries it would be beneficial to strengthen the supply chain trough supporting farmers and investments in infrastructure, transportation, and the food packaging industry. Appropriate food packaging could enable longer shelf life, enhanced safety, and the probability that the food reaches the household. However, in developed (both medium and high-income) countries, the main source of food waste occurs late in the supply chain. Food waste can be linked to wasteful behavior in consumers. Excessive packaging sizes and lack of coordination between actors in the supply chain is also a source of food waste. Arising awareness about food waste among industries, retailers and consumers can help reduce the amount of waste (UN Environment Programme, 2022; Wohner, Pauer, Heinrich, & Tacker, 2019).

Considering the reasoning for food waste worldwide it becomes clear that sufficient packaging is an important measure when combating food waste, and packaging that fails to protect the food product is not worthwhile. This thesis is about designing sustainable alternatives to EPS fish boxes, which is a type of packaging made from plastic. An important part of the process when designing the new packaging is to ensure that the fish is not lost to food waste. Packaging is vitally important in fish products. Fish is a is highly perishable and require immediate processing and packaging after harvesting. Propper packaging is therefore crucial to prevent food waste and to retain its quality and food safety (Kontominas, Badeka, Kosma, & Nathanailides, 2021). Equally, considering the amount of plastic waste that are afflicting our health and polluting the environment, it becomes obvious there is a need for change in how plastics are utilized, and products are packaged.

In an article written about the "New Plastic Economy" initiative by the Ellen MacArthur Foundation, an initiative working with governments, Non-Government organizations, academics, businesses, and other stakeholders to promote circular economy for plastics, it is written:

"It is crucial for everyone involved in the plastics industry to understand that we need to go beyond collecting and recycling more. Both are important but they are not enough – we need to redesign the entire plastics system by starting upstream, thinking carefully about what we put on the market" (Defruyt, 2019, s.78).

The article conveys the need for everyone involved in the plastic industry to rethinking how plastics are used and eliminate all unnecessary plastic packaging. Exemplified in the article, 30% of plastic packaging that are available on the market today is ether too small or too complex to be recycled. Such packaging can typically be small wrappers and sachets or those who contain multi-layered materials. There is a need for a fundamental redesign and innovation to make these products sustainable (Defruyt, 2019).

According to the "Ellen MacArthur Foundation" together with increased recycling, composting and reuse, without elimination of unnecessary plastics, achieving a circular economy will not be possible. Some plastic packaging can in fact be avoided without it affecting the utility of the product, especially important are those in single use packaging. Furthermore, the businesses producing/ selling packaging should take responsibility beyond design and use. They should contribute in a way that ensures that the packaging that is truly needed ends up in a system that either reuse, recycle, or truly compost. Composting plastics is not a viable solution in all cases, but should be

considered if effective (Ellen MacArthur Foundation, 2022).
While one of their goals is to compost more the performance is often limited due to lacking infrastructure and effective collection. Therefore, whenever reusable solutions are relevant, this possibility should be explored as a favorable solution towards reducing plastic consumption (Ellen MacArthur Foundation, 2022).

In an article published on the website of The Sustainability Institute by ERM, they emphasize that the goal is not to oversimplify the problem by banning all single use plastics, but instead to reduce the plastic consumption where possible through calculated reductions. For businesses there is a cost associated with changing packaging, but there are also possible benefits. Reducing plastic volumes overall strengthen the relationship with consumers and potentially save logistic costs. There is however a risk associated with removing packaging material, and that is the one concerning food waste. Therefore, eliminating all plastics is not the definitive solution, and something that should not be taken lightly. A good start is to map out the excessive use of plastics, because plastic is not a bad material, it is just used inappropriately (Ledsham, 2022).

The environmental organization Green Warriors of Norway (Norges Miljøvernforbund) has made a list of suggestions towards what the plastic industry should focus on when working with product design. Translated from Norwegian, the list goes as follows:

- “Increase the lifespan of the product (for example electronic products)”.
- “Avoid mixing materials that is not easily separated”.
- “Avoid unnecessary material use (for example when packaging products)”.
- “Avoid using additives”.
- “Replace virgin plastic with recycled material”.
- “Label the plastic clearly so it is easier to sort. This will increase the possibilities of recycling”.
- “Replace oil-based plastics with bio plastics (not necessarily biodegradable), provided that the plastic is produced in an energy efficiently way from agricultural waste and does not cause problems in plastic recycling” (Norges Naturvernforbund, 2006, s.15).

Should the fish farming industry use plastics for industrial packaging? Based on the information provided above there is no definitive answer on whether the fish farming industry can justify using plastics, it is rather a question of necessity for each individual product. As presented in part 2 chapter 2, there is full-fledged alternatives to the industry standard EPS fish boxes, some of which are reusable. This is in accordance with the statement from the Ellen MacArthur Foundation, which express that reusable systems should be considered wherever possible (Ellen MacArthur Foundation, 2022), however, based on the information provided about the current industry standard practice in the fish farming industry, it will require a shift in how the industry operates and corporate with others. It is further emphasized by the Ellen MacArthur Foundation that the industry should consider their ethical obligations, and if they feel responsible for the outcome of their own products (Ellen MacArthur Foundation, 2022). Reducing unnecessary plastics can be more than just an ethical obligation, it can also be an opportunity. According to the Sustainability Institute by ERM, reducing packaging volumes and unnecessary plastics can strengthen the brand, relationships with customers, and cut packaging and logistical costs (Ledsham, 2022). Finally, considering the EU's ambition to cut emissions and become climate neutral (European Commission, 2022) and the transition towards the upcoming advanced pilot implementation of the physical internet as early as 2030, which largely concerns the food export market (ALICE, 2020), the fish farming industry should therefore strive to not only cut unnecessary plastics but also work towards implementing reusable solutions.

2.22 Bioplastic packaging

An alternative to conventual fossil-based plastics are bioplastics. Plastics that are made from renewable sources are often referred to as bioplastics, but are in fact not a new phenomenon, but rather a rediscovered class of materials, that are now experiencing a new renaissance. Caseins, celluloid, cellophane, gelatin, linoleum, rubber and shellac are among the first polymer materials synthesized by man, and they are all based on renewable sources. The explanation is simply that there was no petrochemical material available at the time (Endres, 2019). However, the current demand for bioplastic is manly driven by the desire to replace fossil-based polymers due to environmental concerns like the limitations in fossil fuel and waste disposal. Bioplastics will broadly be classified as ether bio-based and/or biodegradable. When discussing bioplastics, it is important to know that not all bio-based materials are categorized as biodegradable, as well as not all biodegradable materials are bio-based. Moreover, the term bio-based is used to describe a material where the focus of the material is on the carbon building blocks, not considering end of life treatment (Ali Ashter, 2016, ss. 1 - 17).

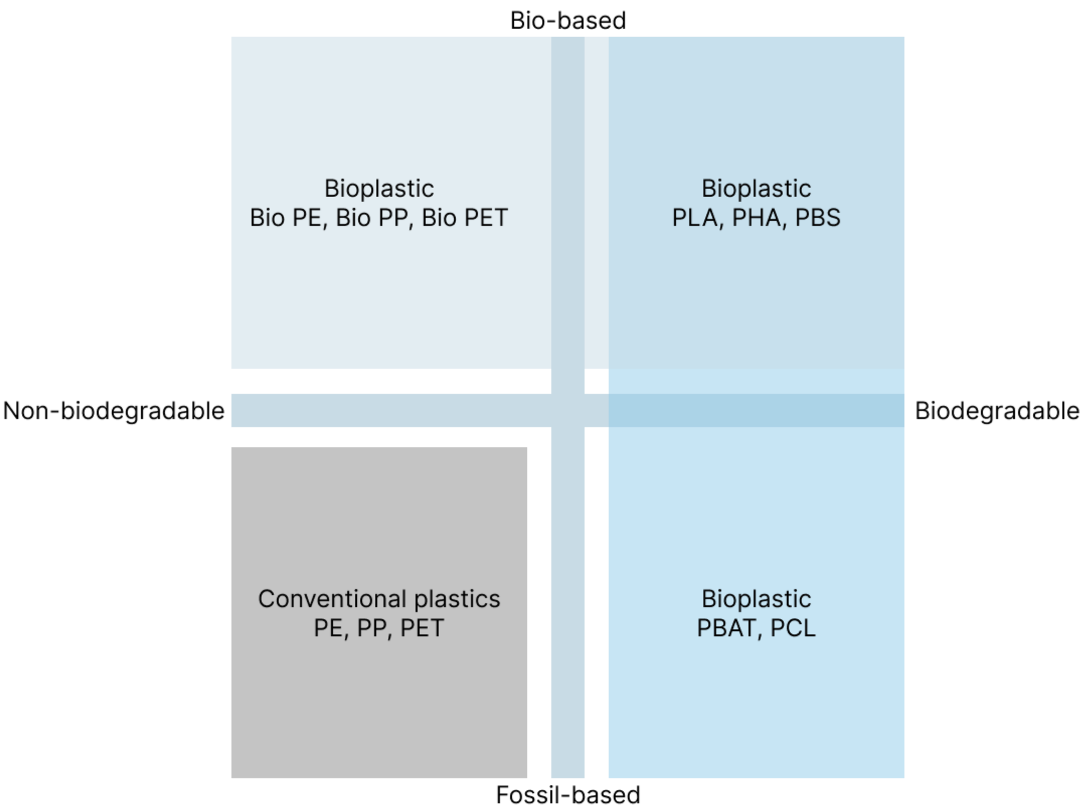


FIGURE 21. BIOPLASTIC

“BIO-PLASTICS EUROPE” is a research program, which has reserved funding through the European union’s Horizon 2020 research and innovation program. They discourage the use of the term “Bioplastics” because of the lack of precision. Instead, they encourage people to use the terms “bio-based” and “biodegradable” (BIO-PLASTICS EUROPE, 2022). The Norwegian environmental agency agrees, claiming that the term bioplastic is confusing because it covers a range of different types of materials, the term should therefore be avoided (Miljødirektoratet, 2019).

The term bio-based is used for materials that are fully or partly derived from biomass, meaning materials of organic origin, but excluding those who are embedded in geological formations and/or fossilized. Materials produced from any organic waste can also be considered bio-based. (BIO-PLASTICS EUROPE, 2022) There are no agreed standards for the minimum amount of bio-based content a product or plastic must contain to be classified as bio-based plastic. There are however independent certifications that manufacturers can use to indicate the bio-based content with the use of labeling schemes (Miljødirektoratet, 2019). The term biodegradable is used to refer to materials that can be turned into natural substances such as water, CO_2 and compost by naturally occurring organisms. The term biodegradable does not refer to any specific timeframe or environmental conditions where the material is supposed to naturally degrade. It is important to know that biodegrading materials are strictly dependent towards the conditions in which it is supposed to degrade. Like the conditions of the microorganisms in the water and soil, and the presence or absence of oxygen. For most biodegradable plastics, the microbiological biodegradation is the most important process for the degradation (BIO-PLASTICS EUROPE, 2022). A biodegradable plastic may only decompose in an industrial composting facility, or considerably slower to not at all in the marine or land environment. Because the term biodegradable does not refer to the material itself but its performance in different environments, it is far more difficult to standardize. On the contrary, there have been implemented some international standards for biodegradation in industrial composting and anaerobic degradation. But there are skepticism concerning the standards and methods that are used, the argument being that the environment which the material is exposed to is impossible to recreate (Miljødirektoratet, 2019). Furthermore, as discussed earlier in the texts under the section “Disposal of packaging in bio waste” in part 2, chapter 2 about currently available alternatives to EPS fish boxes, there are rules for what is accepted into Norwegian composting facilities and biodegradable plastics may cause problems when producing fertilizer and biogas (Avfall Norge, 2020).

They may also cause contamination and quality issues in recycling facilities when mixed with fossil-based plastics. It is possible that NRI (Near infra-red) sorting technology could be programmed to sort out biodegradable plastics, but it is uncertain how small quantities of biodegradable plastic it takes to affect the quality of the recycled material. Furthermore, to categorically state that biodegradable plastic will biodegrade in all natural environments, especially uncontrolled and open environments, like the marine environment that consist of varying temperatures and organic life – may be an impossible task (Miljødirektoratet, 2019).

2.22.1 Bio- based, novel and drop in plastics

Bio-based plastics can be further categorized into two categories, novel and drop in plastics. the novel plastics has a unique chemical structure like no other plastic, a common example is PLA. On the other hand, drop in plastics are easier to recycle because their chemical structure is identical to its fossil-based counterpart, but they use a biomass feedstock. Drop in plastics can be processed in already existing manufacturing and recycled system. Examples of drop in plastic are bio-based PE, PP and PET. Novel plastics such as PLA which can be considered a new bio-based plastic and cannot be recycled together with conventional fossil-based plastics. PLA and other new bio-based plastics must therefore be separated into its own stream for recycling. The existing sorting plants may not have the capabilities to recycle these materials and they will therefore go to incineration with energy recovery (Miljødirektoratet, 2019).

2.22.2 Feedstock

Biobased plastics are made from material collected from different types of feedstocks. The more commonly used feedstock to this date is the one that is referred to as “first generation feedstock”. This feedstock is sourced from carbohydrate-rich food plants, such as corn, sugarcanes, and oily plants. The first-generation feedstock is currently considered to be the most resource and cost- effective way to produce biobased plastics. There are also ongoing research concerning development of “second generation feedstock” and “third generation feedstock”. The second-generation feedstock is made from cellulosic raw material and non-edible by-products stemming from food crops such as straw, corns stove, bagasse, and organic waste- which are all linked to food production. The third generation of feedstock is not linked to food production, but rather made from algae and non-agricultural waste (BIO-PLASTICS EUROPE, 2022).

The Bioplastic Feedstock Alliance is a multi-stakeholder forum composed of world leading consumer brands, with support from the World Wildlife Fund (WWF), their focus is to promote responsible sourcing of bioplastics (Bioplastics Feedstock Alliance, 2022). They state that it is important to diminish our dependance on fossil fuel, in exchange for a more sustainable plastic production and biobased products represents an opportunity for just that, but biobased plastics is not free of environmental impacts. While we all stay dependent on fossil fuels as long as nothing change - the change will not come without cost and responsible sourcing is key to realizing its true potential (Bioplastics Feedstock Alliance, 2015).

Feedstock stemming from food production pose immediate challenges that needs to be addressed. Environmental concerns related to production of crops challenge the sustainability of bioplastics. It is important to consider the impact biobased products has on people’s food security, land consumption, water use, animal feed, and how the use of pesticides affect the climate, workers, and its inhabitants (Bioplastics Feedstock Alliance, 2015; BIO-PLASTICS EUROPE, 2022).

According to the World Food Program (WFP) the world is in a food crisis, where 811 million people are going to bed hungry every night. The number of people that is facing food insecurity has doubled since 2019, from 135 million to 276 million people, while a total of 44 million people is at the brink of famine. The big drivers of hunger are conflict, climate shocks, economic consequences of COVID-19 and increasing costs of supplying food to those in need, due to an increase in food prices and delivery cost (World Food Programme, 2022).

When addressing the problems concerning bio-based plastic production and food security, it is therefore important to look beyond simply the threat of how the production is challenging amount of food that is being produced, but also consider how it is affecting peoples nutrition and diets, quality of food grown, availability, and whether they can afford food (Bioplastics Feedstock Alliance, 2015).

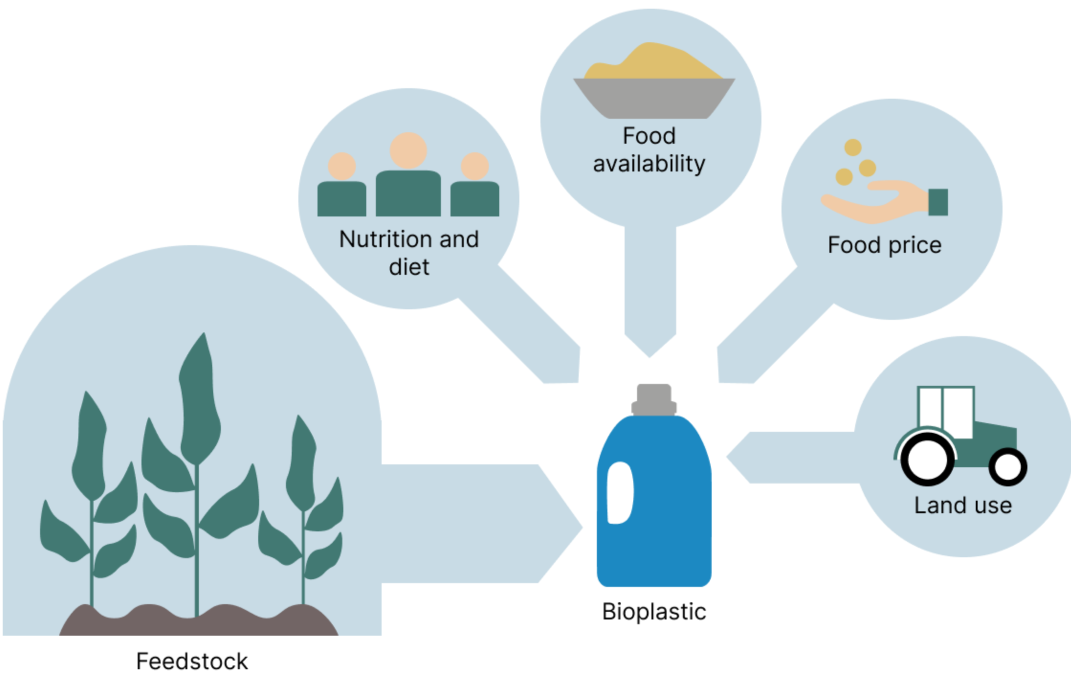


FIGURE 22. FEEDSTOCK

2.22.3 Application of bioplastics

For some industries, bioplastics have become a necessity, this is especially true in food packaging, agriculture, composite bags, and hygienic products. Bioplastic can also be commonly found in biomedical, structural, electrical consumer products including automotive applications and textile. Packaging is still the most common uses of bioplastics, with a special attention to biodegradable products (Ali Ashter, 2016, ss. 251 - 274). According to Bhagwat, et al. the production of bioplastics is expected to reach 2.62 million tons in 2023 (Bhagwat, et al., 2020). This number is less than what the interest organization "Europe Bioplastics" (not to be confused with the research program BIO-PLASTIC EUROPE) claims on their web page. They claim that bioplastics represent less than one percentage of the world's plastic production of more than 367 million tons annually, but bioplastic production will increase from 2.42 million tons in 2021 to its two percentage overall plastic production shares of 7.59 million tons in 2026. Their predictions can be seen in more detail in the following graph posed on their web page (European Bioplastics, 2022).

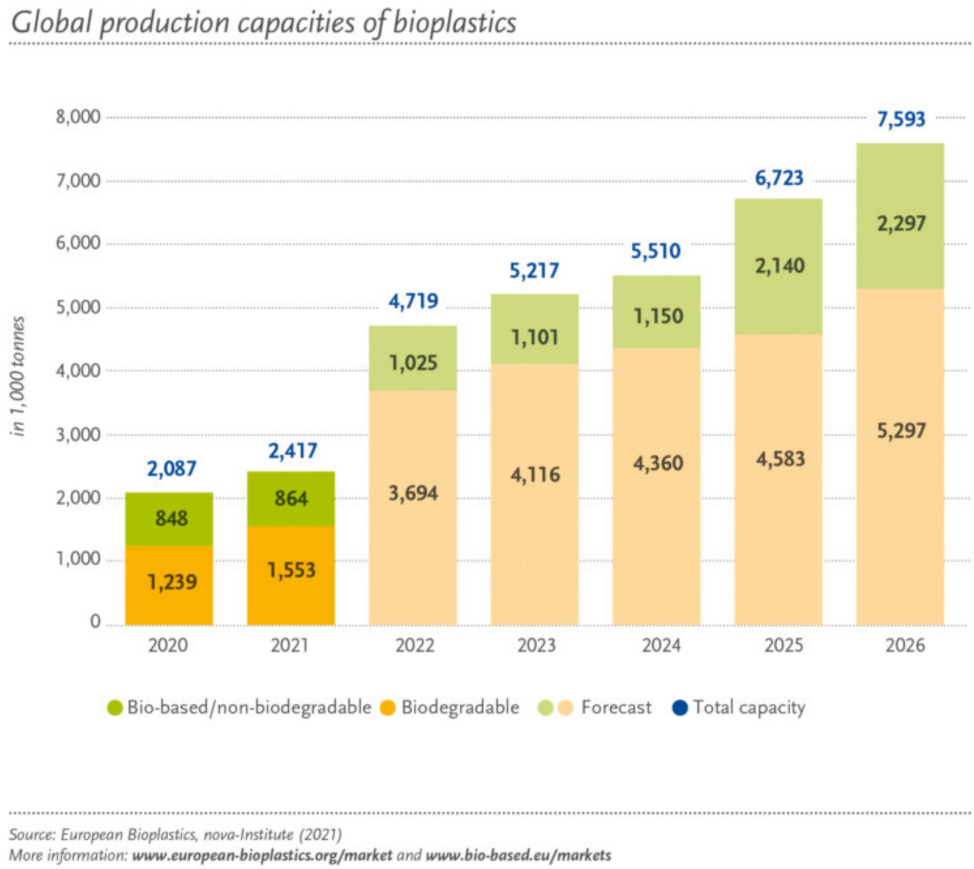


FIGURE 23. GRAPH GLOBAL PRODUCTION CAPACITES OF BIOPLASTIC, 2022, EUROPEAN BIOPLASTICS. HTTPS://WWW.EUROPEAN-BIOPLASTICS.ORG/MARKET/

From a greenhouse gas emissions and energy demand standpoint it may appear advantages compared to conventional fossil-based plastics. Furthermore, increasing global anti-waste movement, which often endorse the use of bioplastics as a full-fledged substitute to conventional plastics have given birth to a corporate promotional strategy where bioplastics are promoted as "greener" and more "environmentally friendly", some even claiming they are "fully biodegradable" or "100% compostable". The fact of the matter is that this type of promotional strategy can create a false sense of responsible behavior towards the environment. Just as conventional plastics, bioplastics have the potential to create a global environmental and social problem. In 2019 the bio-based plastic production inhibited about 0.016% (0.79 million hectare) of the global agricultural land. With increasing use of bio-based products and new innovative bio-based plastics entering the market, the land consumption is expected to increase to 0.021% (1 million hectare) by 2024. These numbers may seem low, but the increasing demand for bioplastics can certainly put additional pressure on limited resources, like water and arable land, while threatening food security and the environment. It is necessary to find an alternative to large scale bioplastic production to support the growing demand without creating further implications (Bhagwat, et al., 2020). The interest group "European Bioplastics" disagree when it comes the question of competition between food production and bioplastic feedstock production. According to their predictions the bioplastic feedstock production will not exceed 0.06 percentage of land use shares – and therefore argue that it will not be in competition with food production (European Bioplastics, 2022).
However, a common public perception is that growing food crops for non-food related purposes can cause food insecurity, because growing non-food crops for non-food purposes can have the same effect on food security due to land use. The land use efficiency is a measurement of how much land is needed for a crop versus yield. The land use efficiency is a critical measurement, which affects not only the food security but also the eco system and biodiversity. An example of different land use efficiency is the amount of land it would take to produce 100 tons of bioplastic Polylactic Acid (PLA) made from corn versus bio-polyamide bioplastic made from castor oil plants: where the PLA production will only require 37 Hectare, the bio-polyamide bioplastic will require 588 Hectare. It is worth mentioning that the two materials mentioned in the example is generally used for different purposes, but is douse illustrate how land use efficiency can affect the landscape. Furthermore, because of the complexity of the issues concerning bioplastic feedstock, one cannot rely solely on whether the feedstock is a food or a non-food crop, or the generation designation to predict the effects the said feedstock will have on food security and environment. Each feedstock needs to be assessed based on their regional impact, advantages, and trade-offs (Bioplastics Feedstock Alliance, 2015).

2.23 Summarizing the findings from the discussion

The discussion chapter has discussed topics, circular economy, single use versus reusable packaging and the physical internet, the necessity of plastics in packaging and the use of bioplastics. From the section about circular economy, it is established that packaging has a great impact on the environmental performance of the packaged food product. Packaging can protect the food product, preserve the quality and safety, while at the same time extend the shelf life. An extended shelf life can not only prevent food waste but will also reduce the likelihood of unnecessarily burdening the environment by losing the packaging as well. Designing packaging is a complex task that require a holistic overview of the entire lifecycle of the product.

In the sections discussing the difference between one-way single use and reusable packaging, and the physical internet, emphasizes the advantages of a reusable packaging system. A reusable system can drastically reduce the amount of packaging waste and the strain in the waste management system. A reusable packaging system will also reduce the need for packaging material and energy for packaging production. The physical internet is an advanced reusable packaging system which relies on shared assets. In the physical internet the packaging is standardized, information moves through a shared platform, and the efficiency of each transportation between shared hubs is maximized trough shared transportation of goods. It is expected that an advanced pilot implementation of the physical internet will be operational and common industry practice by 2030.

In the section about the necessity of plastics we learn that packaging is the biggest consumer of plastics, virgin material is excessively used, and a substantial part of packaging is single use. It is argued that plastic packaging has some unique advantages toward preventing food waste, and blindly banning plastic packaging is not the answer. It is however important to redesign unnecessary plastic packaging to reduce the environmental impact of plastics. Packaging is particularly important in fish because it is a highly perishable product. Propper packaging is therefore a crucial to reduce food waste. There are however available alternatives to the single use EPS fish boxes, and they should be the favoured solution.

In the section discussing bioplastic packaging it is highlighted that bioplastic is actually a unprecise and misleading term, and we should instead categorise bioplastics as ether bio-based or biodegradable. The term biodegradable can be misleading because it does not refer to any specific timeframe or environmental conditions where the material is supposed to naturally degrade. Biodegradable plastics may require industrial composting and highly dependent on having the right the conditions. Biodegradable plastics may also cause problems in composting facilities and contaminate recycling.

Bio-based plastics can be categorized into two categories, novel and drop in plastics. While the novel plastics has a unique chemical structure, the drop in plastics has an identical chemical structure to its fossil-based counterpart. Drop in plastics can therefore take advantage of the already existing recycling system.

Responsible sourcing of bioplastic feedstock is important. The impact on food security, land consumption, water use, animal feed, and how the production of bioplastic feedstock affects the climate, workers and inhabitants needs to be considered. Even non-food crops can affect food security. Feedstock therefore needs to be assessed based on its regional impact, advantages and trade-offs.

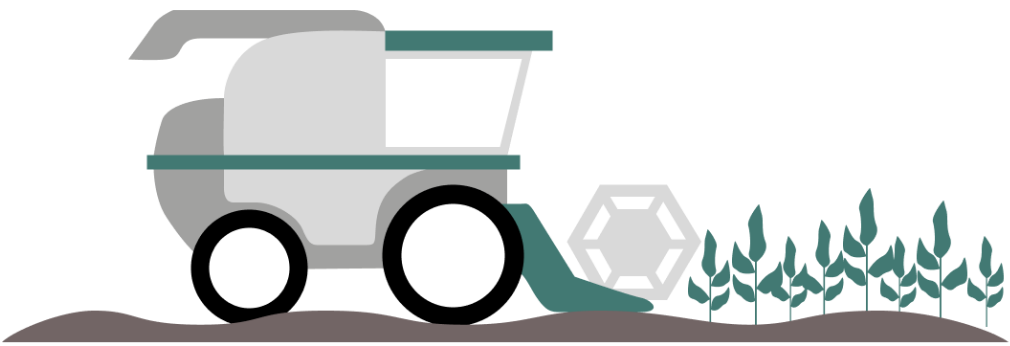


FIGURE 24. HARVESTER

PART 3. CONCEPT DEVELOPMENT:

FIGURE 25. DESIGNER

3.1 Must have functions and requirements

Based on the information provided in this project a list of 11 must have functions and requirements have been made to evaluate the following concepts.

1. ***Reusable:*** in the section "discussing the necessity of plastics" it is uncovered that unnecessary single use plastics should be avoided, furthermore, reusable packaging can limit the amount of plastic waste. A reusable packaging in a shared asset system will ensure that the packaging ends up in a system that truly reuse. It is also in accordance with the upcoming implementation of the "physical internet" and other similar shared asset systems which was discussed in the section "one way or reusable packaging".
2. ***Multipurpose:*** to make the fish box able to function in a shared asset environment like the physical internet the boxes needs to be standardized and multipurpose to be able to carry different chilled food items. A multipurpose box will increase the utilization in a shared asset system.
3. ***Easy carrying and handling:*** to facilitate safe handling in all steps of the supply chain.
4. ***Light weight:*** to decrease the transport mass and ease handling.
5. ***Washable:*** to enable reuse.
6. ***Insulating abilities:*** to retain desired fish temperature when exposed to fluctuating temperatures. Not more than EPS, because it may hinder proper cooling in the cold chain.
7. ***Leakproof:*** to avoid dangerous and illegal leakage onto public roads.
8. ***Have a lid and a function that secures the lid:*** to facilitate transportation, handling, and deliverables to end costumers.
9. ***Branding:*** to provide information about the box, delivery, and content. Should be in accordance with European standards and agreements within the sheard asset systems wherein it operates. Electronic system must also allow for transparency and data sharing.
10. ***Standardized unit size and stacking method:*** in accordance with the European standards and agreements within the sheard asset systems wherein it operates - to maximize the utilization of space during transit.
11. ***Mono material:*** to accommodate easier recycling and remanufacturing with no need for separation of materials

3.2 Choosing a production method

There are many possible production methods that can lead to a similar result, however reciting all possible solutions would not be beneficial to this project. The main goal of this project is to explore the environmental challenges within industrial packaging design and the fish farming industry rather than evaluating all possible production methods. Instead, there has been chosen two common production methods previously used to produce insulated products, and both capable of producing insulated boxes in a single mould. The purpose of this is to exemplify what a solution could look like and take the theoretical background and discussions into practise. The proposed solution should be considered in conjunction with the system in which it is going to operate in, where there are room for multiple solutions.

The two following solutions represent manufacturing techniques that could make packaging that fulfill the requirements of reusability, lightweight and insulation. As established in the section "discussing the necessity for plastics" reusable systems are the favorable solution towards limiting unnecessary single use plastics, the material does however have properties which will be beneficial in a reusable shared asset system and allow for a long service life. The packaging will therefore be made from plastics.

3.2.1 Production method number 1: Structural foam injection moulding

A structural foam refers to an injection molded component with a cellular core, in a structural foam the outer surface is denser than the core. This type of mold has a higher stiffness ratio than compact molds. There are two ways of producing structural foam. The recommended method is to use a purposely made injection mould machine, because this method will deliver the most consistent quality mouldings. This process is performed under low pressure, the machine will inject gas into the melted plastic. The plastic will then be injected into a mould. The second way of producing structural foam is to use a conventional moulding machine and add a blowing agent into the material. The plastic injected into a mould, where the heat from the melted plastic will cause a reaction which forms a gas. The gas expands the plastic, resulting in a moulded component. Structural injection moulds will have a slightly rougher surface finish than other moulds, but it can be treated with fillings and paint if the surface finish is not acceptable. The purposely made machines has the ability to create larger parts and thicker walls (5 - 15 mm) than the compact non-structural injection moulds. Almost all thermoplastics can be structurally moulded, typically used materials are acrylonitrile butadiene styrene (ABS), polystyrene (PS), polycarbonate (PC), polypropylene (PP), and polyvinyl chloride (PCV) (British Plastics Federation, 2022).

There are advantages when using thermoplastic foams, they are lightweight, energy absorbent, high specific strength, and good sound and thermal isolation. Thermoplastic foams are widely used in automotive, packaging and aeronautics. For the automotive and aeronautical industry lightening components which in turn reduces the transport mass using composite structures and structural foams is an effective way of reducing emissions. As well as lightening components, replacing fossil-based plastics with bio-based plastics may also reduce the environmental footprint (Ykhlef & Lafranche, 2020). Lower cavity fill pressure when structural foam moulding, results in a lower tooling cost than conventional injection moulding. The moulding tools are cheaper because the low cavity fill pressure allows for lighter grade materials like cast aluminium and cast steal to be used to make the moulding tools (British Plastics Federation, 2022).

3.2.2 Production method number 2: Rotational moulding

Rotational moulding is an ideal process for producing hollow parts and almost any shape can be produced with almost no limit on the size of the mould. The moulding process involves the following stages, in the first stage a hollow mould is filled with powdered plastic resin. Secondly, the mould starts rating in a two-axis motion while it is being transferred into an oven. Third, the mould keeps rotating while the plastic resin melts and coats the walls inside the mould. Lastly, the mould is moved out from the oven and cooled. When the moulded part has hardened into its desired shape the rotation can stop and the finished part can be removed from the mould. In this process plastic powder is used instead of granulated plastic. For the majority of the moulds PE is used as the plastic resin, because it is a readily available polymer, easy to grind and has low chemical degradation when it is exposed to high temperatures. Because this is a low-pressure process, the tooling cost is relatively low because the mould can be made from low-cost materials. Short production runs of less than 3000 units annually can therefore be made in a relatively economical manner (British Plastics Federation, 2022; Gemini Group, 2022). Rotational moulding is very versatile and can produce a range of different products, some common products include environmental products, automotive products, boats, outdoor products, toys and playground equipment, tanks, containers, crates, pallets, and even insulated fish and cooler boxes (British Plastics Federation, 2022).

According to the supplier of engineered plastic components and metal tooling solutions “Gemini group”, There are advantages and disadvantages with rotational moulding. Unlike thermoforming and blow moulding, there are no pinch- off seams or welds, giving it high durability. Foams can be added to the part for additional thermal insulation and stiffens. Fine detail finishes like textures and logos, symbols and letters can be easily added. This method results in a consistent wall thickness with high stability which reduces the risk of defects and strength. Some of the drawbacks are high output times, the limited material options because the powder used must have a high thermal stability which in turn limits the material options to poly-based resins, this also adds additional raw material cost, and the cost of required additives (Gemini Group, 2022).

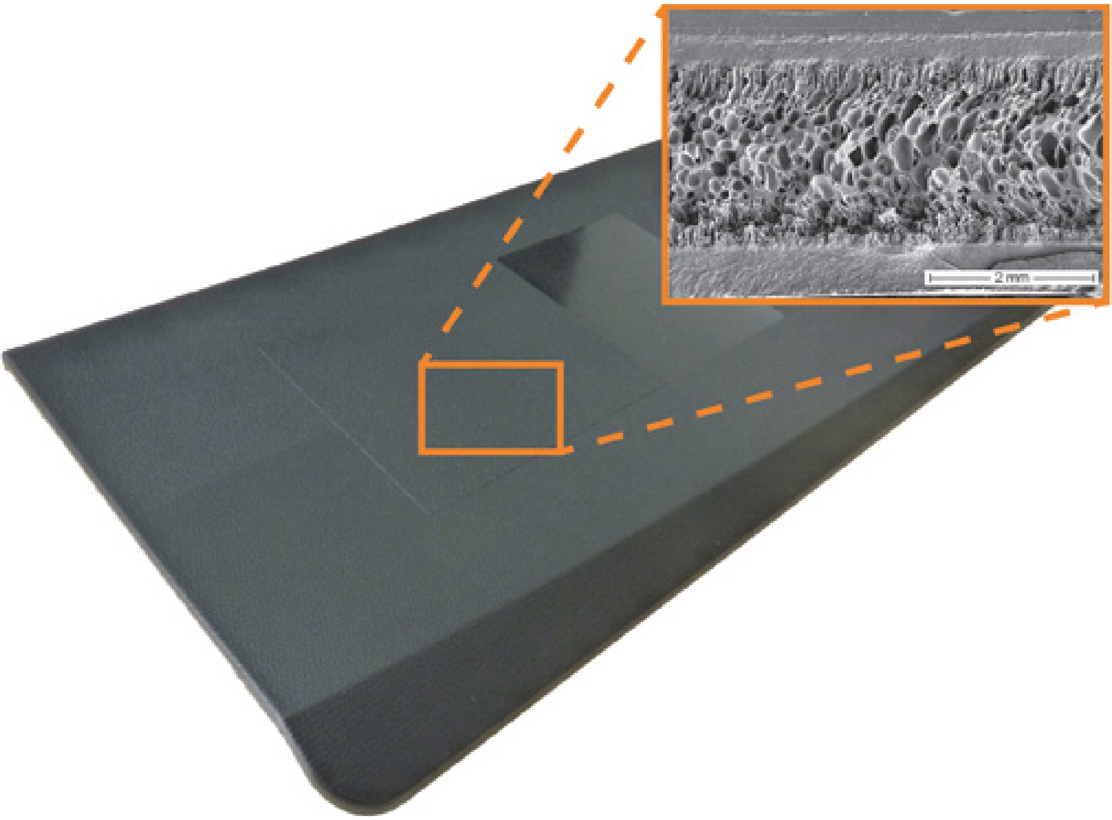


FIGURE 26. STRUCTURAL FOAM INJECTION MOULDED PART, 2022, NEUE MATERIALIEN BAYREUTH GMBH. HTTPS://WWW.NMBGMBH.DE/EN/MATERIALS/INTEGRAL-FOAMS/

FIGURE 27. ROTATIONAL MOULDED PART WITH FOAM FILLING, 2022, GREGSTROM CORPORATION. HTTP://GREGSTROM.COM/ROTATIONAL-MOLDING/

3.2.3 Choosing a production method, comparing structural foam moulding and rotational moulding

As for comparison to structural foam, according to the structural foam moulder "DeKALB Molded Pastics", both techniques can be used to produce large parts. However, there are some benefits when switching to structural foam moulding like; increased material options, higher production range, reduction in production time and more precision wall thickness (DeKALB Molded Plastics, 2022). According to a case study cared out buy the company "Horizon Plastics International" when they replaced rotational moulding in favour of structural foam moulding to produce a heavy-duty tote box, they also managed to increase the throughout, lower the tooling costs while also increasing part performance (Horizon Plastics Iinternational, 2019). Considering the limitations in production capacity and material options in rotational moulding. Also considering the need for additional foaming and separation of materials before recycling rotational moulded parts, which do not fulfil requirement 11 in the "Must have functions and requirements". Structural foams semes to be the favourable production method for this product.

	Structural foam moulding	Rotational moulding
Tooling cost	Low tooling cost because tools can be made from lighter grade materials.	Low tooling cost because tools can be made from lighter grade materials.
Mono material	Yes.	Not necessarily the same when foamed.
Thermal abilities	Foam structure provide thermal abilities.	Need to be added with foam.
Surface finish	Rougher surface finish than rotational moulding.	Finer surface finish than structural foam.
Material options	Compatible with many plastics.	Limited number of plastics.
Production rate	Faster than rotational moulding.	Slower than structural foam.
Precision of wall thickness	Greater than rotational moulding.	Lower than structural foam.

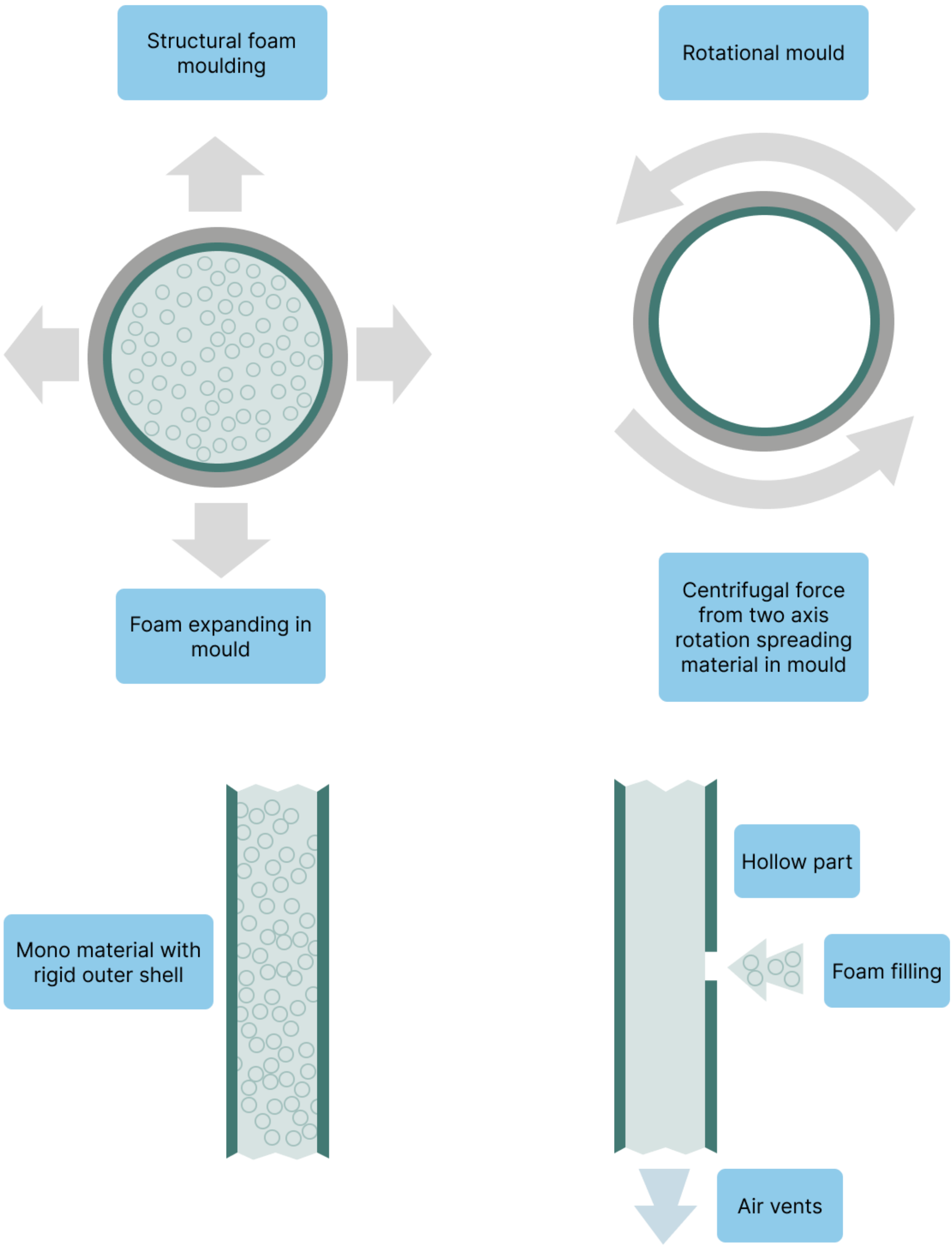


FIGURE 28. STRUCTURAL FOAM VS. ROTATIONAL MOULD

3.3 Choosing a material

3.3.1 Comparing bioplastics and fossil-based plastics

The following table summarize and compares bioplastic with fossil-based plastic based on the information previously provided.

	Pros	Cons
Bioplastic	Bio-degradable plastic: • May be industrially composted. • Possible environmental gains compared to fossil-based plastics during production.	Bio-degradable plastic: • Biodegradability is dependent on the environment. • Debatable standards. • Do not biodegrade in the environment, can be misleading. • Can cause contamination in recycling plants.
	Bio-based plastic: • Made from sustainable sources. • Drop-in plastics in existing manufacturing and recycling. • Possible environmental gains compared to fossil-based plastics during production.	Bio-based plastic: • Not enough recycling worldwide. • Feedstock can threaten: Food security, biodiversity, water availability and land use. • No standards. • Currently no widespread recycling facilities for novel plastics.
Conventional fossil-based plastic	• Cheap and widely available. • Established recycling facilities.	• Not enough recycling worldwide. • Cause of large amount of waste and pollution. • A lot of single use unnecessary fossil based plastic products. • Do not biodegrade. • Dependent on scarce resources, petroleum. • Public attention towards getting rid of fossil-based plastics.

3.3.2 Comparing bioplastics

The following table contains information about the most common bio-based and biodegradable plastics. Information about the listed materials are derived from the "European bioplastics" list of most common bioplastics (European Bioplastics, 2022), and compared with the list of most common bioplastics from the "Norwegian Environmental agency" (Miljødirektoratet, 2019):

Biobased	Recycling	Biodegradability	Typical biobased carbon content	Other information
Bio-PET	Drop in plastic.	No.	20-30%	Ongoing reserch on 100% bio-PET.
Bio-PE	Drop in plastic.	No.	100%	
PEF	Not commonly recycled.	No.	100%	Alternative to Bio-PET.
Bio-PP	Drop in plastic.	No.	30%	
Bio-PA	Drop-in plastic.	No.	30-100%	Widley used in textiles and engineering.
PTT	Drop in plastic.	No.	37%	Used in fibres for textiles and carpets.
Biodegradable				
PLA	Not commonly recycled.	Industrial composting.	100%	Low cost compared to other bioplastics.
PHAs (incl. PHB, PHV, PHH)	Not commonly recycled.	Completely biodegradable, fit for industrial and home composting.	100%	
Starch Blends	Not commonly recycled.	Wide variety of biodegradability grades.	25-100%	Includes different types of plastics.
PBS and PBSA	Not commonly recycled.	Home and industrial composting.	0-20%	Can be made from both 100% biobased material and fossil based.
	Not commonly recycled.	Industrial composting.	0-50%	Fossil based plastic.

3.3.3 Choosing a material, comparing bioplastic and fossil based plastic

Based on the information so far provided about the possible environmental gains of bioplastics in the event of a sustainable sourcing of feedstock, the recommendation from the “Green Warriors of Norway” to replace fossil-based plastics and considering the reduced need for constant production of new fish boxes due to reuse. Which will therefore reduce the need for new plastic material which could otherwise put a strain on scares resources - it is concluded that for this application it will be appropriate to favor bioplastic over conventional fossil-based plastics, where drop in plastics should be favored. The advantages of using drop in plastics are, the possibility of recycling the plastic material in the same recycling stream as it’s petroleum-based counterpart, this enables the possibility to mix the two recycled plastics to make new fish boxes when using drop in plastics.

3.4 Description of the reusable fish box

According to the environmental product declaration owned by “EPS foreningen” and published by “The Norwegian EPD federation” declaration number: NEPD-1924-793-EN, the dimensions of fish boxes are standardized in the industry. The 20kg box is the box that best represents the typical fish box for Norwegian fish export. The standard dimensions for a 20 kg fish box measured in mm is 800x400x195 (220 whit the lid on) and the thickness is 25 to 28 mm. Fully loaded the box can hold 22,5 kg of fish packed with 5 kg ice (EPS-foreningen, 2019).

There are requirements towards packaging and labelling of fish and fish products in Norwegian law in the regulations on the quality of fish and fish products, 2013, booklet 11 (Forskrift om kvalitet på fisk og fiskevarer, 2013, hefte 11). In chapter X we find the requirements for packaging and labelling of fish and fish products (Kapittel X. Krav til emballasje og merking av fisk og fiskevarer, §§ 28 - 35). In § 28 we find the general requirements for packaging (§ 28. Generelle krav til emballasje):

«Emballasjen skal være framstilt av materialer med tilstrekkelig mekanisk styrke, ha glatt overflate og slik utforming at den effektivt beskytter varen og sikrer dens kvalitet under normale transport- og oppbevaringsforhold» (Lovdata, 2022).

There is no official English translation of the regulation, but informally translated, the regulation can be interpreted to express that the packaging has to be made from a material that has sufficiently mechanical strength, has a smooth surface and a design that effectively protects the content and ensures its quality under normal transport and storage conditions (Lovdata, 2022).

The reusable fish box design developed for his thesis has been designed to mimic the industry standard 20 kg fish box in shape and properties. The reasoning is that it will then be able to comply with industry standards while at the same time covering the industry needs.

The European standard NS-EN 17099:2020 is to date the valid standard for labelling of distribution units like fish boxes, cartons and bags for fishery and aquaculture product trade in Europe. The standard also includes labelling standards for logistics units like pallets, cages and trolleys. According to what is written in the standard itself, the reasoning for the implementation of such standard is to ensure that the information regarding traceability is correct and available through the whole supply chain, both nationally and internationally. Introduction of such labels will also increase trust in the origin and quality of the product, improve food safety and the supply. It is further claimed in the standard that, standardised labelling will improve the quality and availability of traceability data, as well as supporting interoperability between different information systems. Furthermore, the improved traceability will prevent the trade of illegal, unreported, and unregulated fishery products. The standard includes a description of the label design. The examples of label design included in the standard are based on a sample label size for logistical units with the dimensions, length 105 mm and hight 148 mm. These dimensions are not mandatory (although there are restrictions concerning seatrain parts of the label) and may be different from the ones printed on the actual distribution unit because they may be determined by the size of the distribution unit and the available space for print. The dimensions may also be determined by the available printing system and the need for additional data. According to the standard the label should be printed on the short side of the distribution unit and as to be attached in such a way that it stays on as long as the label is needed. If the label cannot be attached to the short side, it should then be attached in a way that enables easy scanning and reading of texts (Standard Norge, 2020).

The fish box needed a bright colour that would differentiate itself from the single use EPS fish boxes and enhance the impression that is a reusable box. Yellow was chosen for this design, but it is not the only colour that would fit the requirements and may be changed in the future if needed.

3.5 Exploratory design process

3.5.1 Idea sketching of stacking system and handle

I made drawing explore different stacking methods and handle for griping the fish box. In these drawings I was looking for a solution that allowed for box on lid stacking, box on box stacking, lid on lid stacking, as box on pallet stacking. the boxes must therefore be able to stack directly on top of each other and turned at a 90-degree angle for pallet stacking (se correct stacking method in the section “Plane, truck and sea transport and standards” in part 2 chapter 1). Drawing is a great way to generate new ideas and explore different stacking options. Because the stacking system is a complex part of the fish box, it way very helpful for me to make drawing so I could visualize and plan further 3D modelling work. There were also multiple options for the handles, but I wanted to maintain a single tooling direction in the moulding process to ease the complexity of the moulding tool.

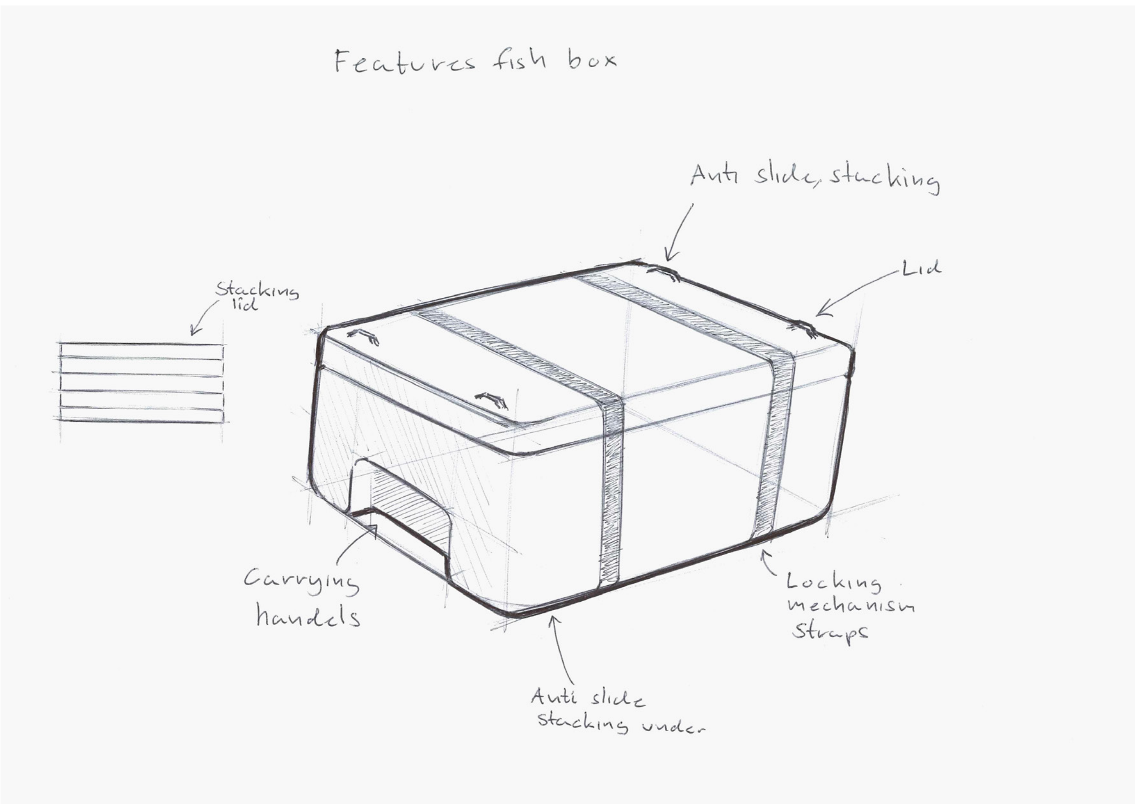


FIGURE 29. DRAWING OF FISH BOX

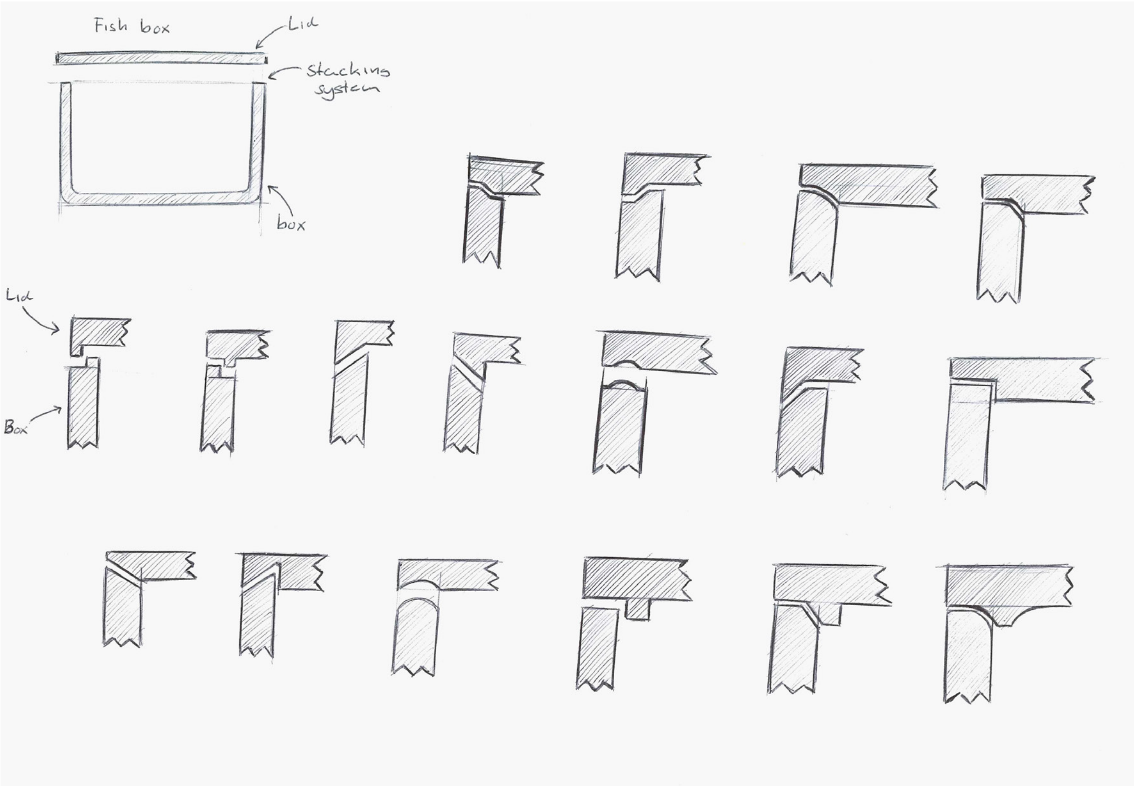


FIGURE 30. DRAWING SHEET 1- STACKING SYSTEM

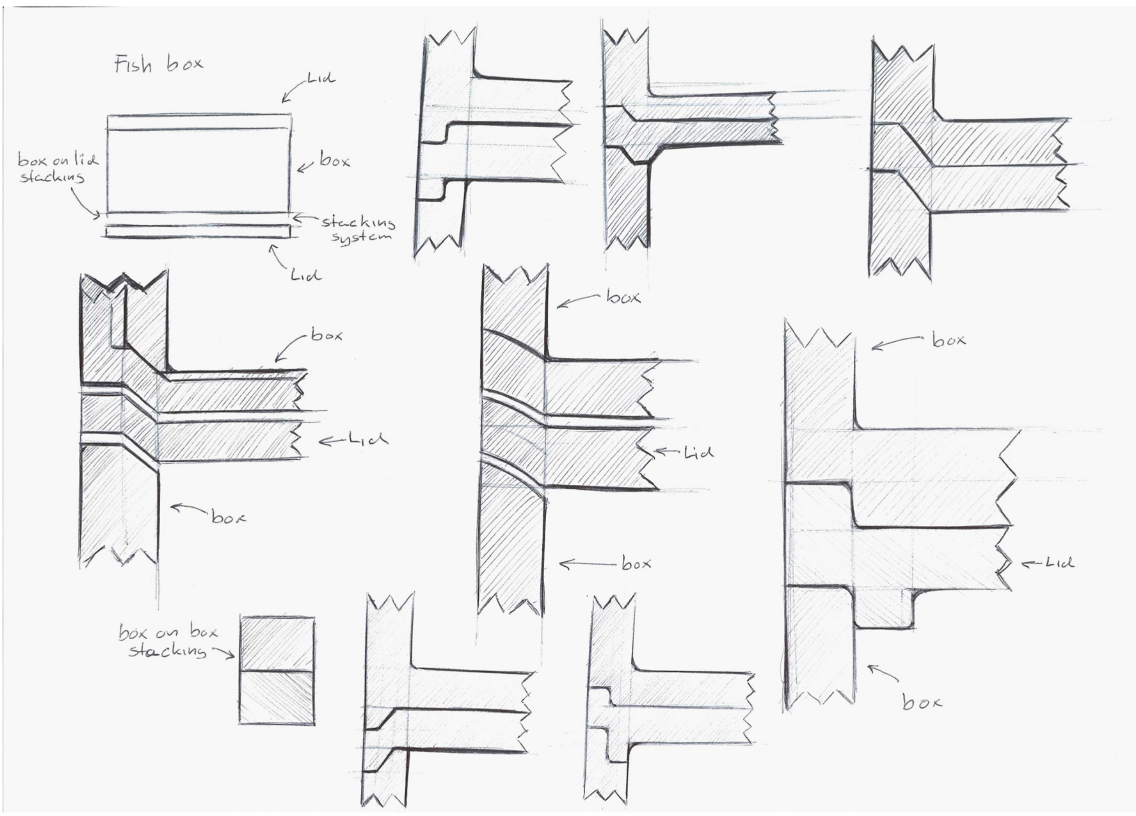


FIGURE 31. DRAWING SHEET 2- STACKING SYSTEM

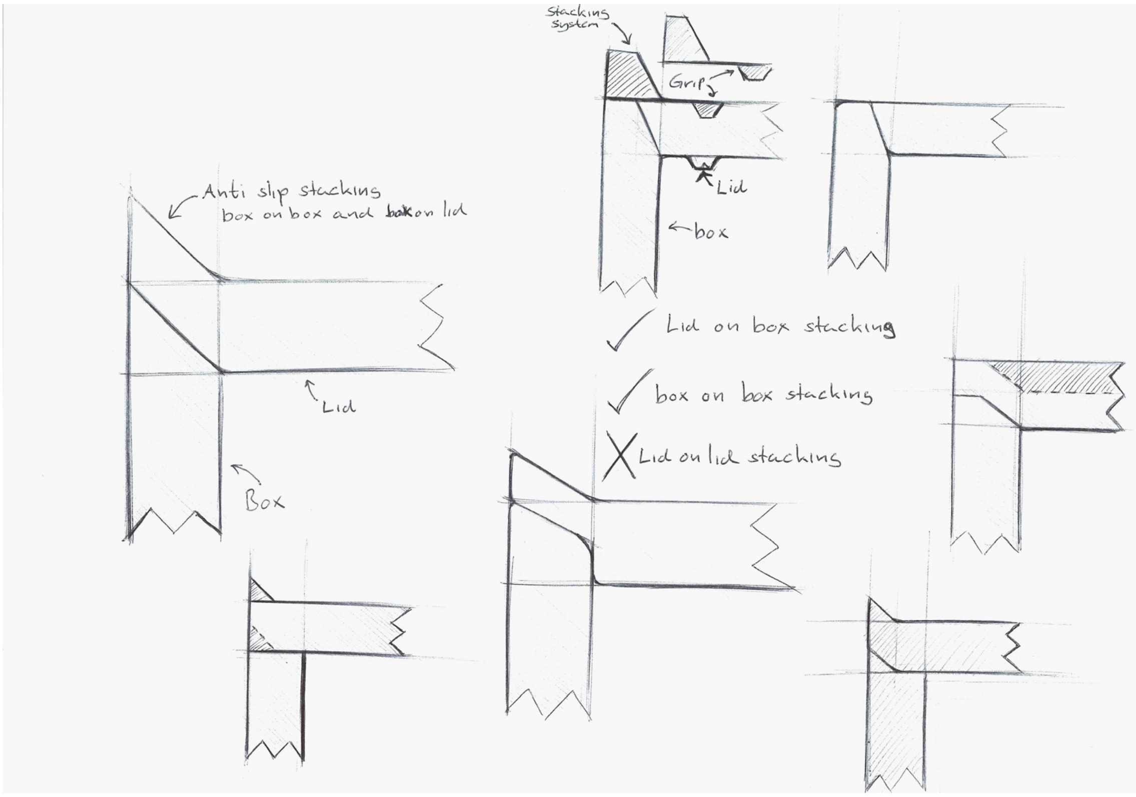


FIGURE 32. DRAWING SHEET 3- STACKING SYSTEM

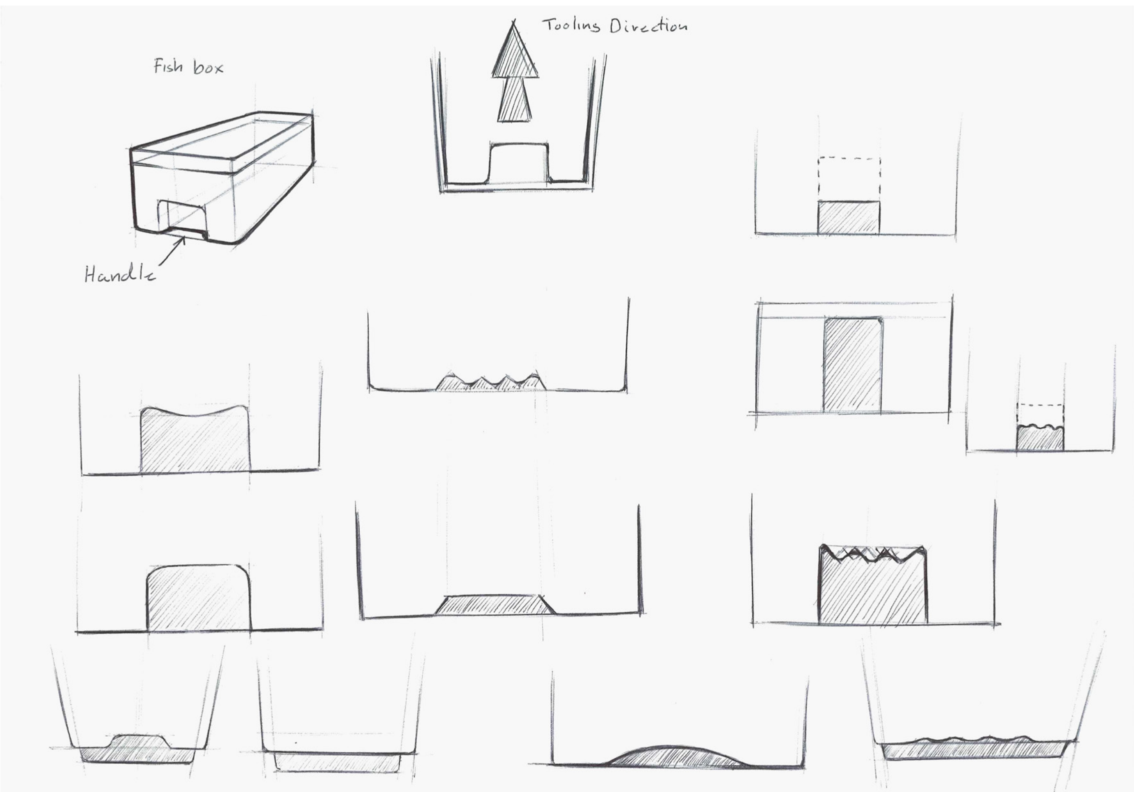


FIGURE 33. DRAWING SHEET 4- HANDLE

3.5.2 First iteration of 3D model

I decided to discard the first iteration of the 3D model because on closer inspection in Autodesk Fusion 360, I noticed that the box was higher than the standard dimensions of fish boxes. This was not my intention, as I feared it would affect the space requirements for each box. I later noticed that the box would not be able to stack the fish boxes on pallets according to industry standard practise because of the way the stacking system was composed. I decided to redo the staking system to lower the overall hight of the box down to the industry standard hight and enable pallet stacking.

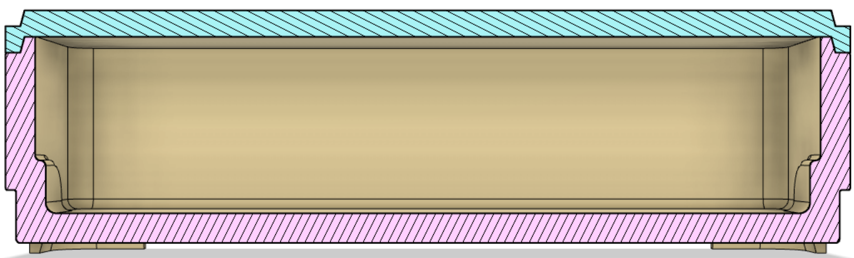


FIGURE 34. 3D MODEL- ITERATION 1 SLICE

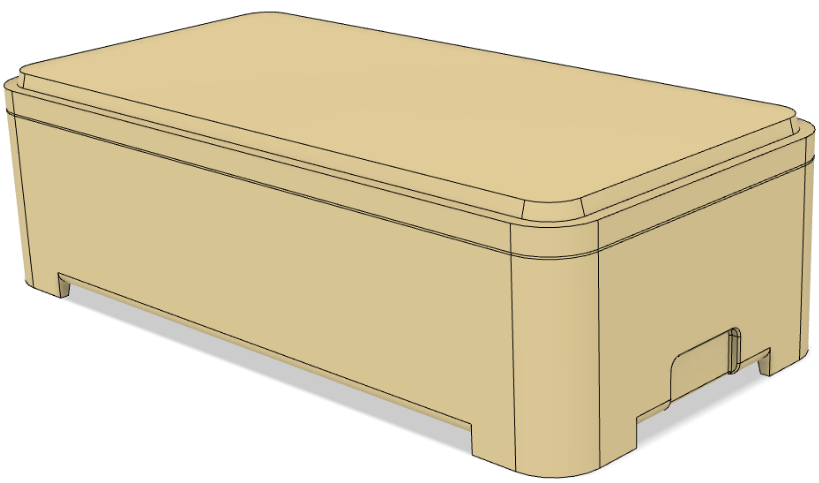


FIGURE 35. 3D MODEL- ITERATION 1

3.5.3 Second iteration of 3D model

In the second iteration of the 3D model, I have included a new stacking system. This design is the same hight as the industry standard fish box and allows for pallet stacking. There was also added groves to ensure that the straps would not move out of place. I was still not happy with the floor of the fish box because it now had a long grove stretching across the floor. My concern was that this groove would affect the thermal abilities of the box and lower the strength.

FIGURE 36. 3D MODEL- ITERATION 2 FLOOR VIEW

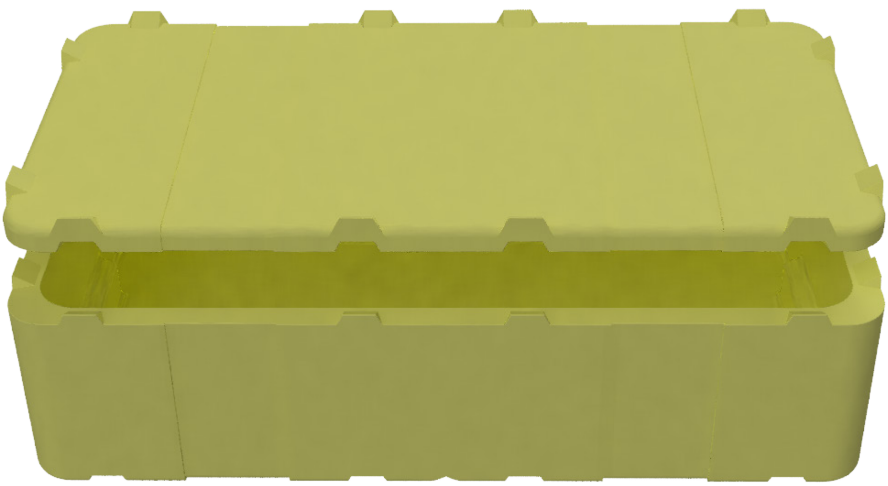


FIGURE 37. 3D MODEL- ITERATION 2 TOP VIEW

3.5.4 Third iteration of 3D model

In the third iteration I have explored labelling of the fish box. The glued-on label on the right is sourced from EU standard for labelling of fish boxes (Standard Norge, 2020). Furthermore, I explored the possibility of including a standardized system for registration numbers and QR codes to track the ownership of the box within the sheard asset system. The QR code enable the reader to gain information about box, like number of uses and its abilities. I noticed that I needed separate registration numbers for boxes and lids. In this model there was only a registration number on the box, which would mean that they would have to be paired. I feared this would be a difficult logistical task and problematic if only one part gets damage and has to be remanufactured – resulting in both parts would have to be remanufactured. Pairing of boxes and lid would also make it difficult to transport goods using box on box stacking if that would be desirable.

FIGURE 38. 3D MODEL- ITEWRATION 3

3.5.5 Exploration of stacking system using 3D-print

I wanted to explore the staking system in further detail, so I decided to 3D-print small piece of the lid and box both top and bottom corner. I only printed small pieces because the fish box it to big for the 3D printer and I wanted to explore multiple solutions. The pieces are stacked in the following order: In the bottom is a piece from upper part of the wall, in the middle is a piece of the lid and on top is a piece of the floor. The pieces are stacked to simulate how they would be stacked on a pallet.

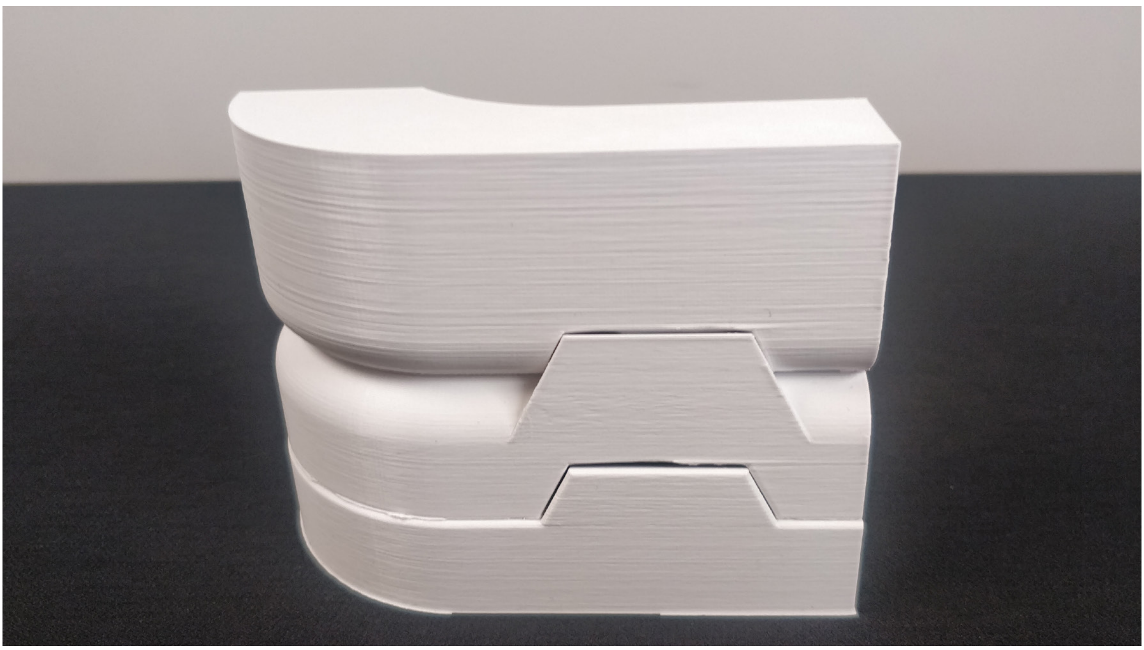


FIGURE 39. 3D PRINTED PARTS STACKED ON TOP OF EACH OTHER

3.5.6 Exploration of stacking system using 3D print part 2

I wanted to explore if I could improve the stability of the stacking system by increasing the thickness on the inside if the lid from 25 mm to 28 mm, still within the range of standardized thickness of fish boxes.

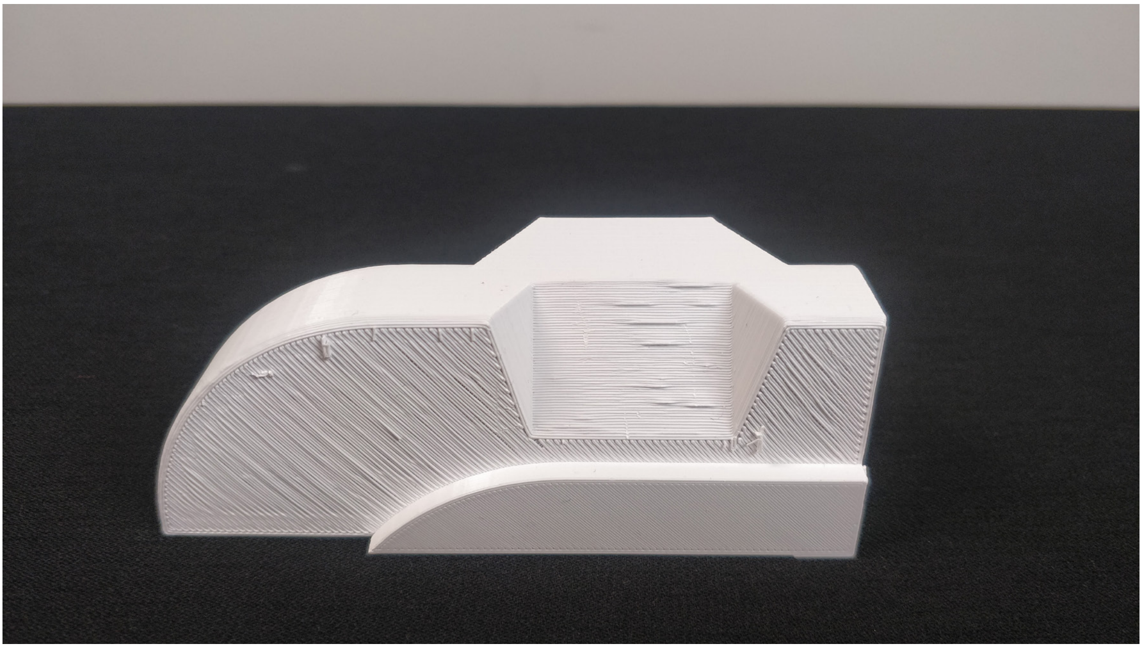


FIGURE 40. 3D PRINTED PIECE OF FISH BOX LID

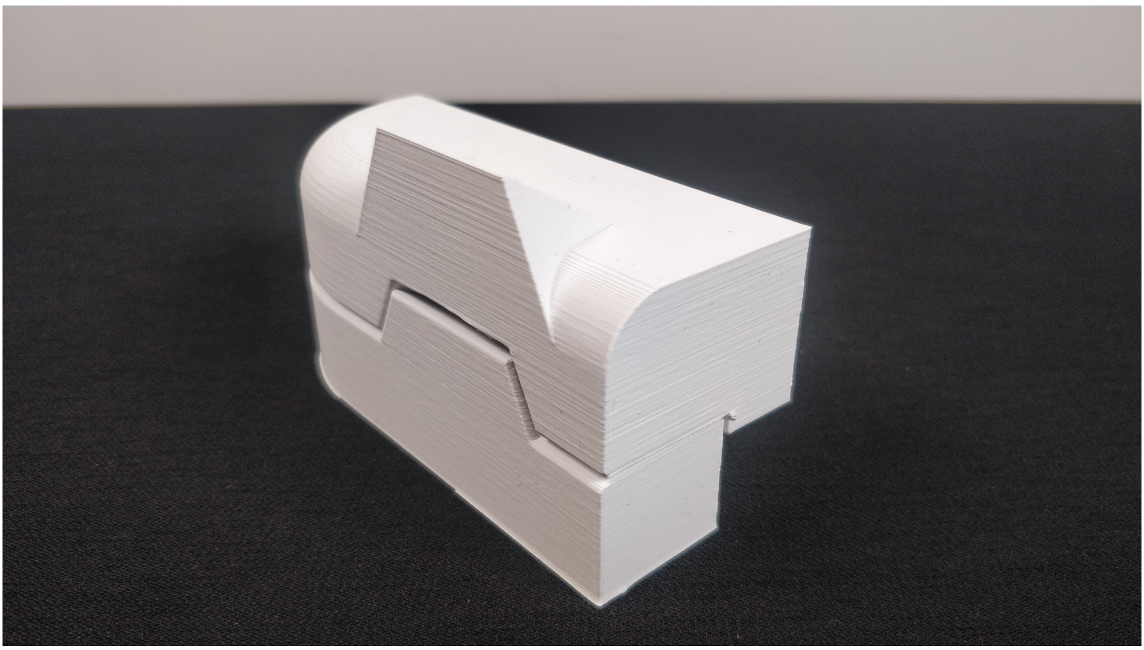


FIGURE 41. 3D PRINTED PIECES OF LID AND BOX STACKED ON TOP OF EACH OTHER

3.5.7 Exploration of stacking system using 3D print part 3

I change the shape of the staking system by adding a “brick” on the already existing system to see if that would affect the stability of the stacking system. The system reduced the movement of the lid, but it did not create the results I was looking for. I was more pleased with the result from 3D print 2.

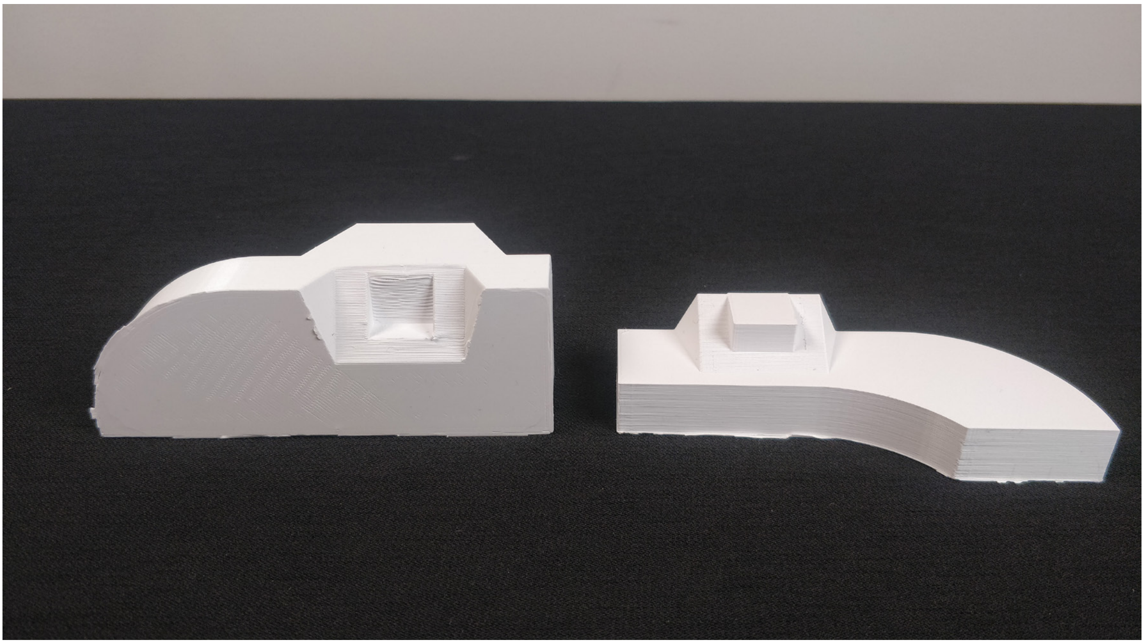


FIGURE 42. 3D PRINTED STACKING SYSTEM PART 3

3.5.8 Exploration of stacking system using 3D print part 4

I added larger fillets to the stacking system to change its appearance because I was not happy with how the sharp corners looked. I wanted the fish box to appear like a rigid product. I also added fillets on all sharp corners. The fillets are necessary for injection moulding in the finished product.

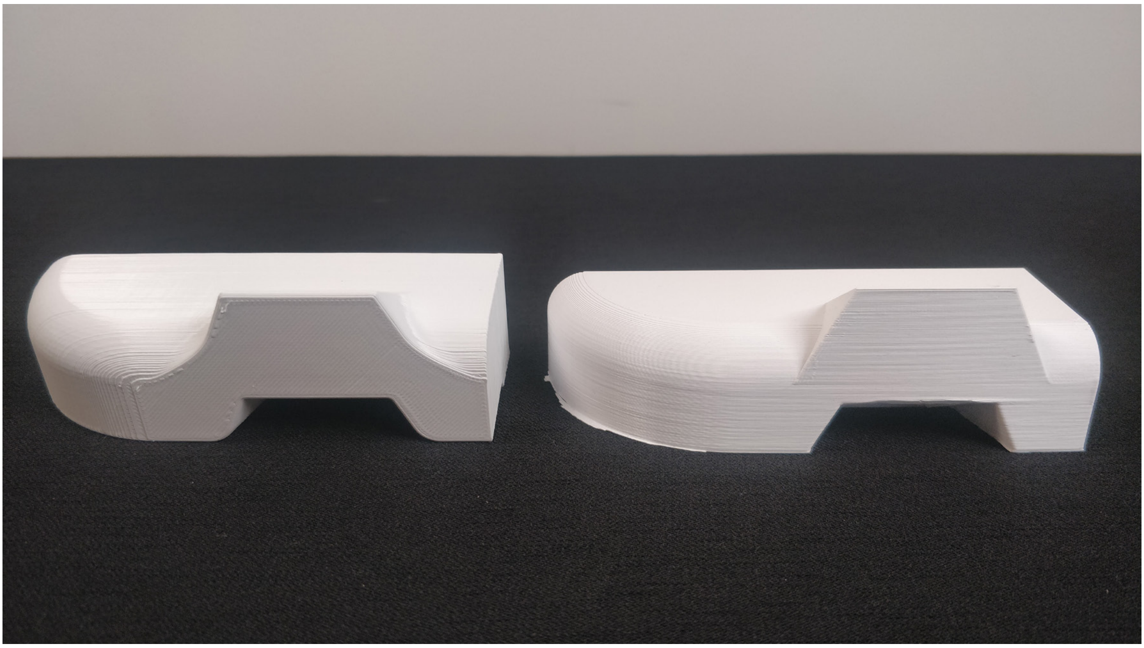


FIGURE 43. 3D PRINTED PIECES WITH ROUNDED EDGES

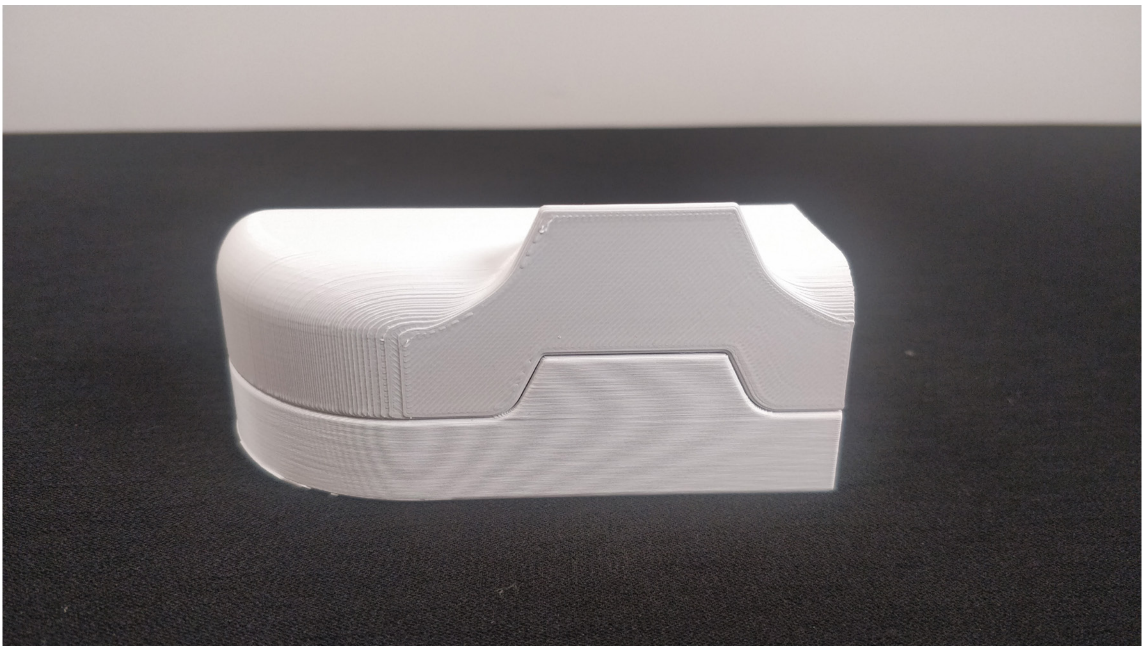


FIGURE 44. 3D PRINTED PIECES WITH ROUNDED EDGES STACKED

3.5.9 Exploration of stacking system using 3D print part 5

Because of the added thickness of the lid in 3D print 2, the lid no longer stacked properly on top of other lids. To correct this, I added a similar indent on top of the lid.

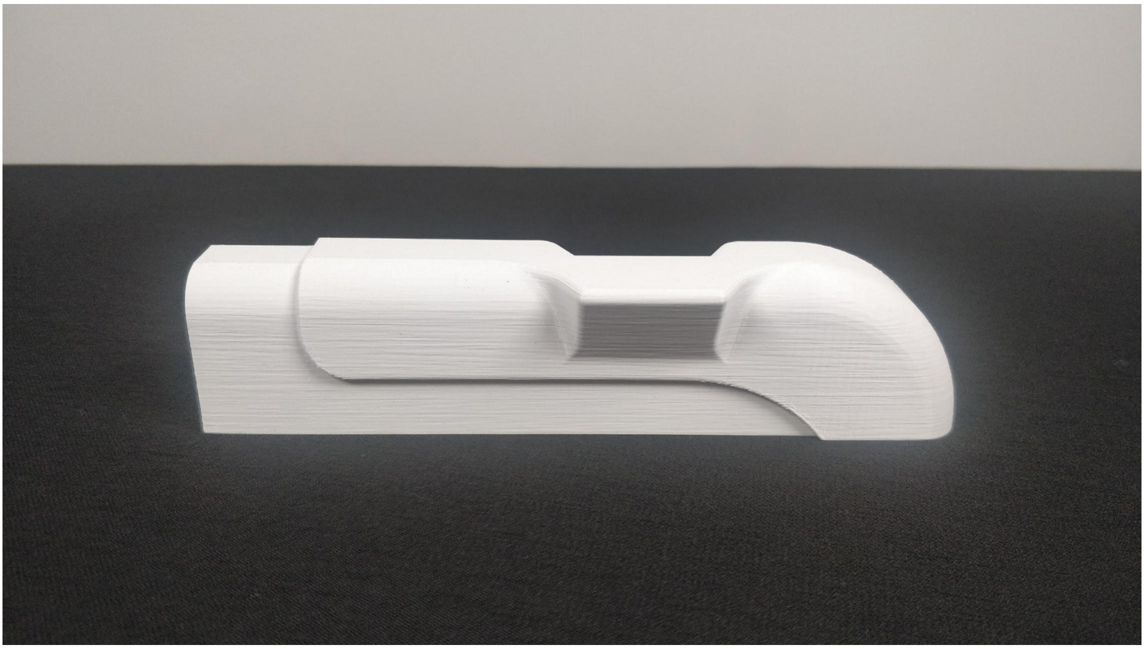


FIGURE 45. 3D PRINTED LID WITH INDENT

3.5.10 Exploration of handles using 3D print

I printed one of the handles to test the grip and see how they would look on the finished product. Because some people may have larger fingers or use gloves while working, I tested if my fingers would fit with and without gloves. The handles have a dept off 20 mm, length 100 mm and height 50 mm. My test revealed that the handles and its dimensions functioned as anticipated. I therefore decided to move on to detailing of the final 3D model.

FIGURE 46. 3D PRINTED HANDLE

3.5.11 Final iteration of 3D-model

In the last iteration of the 3D-modell the floor of the box has been changed so there are only small indents that will facilitate for stacking, rather than a indent running across the box. There is also added an additional registration number and QR-code on the lid. The changes made to the lid trough 3D-print 2 and 5 is have been added so the lids will stack propperly by themselves. There has also been added fillets to the box as exsplained in 3D-pritn 4.

FIGURE 47. FINAL ITERATION OF FISH BOX FLOOR VIEW

FIGURE 48. FINAL ITERATION OF FISH BOX

3.6 Final evaluation of the Fish box

Criteria	Approval	Comment
Reusable	Yes.	Reused until it is damaged or no longer functioning, then it will be used as material for remanufacturing.
Multipurpose	Yes.	Possible to use the fish box to transport other cooled goods, although the design is primarily meant for fish products.
Easy carrying and handling	Yes.	Handles on each side, can also be lifted by straps and vacuum.
Light weight	Yes.	Foamed structure makes the box lighter than conversional injection moulded parts.
Washable	Yes.	Yes, but label needs to be removed.
Isolating abilities	Yes.	Suited for modern complete cold cain, less isolation results in faster cooldown time than EPS fish boxes in cold storage.
Leakproof	Yes.	Made from a leakproof material.
Have a lid and function that secures the lid	Yes.	Lid secured by stacking system and industry standard straps.
Branding	Yes.	EU standard label. Unit registration number, identification of box owner for use in shared asset system.
Standardized unit size and stacking method	Yes.	Industry standard 20kg dimensions.
Mono material	Yes.	Single foamed material.

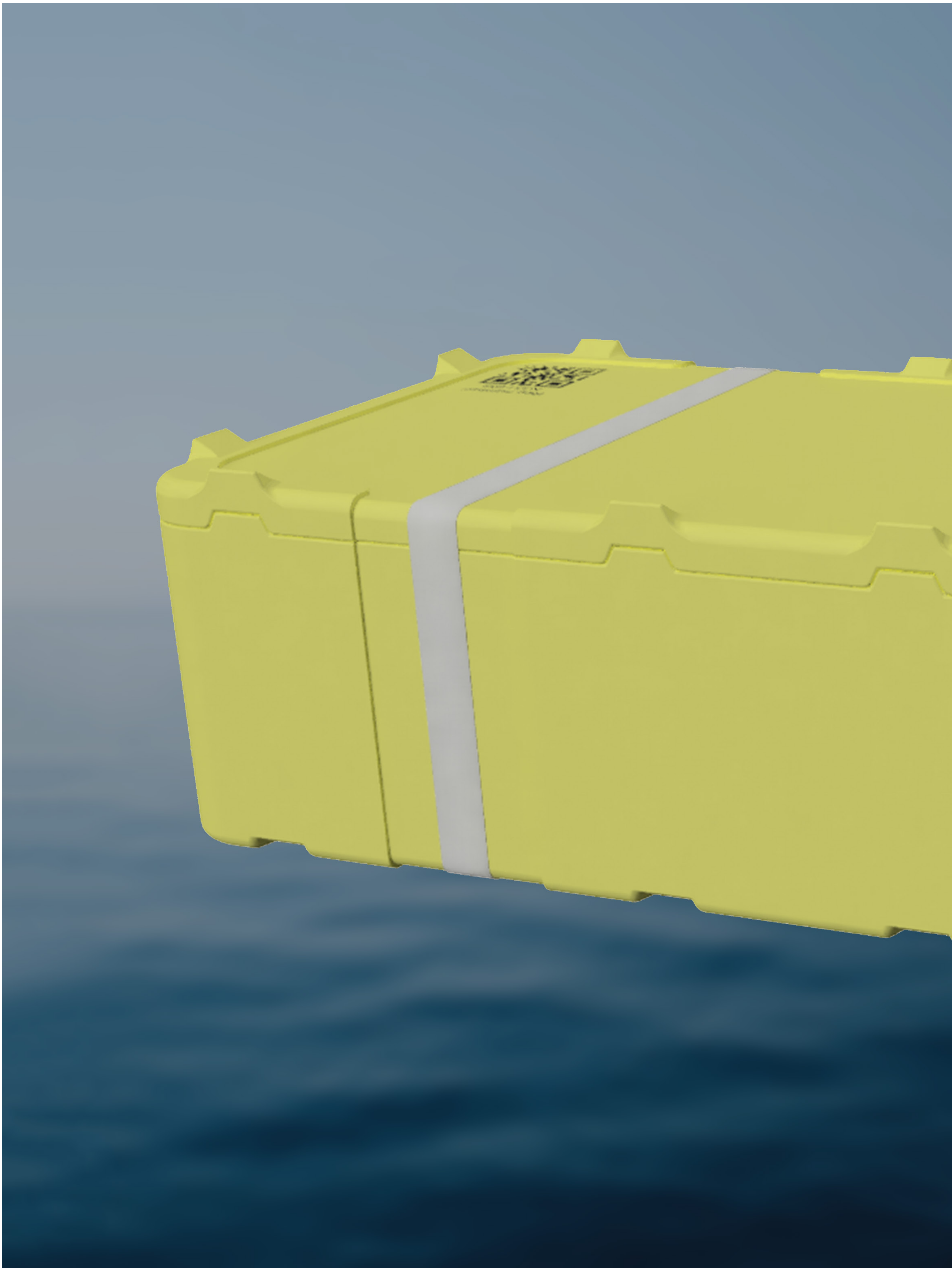


FIGURE 49. FINAL ITERATION OF FISH BOX WITH STRAPS


Reg. number:

3.7 Description of the new sheard asset system and comparison to the current system

The following illustration shows how cooled goods suppliers and logistical service providers could operate in cooperation in an interconnected system. It is a sheard economy system similar to the “physical internet” proposed by the EU. Like the “physical internet”, this system also utilizes shared hubs and data sharing through the “ICONET” platform. In this shared asset system packaging manufacturers can supply specialized reusable boxes for cooled goods in a competitive environment as long as it complies with standardized dimensions, snackability and and opensource information sharing including standardized branding. The provider of cooled goods has the opportunity to reduce cost and emissions trough shared assets, and the logistical companies can take advantage of the booking system and efficient transport.

The shared asset system aims to decrease empty running of trailers and increasing fill rate by eliminating the number of trips reserved exclusively for one supplier and instead favor shared transportation and sheard hubs. The new shared asset system also aims to eliminate single use fish boxes and in turn reduce the worldwide plastic production. An important difference between the current linear system and new shared asset systems is the constant flow of new EPS boxes in the current system opposed to the new sheard asset system where the fish boxes are used several times. In the current system the EPS fish boxes are only used once before disposal, as established earlier, this leads to a higher demand for new fish boxes and a grater material usage. Because EPS fish boxes generally require virgin material, the current system is not operating in a closed material loop. After use the EPS fish boxes are in some cases recycled into building material, but it is not the case for all EPS fish boxes. Some EPS is burned in insinuators and other even end up in an open landfill. The reduced plastic consumption in the shared asset system is achieved by introducing a far longer lifespan for fish boxes in a closed loop system where the already existing plastic material is used for remanufacturing and new material is only introduced when the current material investments run out.

The system relies on the availability of local shared hubs, which will reduce the distance between the supplier and storage in hubs and the network of shared hubs can grow when new participants emerge. Because the system relies heavily on the availability of local hubs, it is my conclusion that all elements of the system need to follow EU and industry standards, and regulations, to be able to cooperate with other already established logistical systems. The argument is that cooperating with other logistical systems will increase its reach and hopefully enhance future growth.

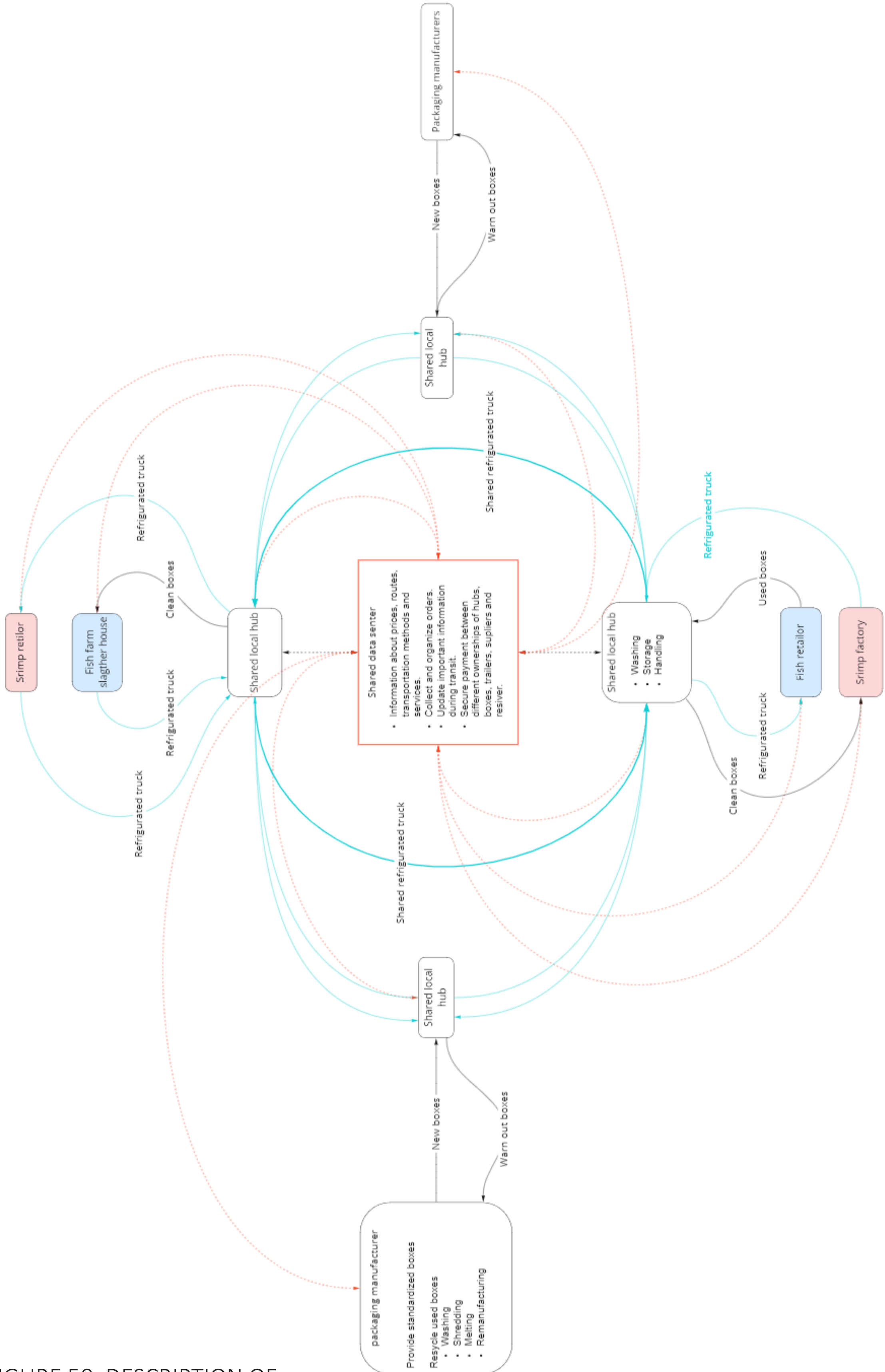


FIGURE 50. DESCRIPTION OF SHEARD ASSET SYSTEM

3.7.1 The new asset system

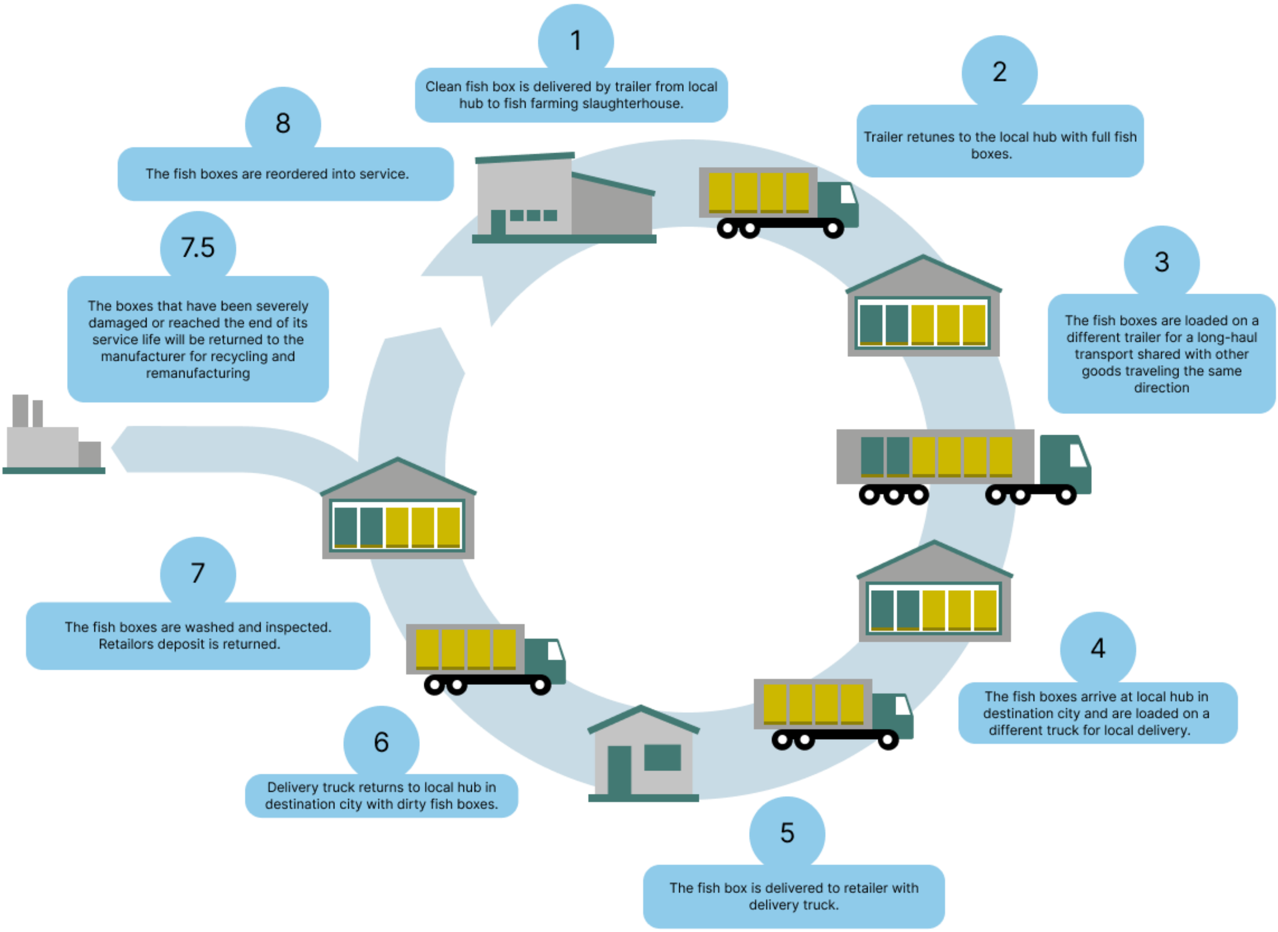


FIGURE 51. NEW ASSET SYSTEM

3.7.2 Simplified visual representation of current system

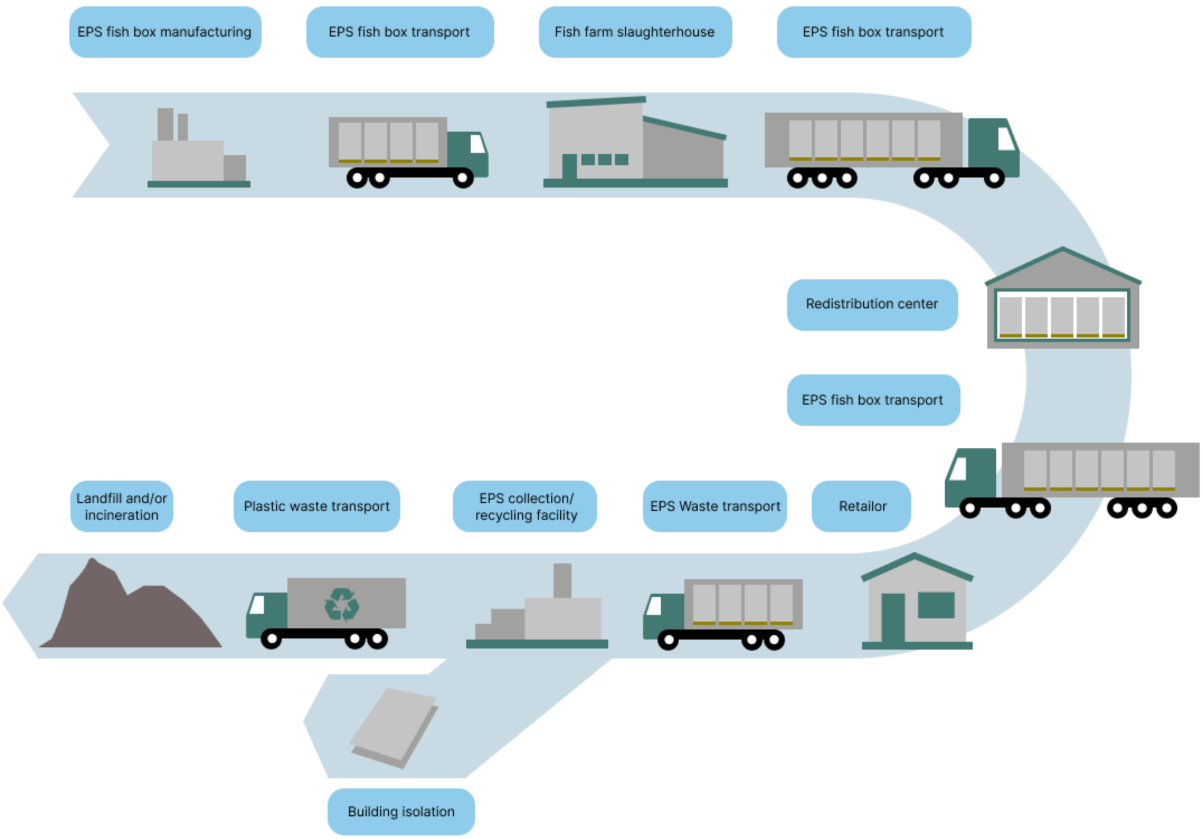


FIGURE 52. CURRENT FISH BOX EXPORT SYSTEM

3.8 Conclusion and future work

In this master's thesis I have been researching the topic design of sustainable alternatives to the industry standard EPS fish box. Researching this topic has been a challenging task. During my work it has become obvious there is no easy way to resolve all environmental challenges in the fish export industry. but I am now confident that designing a sustainable alternative to EPS fish boxes will go a long way in terms of improving the environmental footprint of the fish export industry.

I feel like I have learned a lot about the fish export industry and environmental challenges that I previously did not know existed. This thesis has though me that there is a need to not only replace the EPS fish boxes, but the whole logistical system must be changed for fish boxes to be truly sustainable. To limit the plastic consumption and waste material it is necessary to transform the whole logistical system. The fish boxes need to have have circular lifespan instead of the linear lifespan like the current EPS fish boxes. Only then can we ensure that fish boxes don't end up in places where they should not, like open landfills and in our oceans.

Although I am pleased with the result, there is still a lot of work to be done until a truly sustainable alternative to the EPS fish boxes is ready. There is still work to be done researching the material for the fish box to find the best suited material in respect to thermal albites and the box durability. When choosing a material, it is also necessary to consider recycling and remanufacturing. A prototype of the fish boxes needs to be made. With the prototype the performance of should be tested in a lifelike environment, uncovering its thermal abilities and its ability to protect its content. Lastly, a pilot version of the shared asset system needs to be constructed and routes and services needs to be optimized. That way it is possible to optimize the system in a way that will increase the efficiency of every fish box and every delivery.

3.9 Final remarks

I am personally very pleased with how the project turned out and hope someone is willing to continue working with designing sustainable alternatives to EPS fish boxes for export of fresh fish. The work is far from over and there are many challenges to overcome. I hope those involved with the fish export industry will see the challenges ahead and change their old ways by embracing innovation. Because sustainability is important, and we are all living on the same earth.

Picture and illustration sources

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- Figure 3. EPS fiskekasse med fisk, Brødr. Sunde, 2022. https://www.sundolitt.co.uk/no/om-oss/nyheter/fiskekasser-resirkuleres/#
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- Figure 10. Stacking fish boxes in trailer, 2022, EPS-foreningen. https://www.norskindustri.no/kampanjesider/eps-gruppen/aktuelt/handtering-av-fisk/
- Figure 12. Corrugated board assembly, 2022, FEFCO. https://www.fefco.org/about-fefco/what-is-corrugated
- Figure 13. Picture of EcoFishBox , 2022, Stora Enso. https://www.storaenso.com/en/products/corrugated-packaging-solutions/ecofishbox
- Figure 14. Picture of CoolSeal, 2022, Tri-pack Packaging Systems. https://tri-pack.co.uk/coolseal/
- Figure 15. Picture of iTUB, 2022, iTUB. https://itub-rental.com/sustainability/
- Figure 16. Picture of 25KG Salmon Fish Box, 2022, PPS. https://www.ppsequipment.co.uk/products/fish-boxes/
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- Figure 23. Graph global production capacites of bioplastic, 2022, European Bioplastics. https://www.european-bioplastics.org/market/
- Figure 26. Structural foam injection moulded part, 2022, Neue Materialien Bayreuth GmbH. https://www.nmbgmbh.de/en/materials/integral-foams/
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