Application of Environmental Indicators for Seafood

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Abstract

The purpose of the study was to calculate, using LCA, the carbon footprint of the post landing activities of cold fish supply chains. Two different transportation modes were analysed, transportation by container ship and air freight.

The results from the LCA calculations show that the choice of transportation mode is very important in terms of greenhouse gas emissions. It was found that the air freighted cold supply chain has 18 times larger carbon footprint than the sea freighted supply chain. The carbon footprint of 1 kg of air freighted fresh demersal fish was found to be 4.7 kg CO_2-equivalents and 0.3 kg CO_2-equivalents for the sea freighted fish.

The opinion of stakeholder to apply environmental indicators for seafood in marketing purposes was explored. Stakeholders of the cold supply chains received a web based survey.

The results from the survey indicate that the knowledge of Icelandic seafood producers on their environmental performance is fair and in general environmental consideration in the industry is increasing. The industry sees a value in utilizing environmental indicators for marketing purposes and the stakeholders identified a demand on information on the environmental impacts of their products. Currently the most important factors considered by the stakeholders when selecting the transportation chain is the quality of the product and the costs involved. Environmental considerations are today not taken into account when the transportation phase is chosen. If the demand for environmentally friendly products, from cradle to grave, continues to increase this perspective will have to be reconsidered by the industry.

SAMANTEKT Á ÍSLENSKU

Markmið verkefnisins var að reikna með aðferðafræði vistferilsgreiningar (e. Life Cycle Assessment) kolefnisspor fyrir flutningaferil kældra sjávarafurða frá Íslandi á markað í Evrópu. Flutningar með skipi og flugvél voru skoðaðir.

Niðurstöður vistferilsgreiningarinnar sýna að val á flutningsmáta skiptir miklu máli hvað varðar útblástur gróðurhúsalofttegunda. Flutningaferill þar sem kældar fiskafurðir eru fluttar með flugi hefur 18 sinnum stærra kolefnisspor en fiskur fluttur með flutningaskipi. Kolefnisspor fyrir 1 kg af bolfisk fluttur með flugi var fundið sem 4,7 kg CO_2-ígildi en 0,3 kg CO_2-ígildi fyrir 1 kg af sjófluttum bolfisk.

Möguleikinn á að hagnýta umhverfisgildi fyrir sjávarafurðir í markaðslegu samhengi var skoðaður. Send var út vefkönnun til hagsmunaaðila flutningsferlanna.

Niðurstöður könnunarinnar sýna að þekking iðnaðarins á umhverfisáhrifum frá framleiðslu og flutningsferlum afurðanna er allgóð og að umhverfisvitund hefur aukist í iðnaðnum. Atvinnugreinin sér möguleika í að nýta sér upplýsingar um umhverfisgildi í markaðslegu samhengi og svarendur könnunarinnar eru varir við eftirspurn eftir upplýsingum um umhverfisáhrif söluvörunnar. Um þessar mundir eru það gæði vörunnar og geymsluþol ásamt kostnaði þau atriði sem helst er litið til við val á flutningsleiðum sjávarafurða á markaði. Ekki er litið til umhverfisgilda við val á flutningsleiðum. Ef eftirspurn eftir umhverfisvænum vörum, frá vöggu til grafar, heldur áfram að vaxa verða framleiðendur að fara að endurskoða val á flutningsleiðum.

PREFACE

This study on the Application of Environmental Indicators for Seafood was carried out during June – September 2010. The report was prepared by Gyða Mjöll Ingólfsdóttir under the supervision of Guðrún Ólafsdóttir, Eva Yngvadóttir, Tómas Hafliðason and Sigurður Bogason.

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1 INTRODUCTION

The environmental impact of industrial operations and global transport of goods has been on the agenda worldwide. The food industry is one of the world's largest industrial sectors, an extensive energy user and a great contributor to greenhouse gas (GHG) emissions (Roy et al., 2009). The awareness of consumers towards environmentally friendly products is increasing and today, consumers demand safe food of high quality which is produced with minimal detrimental environmental effects. This has lead governments and businesses to come up with environmental aims and management systems with the goal to minimize the environmental impact from production of goods and services. Increase in certification and ecolabelling programs has lead to the need to standardize and develop methodology to strengthen the scientific grounds of environmental product certifications programs. Furthermore, there is a need to carefully present to consumers what consists in various environmental indicators and sustainability.

The environmental impacts of food supply chains can be observed throughout the entire supply chain, including the production to retail and the final disposal of the food products. The impacts derive for example from energy use during manufacturing, cooking, packaging production, storage and transportation. The seafood industry is aware of the increasing demand for environmentally friendly food products and ecolabelling and environmental production certifications have been on the rise in the industry (Pelletier & Tyedmers, 2008). The Food and Agriculture Organization (FAO) of the United Nations has published Guidelines for the Ecolabelling of Fish and Fishery Products from Marine Capture Fisheries. These guidelines underpin that only seafood products which are fished from stocks which are not overexploited can be certified (FAO, 2005). The Marine Stewardship Council Certification scheme and Friend of the Sea are examples of available certification programs. The Icelandic logo for Responsible Fisheries is a certificate of origin and a statement by the government that Iceland pursues responsible fisheries in accordance with FAO guidelines.

Evaluation of environmental impacts and sustainability of seafood production have focused on the fisheries themselves and sustainable use of fish stocks but not as much attention has been given to the entire life cycle of the food supply chains. The current ecolabelling and environmental certification schemes have therefore focused on the local ecological impacts which are a very important aspect, but there is a need to look beyond and consider the entire food supply chain, from cradle to grave (Pelletier & Tyedmers, 2008). This study is an input to promote research on environmental impact of the Icelandic seafood supply chain as well as to build scientific ground for the definition of sustainable food production.

The aim of this study is to:

1. Perform a literature study on issues relevant to environmental indicators and sustainability of food products in particular fish products.
2. Analyze the environmental impacts (carbon footprint) of typical fresh fish supply chains transported by both air and sea freight.

3. Evaluate the difference in energy use and environmental impact of transporting fresh fish according to requirements of regulations (4°C) and according to the requirements of stakeholders of the cold supply chains (-1°C).
4. Explore the view of stakeholders in the chill chain regarding application of environmental indicators for seafood.

The literature study in Chapter 2 covers a review on sustainability, GHG emissions in Iceland from the activities of the cold supply chains, Environmental indicators with a focus on the carbon footprint, Environmental product certification schemes for seafood products currently in use, Transportation of Food in relation to climate change, issues related to social impacts and a discussions on previous Life Cycle Assessment (LCA) studies relevant to the analysis. Currently there is increased interest in the possibility to transport fresh fillets to distant markets by sea freight as a less costly alternative to air freight. Characteristics of fresh and frozen fish products in relation to their shelf life and consumer perceptions are briefly summarised.

The study considers the environmental effects of two fish supply chains but social and socio-economic considerations are not included. The analysis of the environmental impacts of the cold supply chains was done by calculating the carbon footprint of the post landing activities of cold fish supply chains, with emphasis on the transportation phase. Carbon footprint was evaluated by LCA methodology using the modelling software Gabi 4.3 – Education where two alternative transportation modes were compared and the impact of packaging, processing and chilling was evaluated. The LCA methodology is described in Chapter 3. The LCA study and results are presented in Chapter 4. The results on the energy use and the environmental impacts from transporting chilled food are found in Chapter 4.3.3. To explore the opinions and environmental awareness of stakeholders in Iceland an internet survey was conducted. In Chapter 5 the survey methodology and results are presented.

The results from the LCA will provide information to authorities to further define and support the Statement on Responsible Fisheries in Iceland and support the environmental benchmarking of Icelandic seafood products. Calculation of the carbon footprint and energy use can also serve as a reference to evaluate progress obtained with specific measures made to improve the environmental performance and sustainability of seafood supply chains. Opinions of the stakeholders obtained in an internet survey gives an indication of the importance of environmental indicators for Icelandic seafood and information on from which markets there is a demand for environmental information on seafood products.

2 BACKGROUND

2.1 SUSTAINABILITY

Sustainable development is becoming increasingly important in modern business environment. In the report *Our Common Future* from the World Commission on Environment and Development sustainable development is defined as follows: *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (Common & Stagl, 2005).

The objective of sustainable development is to improve the quality of life for all people without using natural resources beyond the earth's carrying capacity. The challenge is therefore to balance economic development with social and environmental objectives. The relationship between the three dimensions of sustainability are shown in Figure 1.

- *Economic dimension:* Economically sustainable system must produce goods and services on a continuing basis, to maintain manageable size of government and external debt and to avoid sectoral imbalances (maintain diversity).
- *Environmental dimension:* Environmentally sustainable system must maintain the stock of resources and avoid over-exploitation of renewable resources. Depletion of non-renewable resources can only be to the extent that investment is made in adequate substitutes.
- *Social dimension:* Socially sustainable system secures distributional equity, fair provision of social services, gender equity and political accountability and participation (Harris, 2000).

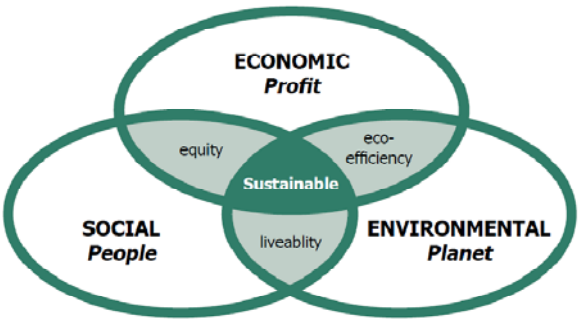


Figure 1: The relationship between the three dimensions of sustainability (Remmen, Jensen & Frydendal, 2007)

All businesses, governments and individuals need to take action in order to reach sustainable development. This involves changing consumption and production patterns, setting policies and changing practices. Businesses need to find ways to improve environmental performance of production processes. The traditional economic focus must be expanded to include environmental and social factors. Using the life cycle concept businesses have the opportunity to understand the environmental impact of their products and to find economic benefits, both in production and in markets. Cleaner production processes can result in resources savings thereby leading to pure margins, environmental management systems can improve the businesses and/or products reputation and clean and sustainable products can lead to competitive advantage giving increased revenues (Remmen, Jensen, & Frydendal, 2007).

2.2 Greenhouse Gas Emissions

Climate change is a global concern and the result of human economic activity. To address this problem the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and in 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was developed (Common & Stagl, 2005). In 1997 the Kyoto Protocol was adapted to the UNFCCC which sets GHG emission targets for countries. Iceland has ratified the Protocol and therefore has the obligation to fulfil the emission targets set by the Protocol for the years 2008 – 2012 (Davíðsdóttir et al., 2009).

Under the Kyoto Protocol the Icelandic obligations are twofold; Iceland may increase GHG emissions by 10% compared to 1990 levels in 2008 – 2012 and emit 1.6 million tons annually in the same period based on the so-called impact of single project on emissions. In 2007 the Icelandic government approved a new target for reduction of GHG emissions. The new long-term vision is to reduce GHG emissions by 50 – 75% by 2050 compared to 1990 levels (Ministry for the Environment, 2007).

The main sources of CO_2 emissions in Iceland are from industrial processes, road transport and fisheries. In 2008 fisheries and road vehicles accounted for 14% and 24% respectively of the country's total CO_2 emissions. In 1990 the share of total CO_2 emissions from these two sectors was 30% from fisheries and 24% from road vehicles (Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010). In Table 1 Iceland's total CO_2 emissions and emissions from fisheries and road vehicles in 1990, 2007 and 2008 are shown along with the percentage change in emissions in the periods 1990 – 2008 and 2007 – 2008.

Table 1: Total CO_2 emissions (Gg CO_2 - equivalents), emissions from fisheries and road vehicles in Iceland for the years 1990, 2007 and 2008 and the change in emissions during two periods (Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010)

	1990	2007	2008	Changes 1990 - 2008	Changes 2007 - 2008
Total CO_2 emissions	2,172	3,301	3,595	66%	9%
Fisheries	655	565	517	-21%	-8%
Road vehicles	521	904	851	63%	-6%

It can be seen that since 1990 the total CO_2 emissions have increased and in 2008 the increase amounted 66% with 9% increase since 2007. The increase in total CO_2 emissions can be explained by increased emissions from industrial processes, road transport, geothermal energy production and the construction sector according to Hallsdóttir *et al.* (2010). The main driver is the expansion of the metal production sector. The increased emissions from road transport in 1990 – 2008 are because of increased number of cars per capita and an increase in large vehicles as well as more vehicle mileage. The decline from 2007 – 2008 is due to significant increase in fuel prices occurring simultaneously with the depreciation of the Icelandic Krona. Emissions from fisheries declined overall by 21% during the period 1990 – 2008 (Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010). The emission trend for fisheries from 1990 – 2008 can be seen in Figure 2.

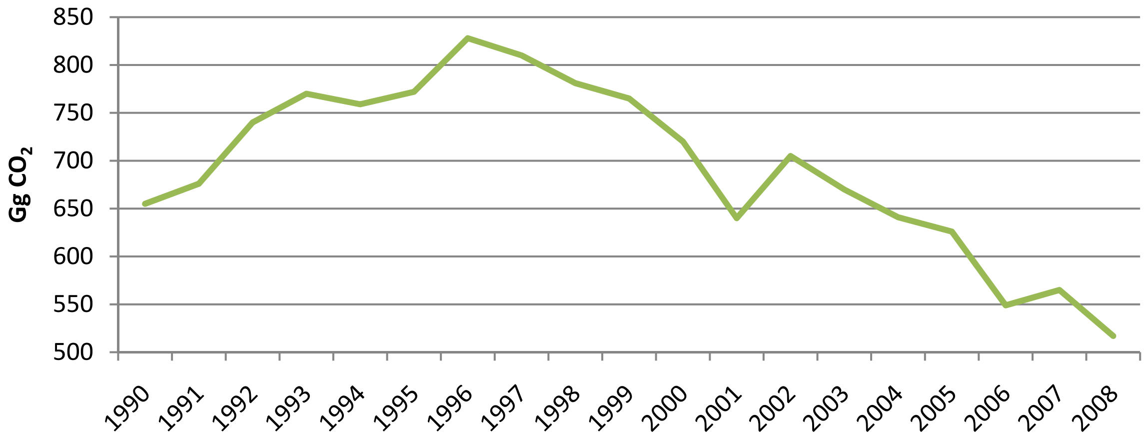


Figure 2: The emissions of CO_2 from fisheries between 1990 and 2008 in Gg CO_2-equivalents (Statistics Iceland, 2010; Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010)

From Figure 2 above it can be seen that emissions from fisheries rose between 1990 and 1996. The increase can be explained by the fact that a considerable portion of the fishing fleet was operating in distant fishing grounds. From 1996 to 2001 the emissions dropped and reached 1990 levels in 2001. The fluctuation in emissions between 2001 and 2008 reflect the intrinsic nature of the fishing industry (Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010).

The emissions from international aviation and marine bunker fuels are excluded from the total emissions reported to the UNFCCC and are reported separately. Table 2 shows the change in CO_2 emissions from international aviation and marine transport in the period 1990 – 2008 and the change between the years 2007 and 2008.

Table 2: Total CO_2 emissions (Gg CO_2- equivalents) from international bunkers in Iceland for the years 1990, 2007 and 2008 and the change in emissions during two periods (Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010)

	1990	2007	2008	Changes 1990 - 2008	Changes 2007 - 2008
Total CO_2 from International bunkers	319	718	656	106%	-9%
Aviation	220	512	428	95%	-16%
Marine	99	207	229	131%	10%

The CO_2 emissions from international bunkers more than doubled in the period 1990 – 2008 but decreases slightly between 2007 and 2008 (Table 2). The reason for the 9% drop in emissions can most likely be traced back to the depreciation of the Icelandic Krona according to Hallsdottir *et al.* (2010). Since 1990 it can be seen that emissions from marine transport increased by more than 130% and aviation emissions almost doubled (Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010). Data from Statistics Iceland show that the large increase in emissions follows among others the significant increase in export of goods and increased passenger flights. Export of seafood has been steadily increasing since 1990 including the export of fresh seafood by airplane or freighters. In Figure 3 the amount of exported fresh seafood in 1990 – 2008 is shown, excluding the landings in foreign ports. Between 2002 and 2004 there was a significant leap in the amount of fresh seafood exported. It can be seen that transportation of fresh fish by air freight has been steadily increasing from 1990 – 2007, but has declined again in the last three years. In addition, there has been a significant increase in fresh fish transported by ocean freighters since 2002 (Statistics Iceland, 2010).

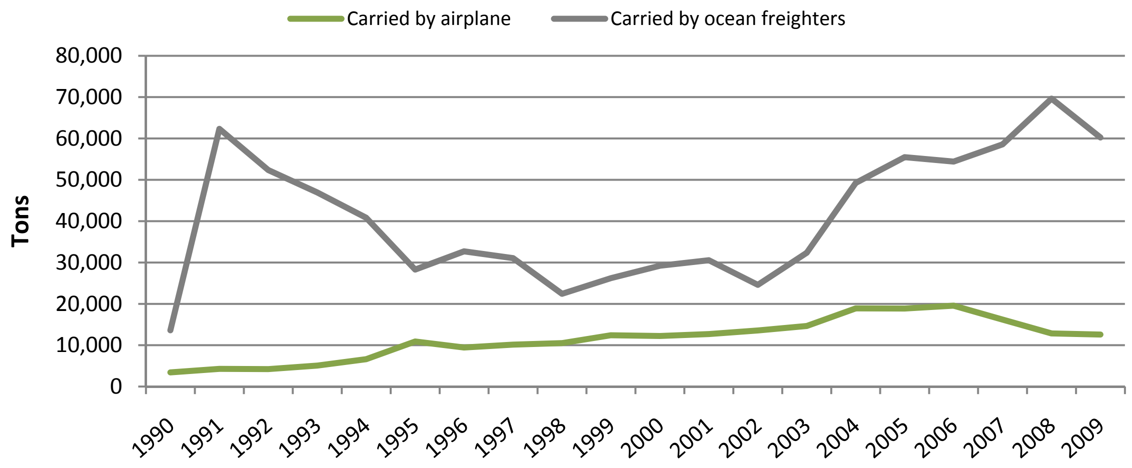


Figure 3: Amount in tons of fresh fish exported by airplane (green line) or ocean freighters (grey line) between 1990 and 2009, excluding landings in foreign ports (Statistics Iceland, 2010)

In a report by Davíðsdóttir et al., 2009 the possibilities to fulfil the government's goal of 50 – 75% emission reductions by 2050 are evaluated. Transportation of fresh fish within Iceland is dominated by Heavy Duty Vehicles (HDV) and it is estimated that during 2010 – 2050 methane vehicles can partly replace current diesel compelled HDV within reasonable costs. The transition from diesel to methane HDV is estimated to reduce the GHG emissions in the period 2009 – 2020 by 110,000 tons CO_2-equivalents. The findings of the report regarding reduced emissions from fisheries include energy saving measures, increase the utilization of environmentally friendly energy and increase the use of electricity from land while at harbour (Davíðsdóttir et al., 2009). Combination of these measures to reduce CO_2 emissions from vehicle transport and fisheries can work together to increase the overall environmental performance of Icelandic seafood.

2.3 Environmental Indicators

Environmental indicators are measures used to track changes in the environment or the environmental performance of products. As the environment is very complex, indicators can be used to quantify and simplify phenomena and inform and alert about changes taking place in a given system, i.e. they can indicate movement towards or away from sustainable development. Concentration of ozone depleting substances (ODS) in the atmosphere over time is a good indicator of stratospheric ozone depletion and a measure of a products carbon footprint can be used to come up with a strategy to reduce the footprint. The use of indicators depends on the context and they must be designed in order to help decision makers understand why change is taking place. Indicators can assist with overall analysis in for example:

- *Performance evaluation:* indicators help evaluate performance if a basis for comparison is clearly identified, e.g. when a target is specified in policy processes.
- *Thresholds*: thresholds are unique and the most important basis of assessment. Crossing a defined sustainability threshold should send message to policy makers and society.

- *Causal loops*: indicators are important to support claims for causality, such as the links between pressures and environmental conditions.
- *Model construction and scenario analysis:* indicators provide real data and support field testing of models and possible future scenarios.

Indicators can be powerful tools to help identify and support integrated environmental assessments. Integrated environmental assessments are processes of producing and communicating policy relevant information on key interactions between the natural environment and society (Pintér, Zahedi, & Cressman, 2000). An example of this is the Pressure – State – Response (PSR) framework, see Figure 4.

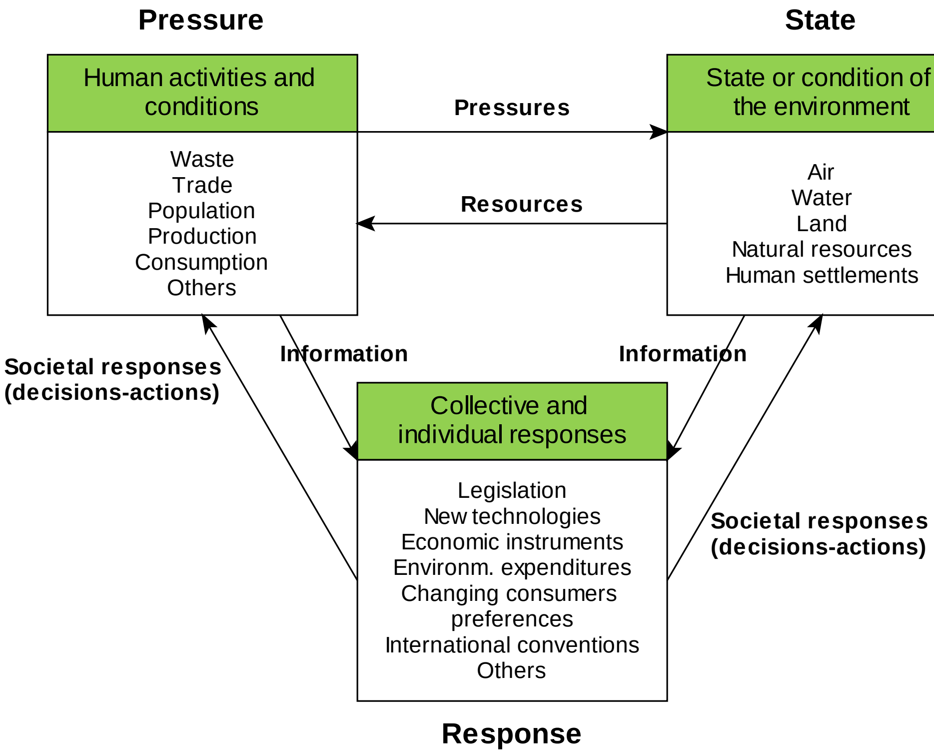


Figure 4: An example of Pressure – State- Response framework (Adapted from: Pintér, Zahedi, & Cressman, 2000)

The interactions between society and the environment is categorised as the PSR relationship. The pressures the human society puts on the environment as a result of human activities, trade and consumption result in direct pressures on the environment, such as pollution and resource depletion. The state is the condition of the environment that results from the pressures, e.g. pollution levels or degree of land degradation. These changed conditions may, in turn, affect human health and well-being. An understanding of both the state of the environment and the direct and indirect effects is needed. The response relates to the actions taken by society, either individually or collectively to prevent or mitigate against negative environmental impacts, to correct existing damage or to conserve natural resources. The responses can for example include public opinion and consumer preferences, changed management strategies and environmental product certification programs (Pintér, Zahedi, & Cressman, 2000).

2.3.1 Carbon Footprint

The environmental indicator of interest for this study is the carbon footprint. For the purpose of this report a carbon footprint is defined as the total set of GHG emissions caused by an organization, event or a product (human activities). It is presented in terms of the amount of carbon dioxide and its equivalents of other GHGs emitted.

The carbon footprint considers the following gases: carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6). By using the carbon dioxide equivalent different GHGs can be compared on a like-for-like basis relative to one unit of CO_2. The CO_2 equivalents are calculated by multiplying the emissions of each of the GHGs by its 100 year global warming potential (GWP). Methane has for example a GWP of 25. The GWP of the six GHGs considered in the carbon footprint calculations is shown in Table 3.

Table 3: GWP of the GHGs considered in the carbon footprint (Birgisdóttir & Ólafsdóttir, 2009)

Greenhouse Gas	GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	310
Hydrofluorocarbons (HFC)	140 – 11,700
Perfluorocarbons (PFC)	6,500 – 9,200
Sulphur hexafluoride (SF_6)	23,900

For a product the carbon footprint measures the GHG emissions at each stage of the product's life. This includes:

- Extraction, production and transportation of raw materials
- Manufacture or service provision
- Distribution
- End-use
- Disposal/recycling

For each of these stages the emissions can result from various sources, such as: energy use, transportation fuel refrigerant losses from air conditioning units, waste or other (Carbon Trust, 2010).

2.4 Environmental Product Certification

In the past industrial societies considered the environment as a limitless source of resources and a limitless sink for waste. This attitude has now changed and there are various drivers of environmental protection in this changing business context. These drivers can be divided into four categories: coercive, market, resource and social drivers (Hoffman, 2000).

The market drivers involve the role of the consumers in driving companies to consider environmentalism in their market strategy. Since the 1980s public awareness of the seriousness of environmental problems and support for environmental protection has been on the rise. However, the environmental consumer remains a confusing presence and the power of this purchasing block has been a debated issue. Public opinion polls have shown that people do care about the environment and claim that this concern can affect their buying decisions. Today the environment is used as a marketing point to an increasing extent and to increase the marketing potential of green products environmental certification programs have been established (Hoffman, 2000).

2.4.1 Environmental impacts from seafood products

The seafood industry generates different environmental impacts at different life cycle stages of seafood products. These impacts can be divided into 6 steps (Figure 5**)** (Thrane, Ziegler, & Sonesson, 2009).

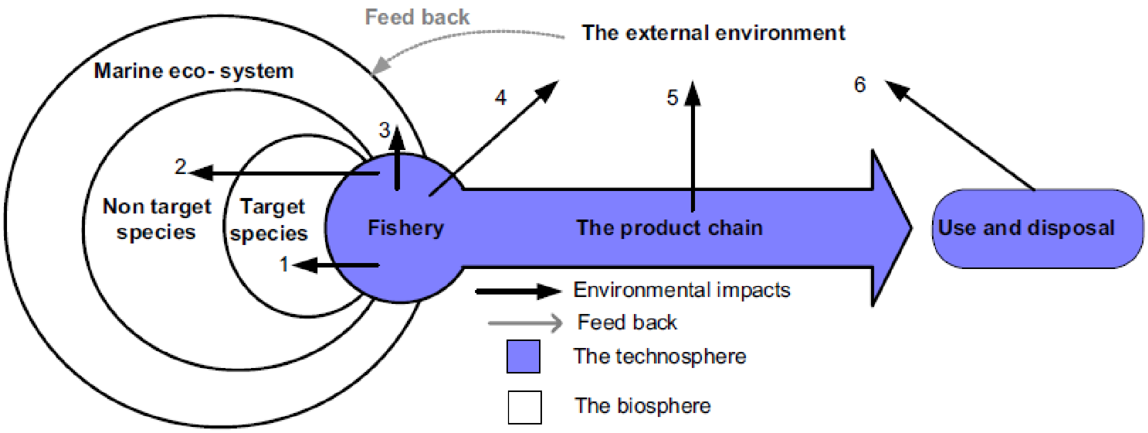


Figure 5: Environmental impacts at different life cycle stages of seafood products (Thrane, Ziegler, & Sonesson, 2009)

The first stage is the fishing activity, having direct impact on the target species. Exploitation of the target species can have further influence on non-target species and the surrounding marine ecosystem. The second stage involves the direct impacts on non-target species which can have indirect impact on the surrounding ecosystem. Stage three involves the direct impacts on the marine ecosystem ranging from damage to the seafloor, loss of fishing gear and release of biocides from anti-fouling paint. The fourth stage is the effects on the external environment because of combustion of fossil fuels and emissions of gases. Stage five is related to the impacts during post-landing. These impacts include the processing, wholesale and transport. The last stage is where the product reaches the consumers. This involves the shopping, storing, cooling, preparation and disposal of packaging and leftovers (Thrane, Ziegler, & Sonesson, 2009).

2.4.2 Ecolabels

In order to identify and distinguish between the environmental performance of products within product categories, product certification schemes have been developed and products fulfilling the criteria of the schemes can be labelled with respective ecolabels. The Food and Agriculture Organization (FAO) of the United Nations has prepared Guidelines for the Ecolabelling of Fish and Fisheries Products from Marine Capture Fisheries which were adopted in 2005. The guidelines are meant to assist in preparing ecolabelling schemes that are designed to certify and promote labels for products from well-managed marine capture fisheries and focus on issues related to the sustainable use of fisheries resources. The guidelines refer to principles, general considerations, terms and definitions, minimum substantive requirements and criteria, and procedural and institutional aspects of ecolabelling of fish and fishery products from marine capture fisheries (FAO, 2005).

The efficiency of product certification and ecolabelling is dependent on the relevance of the criteria employed. The market share of labelled products depends on the consumer preferences and the consumer confidence in and recognition of specific labels. One of the fastest growing food markets are the certified and ecolabelled food products and certification and ecolabelling of seafood products has been on the rise. The driver for these certification programs have been a combination of increased demand for seafood, decline in traditional fisheries and rise of aquaculture. Labelled and certified seafood products are moving from niche markets to competition in mainstream markets (Pelletier & Tyedmers, 2008). Currently used seafood ecolabelling schemes include for example the Marine Stewardship Council (MSC), Friend of the Sea, KRAV and Dolphin Friendly (Figure 6). Environmental product certification schemes require a third party audit and chain of custody certification for labelling of products. The Icelandic Logo for Responsible Fisheries is used to identify Icelandic seafood products and indicate product origin in Iceland from responsible fisheries. Currently the Icelandic logo does not have a third party audit but stakeholders in the Icelandic seafood industry decided in 2007 in cooperation with the government to get a third party certification. The certification is expected before the end of 2010 (Garðarsson, 2010).

Figure 6: Examples of logos for currently used seafood certification schemes and the Icelandic logo for Responsible Fisheries

The future of ecolabels and third party standards is debated among retailers. Food producers and retailers have been turning away from ecolabels and are focusing on building ecological brands. This has become an issue because the food industry has over 500 different ecolabels representing various production and environmental aspects. The debate involves discussions on how ecolabels can meet the rising consumer expectations and on the definition of sustainable food production, sustainability and the lack of sustainability standard and a uniform sustainability ecolabel (Organic Monitor, 2010). European retailers delivered in 2009 a voluntary environmental code of conduct where the retailers signing up to the code commit to a set of principles and measures aimed at reducing their environmental footprint (EU, 2009). Furthermore, large international businesses, such as Tesco, PepsiCo and others have already started to label products as having lower carbon footprints during the production, packaging and transport of certain products.

The World Wildlife Fund (WWF) publishes WWF Seafood Guides for seafood shopping; the seafood is labeled as green, yellow or red. The green fish is labeled as fish to eat, the yellow recommends consumers to think twice and preferably find another option and the red fish is the 'don't buy' option. Supermarkets in Germany have already started to use a similar scheme and many companies have developed a buying policy for fish and seafood.

2.4.3 Evaluation of environmental certification programs for seafood

Pelletier & Tyedmers, 2008 reviewed a number of environmental certification programs for seafood production. From the study it was found that none of the schemes reviewed seriously considered the full range of environmental and social costs generated for the delivery of seafood to the markets. That is, the programs considered the localized ecological impacts (very important aspect) but ignored or gave very little attention to socioeconomic considerations and biophysical impacts that result from the material and energy resources flow that underpins fisheries and the aquaculture production technologies. Thrane et al. 2009 evaluated four eco-labelling schemes for seafood products from capture fisheries. The study found that there has not been much attention on the energy consumption and the contribution to global warming from fisheries and the environmental aspects relevant in the rest of the product chain (Thrane, Ziegler, & Sonesson, 2009).

Current ecolabels do not consider the energy consumption, emissions of anti-fouling agents and post landing activities. Studies have shown that environmental impacts from fish processing, transport, cooling and packaging are significant and it would therefore be appropriate to include the post landing activities in ecolabelling criteria. Furthermore, there is a need for ecolabelling to promote sustainable seafood from a life cycle perspective (Thrane, Ziegler, & Sonesson, 2009). The rapid increase in certification and ecolabelling programs has created a need for standardization method for development of ecolabelling and environmental certification schemes. Many of the current standardization methods recommend that the criteria used, should contain information about full product life cycle considerations although none of the current sustainable seafood programmes employ full LCA considerations (Pelletier & Tyedmers, 2008).

The status of environmental product declarations is that 8% of seafood products have MSC certification and 10% currently have Friend of the Sea certification. In addition it has been found that consumers have not been willing to pay a higher price for environmentally certified products but the labelling schemes have indeed encouraged improved fisheries management (Valdimarsson, 2010).

2.5 TRANSPORTATION OF FOOD

Within the European Economic Area (EEA) freight transport increased significantly between 1992 and 2004. This trend of transporting more goods farther and more frequently makes it difficult to reduce the environmental consequences of transport. The reason for this increase is due to both the demand and supply side of the transport market (Jensen & Schroten, 2006a). It has been estimated that nearly 25% of all petroleum used worldwide is consumed by freight transport and produces 10% of carbon emissions from fossil fuels (Estrada-Flores, 2008).

During the period 1992 – 2004 the share of road transport increased within the EEA which is in disagreement with the objectives of the European Union (EU). The policy initiatives are aimed at shifting freight transport from road to water and rail. In order to achieve the objectives of modal shifts a strong reversal of the current trend is needed. In Figure 7 the development of freight transport during 1992 – 2004 is shown, indicating the increasing share of road transport (dark blue line) during the period. The increase in road transport can for example be explained by the enlargement of the EU and opening up of borders, privatisation of railway companies has resulted in cutback of tracks and higher transport prices, more is demanded for "just-in-time" delivery of goods and perishable and high value goods require fast and reliable transport and the share of these goods has been rising (Jensen & Schroten, 2006b).

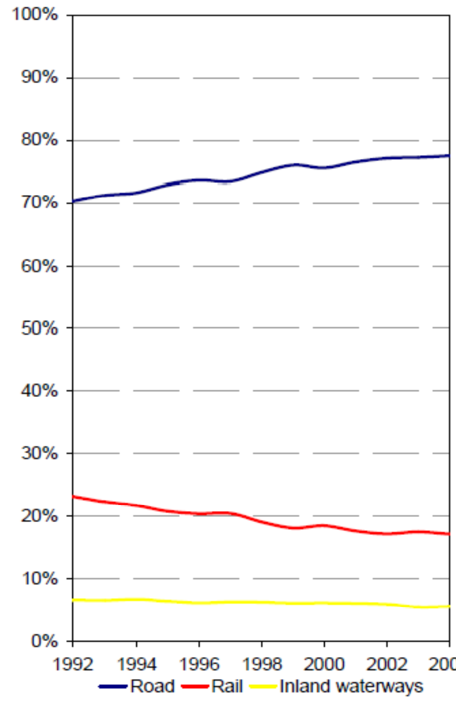


Figure 7: Modal shares in freight transport, EEA-30, 1992 – 2004 (Switzerland and Lichtenstein excluded) (Jensen & Schroten, 2006b)

2.5.1 Refrigerants

The stratospheric ozone layer acts as a shield that absorbs ultraviolet rays, thereby protecting living organisms from exposure to ultraviolet radiation. The volume of ozone in the Earth's stratosphere has been recorded to be declining. The ozone depletion is caused by free chlorine radicals that act as catalysts and remove ozone from the atmosphere and convert the ozone (O_3) to oxygen (O_2). Excess chlorine is present in the stratosphere as a result of releases of manmade chlorine containing chemicals. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are an example of these chemicals which have become widespread because of their chemical properties, especially as refrigerants, in air conditioning and refrigerating systems. The Montreal Protocol on Substances that Deplete the Ozone Layer was designed to protect the ozone layer by phasing out the production of ODS. The production and use of CFCs is now banned and HCFCs are expected to be phased out by 2030 (Wongwises & Chimres, 2005). Currently there are evidence that show that the phase out of the ODS have already lead to some ozone recovery (James & James, 2010).

Recently the focus has been on climate change and is currently the motivator for concern and change which gives the GWP of substances increased importance. The first response of the refrigeration and chemical industry to the Montreal Protocol was to find interim refrigerants with environmentally friendlier properties that could be used until optimum alternatives are developed. Hydrofluorocarbon R134a has been used extensively for food refrigeration and air conditioning applications. R134a has low toxicity levels, a low boiling point and does not contain chlorine and its ozone depletion potential (ODP) is therefore zero. The GWP of R134a is however of 1,300[1] while EU regulations require that new refrigerants have a GWP of less than 150 (James

[1] Carbon dioxide (CO_2) has a GWP of 1 and methane (CH_4) has a GWP of 25.

& James, 2010). An extensive amount of the global warming impact of refrigeration is due to refrigerant leakage and it has been reported that refrigerant emissions from transport refrigeration systems are higher than from stationary systems. This is due to the severe environments the transport refrigeration systems operate under (vibration, weather conditions and operating temperatures). Annual leakage has been found to range from 10 – 37% of the refrigerant charge (Tassou, De-Lille, & Ge, 2009).

There have been developed new alternatives with lower GWP than R134a, for example R152a with GWP of 120 and HFO-1234yf with GWP of 4. In the near future the production and use of R134a will for sure be terminated (James & James, 2010) (Wongwises & Chimres, 2005).

2.6 Food cold-chain and climate change

Food supply chains and climate change are interrelated as the activities of the supply chains enhances climate change which in turn can have major impact on food resources in the future. With increased temperatures it can be expected that dependence on refrigeration and air-conditioning technologies for food preservation will increase to maintain the quality and fulfil safety standards at increased ambient temperatures. This may become particularly important during storage and transport. Simultaneously, the refrigerated transport industry may have to comply with tighter restrictions in terms of diesel use (Estrada-Flores, 2008).

The quality of food is highly affected by the post-harvest practices. Food can deteriorate during transport and distribution if inappropriate measures are employed which lead to food loss (Roy et al., 2009). Refrigeration is an important part during the transportation of perishable food as it reduces the rate of microbiological, physiological, biochemical and physical changes in the food. The cold-chain is designed to provide the best conditions for slowing or preventing these changes to occur for as long as feasible and enables food to be supplied to the increasingly urbanised world. During transportation packaging also plays an important role in avoiding food spoilage, maximizing shelf-life and in avoiding food waste. It has been found that if ambient temperature rise is 2-4°C and the temperature of chilled food is allowed to rise similarly there will be a significant increase in food poisoning and spoilage. With higher average temperatures, keeping food at current temperature during transportation and storage will require increased energy use. Data suggests that currently the food cold-chain accounts for about 1% of the worlds CO_2 emissions and can be expected to increase if current mode of refrigerated transport is continued (James & James, 2010).

In 2007 the EU was the world's second largest importer of seafood, accounting for 23% of global seafood imports (IntraFish, 2010). How the seafood is transported from the ocean to the consumer, and in what form matters. The localized ecological impact of fisheries is a very important part of the supply chain but there is a need to look beyond that. Buying seafood caught in certified sustainable fisheries which has been rushed to an airport and flown in to distant markets is an example of how the carbon footprint of the seafood can inflate rapidly along the cold-chain. Airfreight is the most energy intensive way to move food as well as the fastest option. Currently the requirements of the consumers are fresh seafood, as it is assumed to be the best option in most cases. Improved freezing and storage methods have resulted in the opportunity to provide high quality frozen seafood and it can travel by water and/or rail which are greener forms of transport than air freight (Freidberg, 2009).

2.6.1 Fresh versus Frozen

Currently the general consumer preference is to buy fresh seafood as fresh fish is generally considered better than frozen. In the seafood industry fresh implies that the fish has never been frozen during the cold supply chain from catch to the consumer. Fresh, at best, usually means it is delivered to market up to two or three days after it was caught and sold on the market up to nine days old (Pelan, 2010). Shelf life and quality of fresh foods is dependent on the product temperature. The generally accepted shelf life of three fish species is shown in Figure 8.

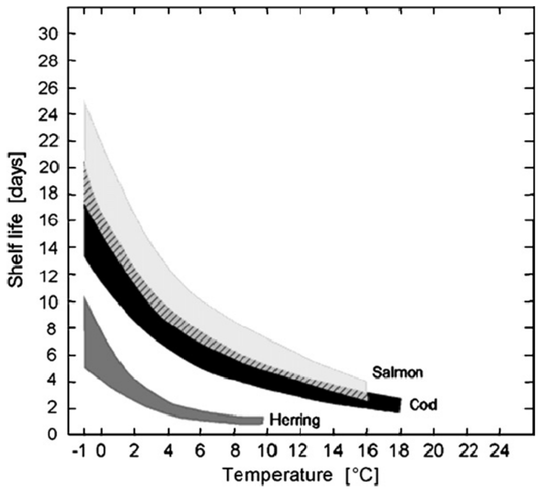


Figure 8: Accepted shelf life of three different fish species (Magnussen et.al 2008)

The current cold chain distribution system in Europe is complex and involves a large number of participants and competing companies. Food producers and retailers depend on various subcontractors to deliver the fresh perishable food. Basic knowledge of chilling is often quite limited and many employers have limited understanding of the significance of energy transfer. Due to the shortcomings of cold chains fresh fish products are often chilled in refrigerated seawater and ice and after packaging in boxes extra ice is added. As a result large quantity of ice is transported with the fish. The current cold chain has many weak links as mistakes and poor temperatures are frequent. This results in reduced product quality and shortened shelf life of the fresh products (Magnussen, Haugland, Torstveithemmingsen, Johansen, & Nordtvedt, 2008).

2.6.1.1 FRESH

The shelf life of cod fish fillets in expanded polystyrene (EPS) boxes is around 10 – 12 days after processing (Magnússon and Martinsdóttir, 1995). Sensory characteristics change during chilled storage and influence the marketability and consumer liking of the fish products. The focus of numerous studies on chilling and packaging technologies has been on the extension in shelf life of fish and the possibility to maintain the fresh like characteristics for prolonged time before the onset of spoilage. Chilling of fillets is traditionally done in the fish industry by immersing the fillets in ice/water or brine solutions. Subsequent chilling in a freezer after packaging has proven useful to store refrigerating capacity into the product. If left too long, slow freezing can occur, causing undesirable ice crystal formation, inducing tissue damage and quality loss (Ólafsdóttir et al., 2006). The development and implementation of new chilling technologies and packaging methods to offer fish products with sufficient keeping quality are under way to meet increasing demand for fresh fish products on the market. Within the CHILL-ON EU funded project a number of chilling techniques such as liquid cooling, partial freezing by the "Combined Blast and Contact" (CBC) cooling and low temperature during storage and transport (< 0°C) have been studied and their efficiency evaluated to maintain quality and extended shelf life of fresh fish products packed in EPS boxes (Ólafsdóttir et al., 2010a).

The CBC technique is based on superchilling by lowering the temperature of the fillets quickly to -1°C. Then the cooling is based on the cooling capacity stored in the skin side surface layer, thus minimizing ice crystal formation in the fillets. The rate of freezing and the size of ice crystals are important factors influencing the survival of microorganisms. The superchilling with CBC and storage at 0.5°C resulted in an overall sensory shelf life of 12.5 – 14 days. In combination with superchilled storage at -1.5°C an extension in shelf life to at least 15 days was achieved (Ólafsdóttir et al., 2006). This extension in shelf life of chilled fish fillets is of importance to allow the transport of products to distant markets at lower cost and by greener means, i.e. ship freight instead of air freight.

2.6.1.2 Frozen

Currently, fishing trawlers are able to clean and flash-freeze fish shortly after catching it. The flash freezing freezes the water inside fish tissues and stops the microbiological activity in the fish, including pathogens which cause spoilage and food poisoning (Pelan, 2010). Improved freezing and storage methods have lead to frozen fish to be much better than in the past, as the fish is frozen very rapidly shortly after being caught. Today, many articles are being published encouraging people to choose frozen rather than fresh seafood. What is most important is to educate consumers on the advantages of buying frozen rather than fresh, emphasising not only the quality, but also the environmental gains of buying frozen seafood products. If the motivation of the environmentally conscious consumers is truly to make diets more earth friendly a new perception is needed: Buy frozen (Scholz, Sonesson, & Tyedmers, 2009).

Nielsen et al., 2003 investigated the consumer’s attitude towards frozen fish. The first study involved questioning consumers about their perception on frozen fish without any tasting experiments. The study found that frozen fish is believed to be of poorer quality than fresh fish. A second test based on a questionnaire to evaluate the consumer´s liking and preferences was conducted where consumers brought home and tasted frozen and thawed fish. The second study showed that the consumers liked the frozen fish of high quality and preferred the frozen fish to the thawed fish (Nielsen et al., 2003). A study by Sveinsdottir et al., 2009 analyzed the quality and consumers attitude towards different cod products. Consumers in four North European countries tasted the different products and were divided into five clusters depending on different liking: farmed cod lovers, freshness lovers, negative consumers, storage lovers and positive consumers. For this study, the highest preference was found for frozen cod products of both short and extended storage time (Sveinsdottir et al., 2009). These two studies indicate that there are good marketing possibilities for frozen fish products.

In Iceland the processing of fish is continuously changing, and in Figure 9 it can be seen that since 2007 demersal fish (cod, haddock, saithe and redfish) that is frozen at sea a few hours after being caught reached the amount of fish frozen in land. It is clear that the proportion of fish frozen at sea is increasing. Meanwhile the amount of fresh demersal fish, iced and exported by air is increasing as well (Statistics Iceland, 2010). Worldwide, the production of frozen fish products is expected to increase in the near future (Agriculture and Agri-Food Canada, 2005)

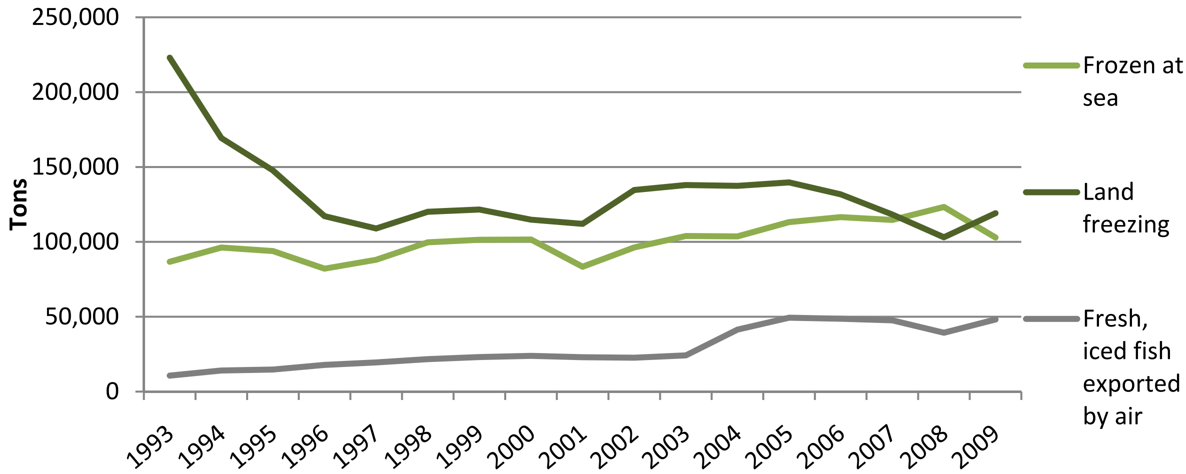


Figure 9: The processing of demersal fish (cod, haddock, saithe and redfish) in Iceland from 1993 – 2009 (Statistics Iceland, 2010)

2.7 Previous Studies on LCA

Various studies on environmental impacts of different food products have been conducted during the last decade. LCA has been used in many of the studies to evaluate the environmental performance of food products and production systems. Two LCA studies on Icelandic seafood have been conducted and a few LCA have focused on the transport of fish from the production to the consumer. Below is an overview of a few studies encountered.

2.7.1 LCA on Icelandic seafood products

In 2003 the Icelandic Fisheries Laboratories and the Technological Institute of Iceland published a LCA of Icelandic frozen cod products. The system boundaries included the entire life cycle including fisheries until the fish is served at a restaurant in England. The project examined the viability and limitations of LCA regarding evaluation of the environmental impacts of cod production, environmental labelling, eco-friendly product development and streamlining LCA for small and medium enterprises. The project demonstrated that LCA indicates where the greatest environmental gains can be expected in the production chain. In the case of Icelandic cod production the greatest environmental impact was traced to consumption of oil during the fishery phase. Operation of the fishing gear (bottom trawls) was the most oil intensive operation, using 70% of the total oil used in a fishing trip. Furthermore, it was found that in order to produce 400 g of fish fillet to the consumer dish an average of 0.65 L of oil was needed. LCA was found to be a useful decision making tool to monitor environmental impacts in production chains and for defining criteria for eco-labelling (Eyjólfsdóttir, Yngvadóttir, Jónsdóttir, & Skúladóttir, 2003).

A master's thesis was published in 2009 at the University of Iceland where the environmental impacts of different fishing methods in Iceland were compared using LCA. The entire life cycle was analysed, from fisheries, processing, transport, consumption and final disposal. The study evaluated the environmental impact of 1 kg of frozen, processed Icelandic cod caught either by a long liner or a bottom trawler. The study found that bottom trawled cod has higher environmental impacts where the most dominating phase was the fishery phase for both fishing methods. The second greatest environmental impact for the long lined cod is the transportation of cod by ship from Iceland to the market in Spain. For both fishing methods the carbon footprint was calculated and found to be 5.14 kg CO_2 equivalence for the bottom trawled cod and 1.58 kg CO_2 equivalence for the long lined cod (Guttormsdóttir, 2009).

2.7.2 LCA on transportation of seafood products

Transportation of fish from aquaculture in Western Norway to Europe was analysed by Andersen, (2002). The analysis shows that the transportation of the finished product is very energy demanding and the dominating factor in terms of energy use. Furthermore, transcontinental transport of fresh fish by air freight uses 10 times more energy than when transported in frozen state by sea (Norway to Japan). This implies that if a product is to be transported long distances the transport should be carried out in a product form suitable for transport by energy efficient transport mode. For transportation within Europe it is possible to continue the fresh transport given a shift in transportation modes from road based transport to sea and rail transport (Andersen, 2002).

The transportation of frozen fish from Ålesund, Norway to Paris, France was analysed in 2000 where two different transportation chains were compared. Transport chain A was mainly water borne, including RoRo vessel, harbours, heavy duty vehicle and roads, chain B was mainly land transport including heavy duty vehicle, roads, loading terminal, car ferry and harbours. The study focused on the operational stage of the transport means and therefore the depletion of natural resources, production and scrapping was not included. The focus was on emissions to air, toxic releases, noise and land use from road transport. For all of the environmental categories investigated except for toxic contamination, chain A (mainly water borne) was found to have a better environmental performance (Karlsen & Angelfoss, 2000).

LCA study on a salmon supply chain where salmon was caught in Alaska and transported to Seattle was done by Freidberg, (2009). The shift of a Seattle based company from air freighted fresh salmon to frozen fish transported by sea was analyzed. The life cycle was studied from ‘cradle to gate’, i.e. from the catching of wild salmon in Alaska and its transport to the retailer located in Seattle. The comparison of the two transportation modes, air versus sea, revealed that there is a dramatic difference in the environmental impacts between the two modes. Emissions from air freight were found to be manifold the emissions from the sea based transport. The Seattle based company therefore significantly reduced the environmental impact of their product, as well as saved money, by shifting from air to sea based transportation and from fresh to frozen (Freidberg, 2009).

In a recent global LCA study on salmon it has been found that “mode matters more than miles”. The final results of the study have not been published yet but the initial findings are that it is important to think about how food was produced and transported, not just where it was produced. Air freighted salmon resulted in substantial increase in the total environmental impacts and increased consumption of frozen food would lead to more transportation by container ships, which were found to be the most efficient and carbon friendly way to transport food. Buying frozen salmon was found to be more important than buying organic vs. conventional or wild vs. farmed (Tyedmers, Walker, & Sonesson, 2010). It is therefore necessary, as mentioned above, to get a greater consumer acceptance of frozen seafood in order to make the shift in transportation mode possible.

2.7.3 LCA on various food products

A literature review by Roy et al., 2009 shows that LCA studies on food products have mainly been conducted on agricultural products. In addition it has been demonstrated that LCA can help identifying more sustainable option in food production. LCA studies on food products identified in the study include:

- LCA of industrial food products: bread, beer and tomato ketchup.
- LCA of dairy and meat production: milk, cheese, meat (beef, pork, chicken)
- LCA of other agricultural products: rice, sugar beet, potatoes, tomato
- Land, water and other approaches in LCA: water consumption, land use, Ecological footprint (EF), Life cycle costing (LCC)
- LCA studies on packaging systems: glass bottles, aluminium cans and steel cans (beer), paper box (tomato import), polylaminate bags and metallic cans (coffee), polystyrene packages and recycled paper packages (eggs), plastic based packaging materials
- LCA of food waste management systems: liquid effluent with high organic content, sludge and solid waste. Incineration, incineration after bio-gasification, bio-gasification followed by composting and composting. Reduction or elimination of wastes or pollutants at source.

A number of LCA studies on fish products were encountered. LCA methodology was used to find the global warming potential of smoked trout fillets cultivated in Danish aquaculture in order to identify the processes with major environmental impacts (Körner and Madsen, 2009). A second study on the environmental impacts from Danish fish products with a focus on LCA results for flatfish identifies the fishing stage as having the largest environmental impact (Thrane, 2005). A Swedish study on the full life cycle of a seafood product found that the dominating phase regarding environmental impacts is the fishing stage followed by the transports of the products. (Ziegler et al., 2003) These findings are in accordance with the findings of Eyjólfsdóttir, Yngvadóttir, Jónsdóttir, & Skúladóttir, (2003).

3 LIFE CYCLE ASSESSMENT METHODOLOGY

LCA is today, the leading tool for identifying and comparing environmental impacts of industrial production systems. It is well suited for assessing biophysical performance of industrial activities. Below the LCA methodology is described.

3.1 LCA

LCA is defined as the compiling and evaluation of the inputs and outputs and the potential environmental impacts of a product system during a product's lifetime (PE International, 2009). In Figure 10 (on left) a typical life cycle of a product is shown. The methodology can be used to assess utilization of resources and global and regional environmental impacts for a process, product or service. Furthermore, LCA can assist in decision making and selection of relevant indicators of environmental performance and help to identify opportunities in improving environmental aspects of products at different points in their life cycle as well as being a valuable input to marketing, for example in terms of ecolabelling schemes and environmental product declarations (PE International, 2009).

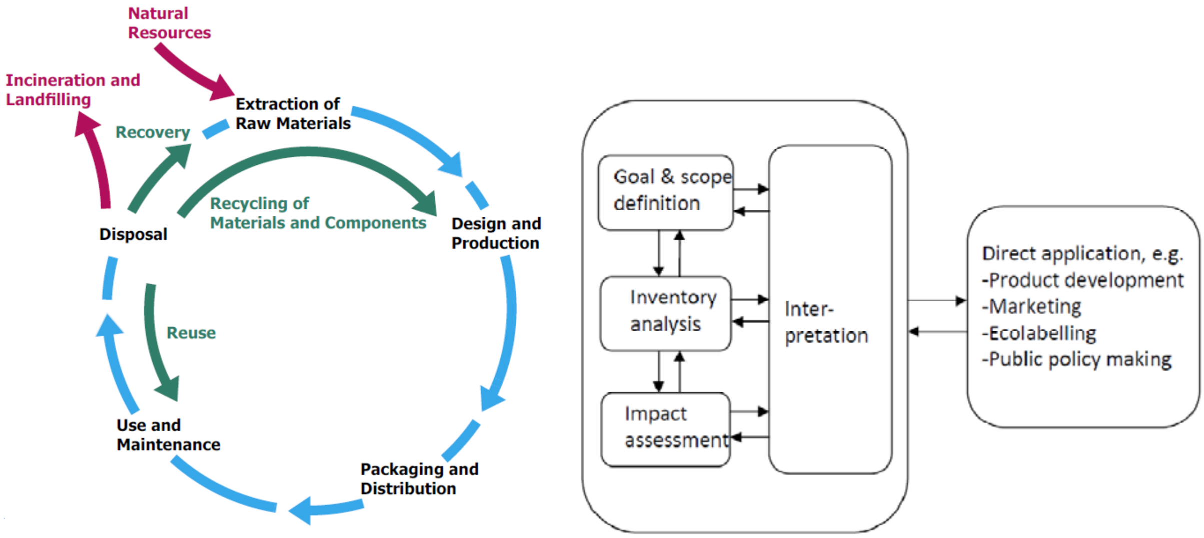


Figure 10: Schematic diagram showing a typical life cycle for a product system on left and the steps of LCA on the right (Remmen, Jensen, & Frydendal, 2007)

The LCA is conducted according to the requirements of ISO 14040 and 14044 and consists of four steps:

1. Goal and Scope Definition
2. Inventory Analysis
3. Impact Assessment
4. Interpretation

Figure 10 (on the right) shows the steps of LCA according to the ISO standards. Each step is described further in the following.

3.1.1 Goal and Scope Definition

In the first step decisions are made for setting up the LCA where the goal and scope of the study are clearly defined. The goal depends on the purpose of the study and its intended application and audience. For the scope definition all assumptions are detailed and the methodology used to set up the product system is defined. Detailed description of the function of the product, the functional unit, system boundaries, allocation and system expansion is required.

System boundaries can be defined in four ways: cradle to grave, cradle to gate, gate to grave and gate to gate, where only cradle to grave considers the entire life cycle.

3.1.2 Life Cycle Inventory Analysis

Inventory analysis involves data collection and quantification of inputs and outputs for the given product system. This step includes compilation of the data collected into a Life Cycle Inventory (LCI) table. This process is the most time consuming phase in the LCA as it includes collection of quantitative and qualitative data for all unit processes.

3.1.3 Life Cycle Impact Assessment

In the impact assessment the significance of the potential environmental impacts arising from the LCI is identified and evaluated. Mandatory elements of the impact assessment include selection of relevant impact categories, classification and characterisation. Optional elements include normalization, grouping and weighing.

3.1.4 Interpretation

The interpretation includes identification of the most significant issues that result in the most significant environmental effects and evaluation of the study. This involves reviewing if the results are consistent with the goal and scope definition and assessing if the study is complete (PE International, 2009).

3.2 Social and Socio-Economic Impacts of the Products Life Cycle

Currently LCA is not fit for performing a full assessment of goods and services within the context of sustainable development. Sustainable development requires that environmental, economic and social aspects of the products life cycle are considered. The social and socio-economic impacts of production and consumption on workers, local communities, consumers, the society and all value chain actors are important to evaluate as well as the environmental and economic impacts. However, social aspects are often qualitative, normative and often subjective and their assessment can be challenging and includes the finding of a consensus on social impact categories and how to measure it (Jeswani, Azapagic, Schepelmann, & Ritthoff, 2010).

The main emphasis of fisheries management has been on the conservation of fish stocks. Today, fisheries management requires that all three pillars of sustainable development are addressed see Figure 11. The fisher's welfare, maximization of economic returns from the fisheries, conservation of fisheries resources and their environment, payment of fees to communities from profits made from the exploitation of public resources and environmental protection are all equally important (Ünal, 2006). Furthermore, the consumer preferences for fresh, safe, healthy and quality seafood must be taken into account.

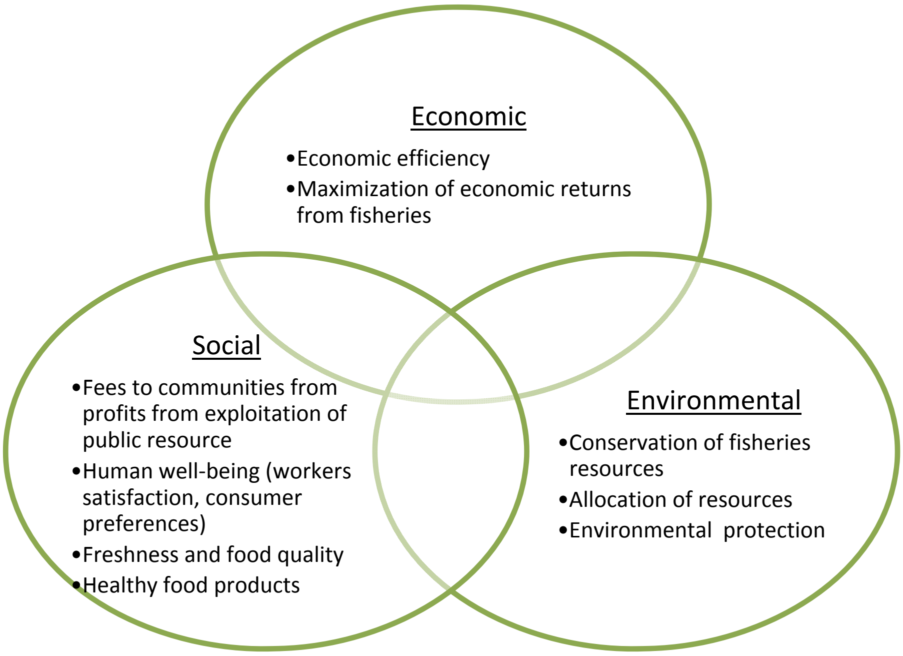


Figure 11: The three pillars of sustainability of seafood production and the corresponding subjects

Guidelines for the assessment of the social and socio-economic life cycle of products have been published in order to assess and report on these impacts and benefits of product life cycle from cradle to grave (UNEP, 2009). Social life cycle assessment is beyond the scope of this report.

4 LCA OF FRESH FISH LOGISTICS CHAIN

4.1 INTRODUCTION

The Carbon Footprint is calculated using the LCA methodology. Two cold supply chains are considered which have been mapped in the European CHILL-ON project and involve transportation of fresh fish fillets/loins in EPS boxes from Iceland to markets in Europe by container ship or by air freight. The chains are typical for exported fresh fish from Iceland since the mapping was performed in connection with actual shipment of products from major seafood companies. The sea freight chain mapping was conducted as a part of field trials in the cod supply chain (IS-FR in March 2010), in connection with validation of wireless sensor technologies for temperature and location of products according to transport route in Figure 12. A documentary about this CHILL-ON field trial was created by Euronews (Euronews, 2010). The air freight supply chain is partly simulated but timelines of the airfreight was based on a mapping trial in 2009, (Jónsdóttir et al., 2009). The assumption is made that products are transported in refrigerated containers during land transport until delivery in Boulogne sur Mer. It is not taken into account that boxes are unloaded from the airplane and stored in coolers until transported. Refrigerated trucks are often used instead of refrigerated containers.

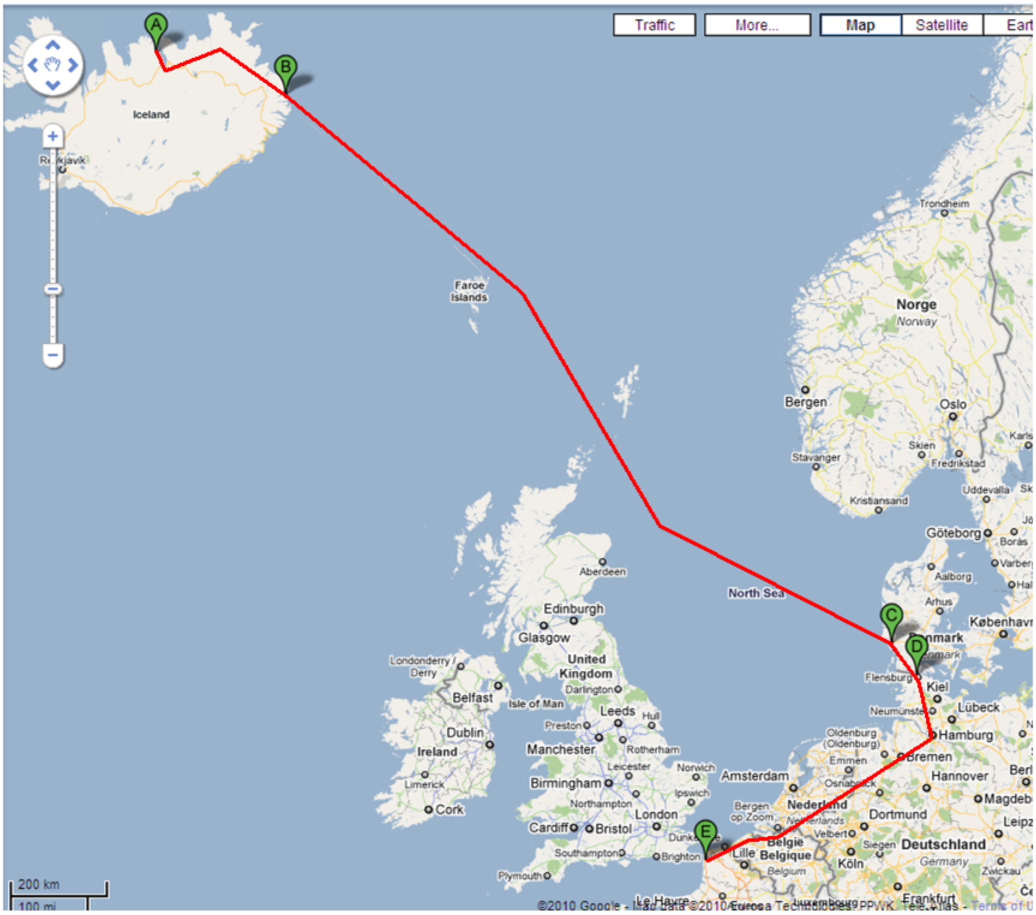


Figure 12: The approximated mapped transportation route for the sea freighted cold supply chain.

The LCA was conducted using the software Gabi Education from PE International. Gabi is a software modelling tool for products and systems from a life cycle perspective. Gabi tracks all flows of materials, energy and emissions and assigns to the appropriate impact category. The version of Gabi used here is as mentioned above the educational version. Access to databases is therefore limited to the PE datasets and the USLCI datasets (PE International, 2009 and 2010).

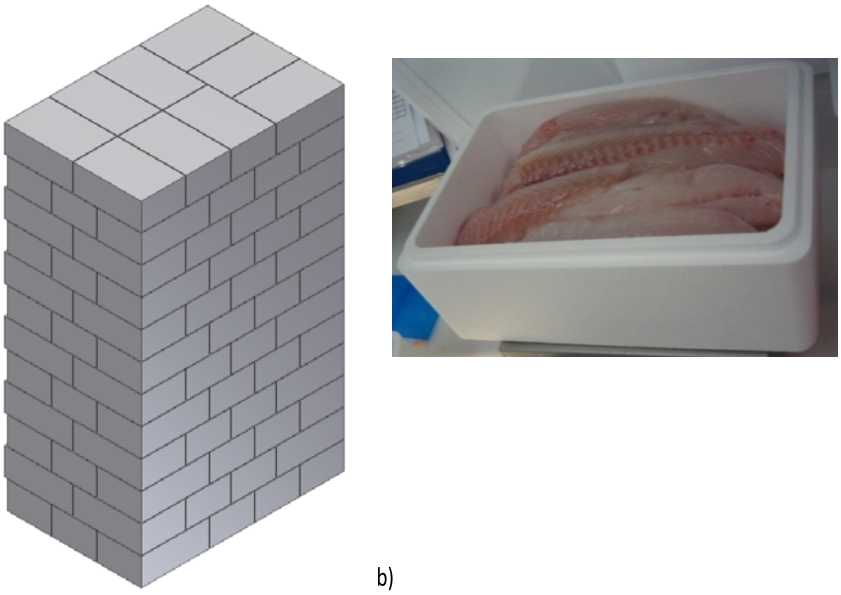
4.1.1 Goal of the study

The goal of this LCA study is to calculate the carbon footprint and evaluate energy consumption for transportation of fresh seafood products (demersal fish) from Iceland to markets in Europe. Furthermore, the goal is to compare the environmental performance of alternative transportation systems. As the Carbon footprint is a measure of anthropogenic GHG emissions the environmental impact coverage will focus on GWP. The GWP is calculated in Gabi Education using the EDIP 1997 method.

4.1.2 Functional Unit

The functional unit is chosen as one pallet loaded with fresh fillets of demersal fish (skin off), caught in Icelandic sea and transported to markets in Europe. Each pallet is loaded with 108 EPS boxes each containing 5 kg of fresh demersal fish fillets, in total one pallet contains 540 kg of fresh white fish fillets. Figure 13 shows the elements of the functional unit.

4.1.3 Description of the Chilled Fish Supply Chain and System Boundary



a) b)

Figure 13: a) The functional unit: one pallet loaded with 108 EPS boxes containing in total 540 kg fresh white fish fillets and b) fresh white fish loins in EPS box

As stated above, the chilled fish supply chain is examined for two different transportation modes. The fish is either transported to Europe by a container ship or by air freight. The LCA study will not follow the fish from ´cradle to grave` but from ´gate to gate` as the entire life cycle will not be considered. This study starts when the fish has been landed on deck in Iceland and is stored in the processing storage and ends when the fish is delivered at a retailer in France. In Figure 14 below the whole life cycle for the fish fillets is shown along with the system boundaries. The steps included in the LCA study are:

1. Processing, packaging and cold storage.
2. Transportation of fish on land in cooled containers.
3. Transportation of fish by sea and air freight.

Consumables used for processing and transport are included in the study but the production and disposal of capital goods (trucks, moulding machines etc.) are not included in the LCA. The production of packaging and fuel production are taken into account.

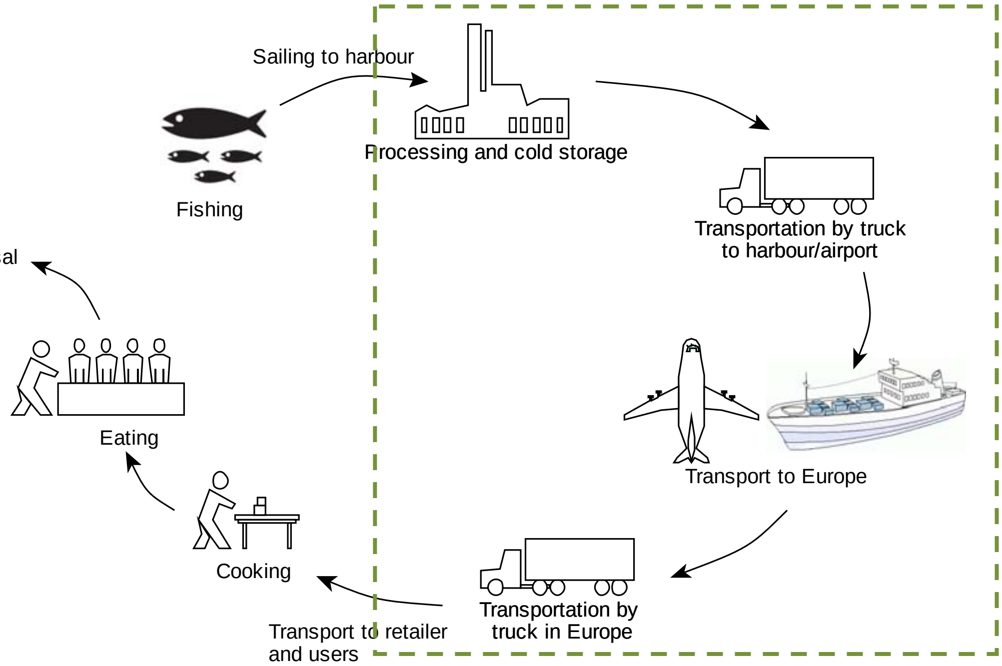


Figure 14: The whole life cycle of demersal fish fillets, from cradle to grave, and the system boundaries for this study are shown within the green dotted square

4.1.3.1 System Description

The system boundaries start when the catch is landed at harbour and transported to the main processing storage. It is assumed that the fish is landed in northern Iceland. The fisheries phase, which has been found to be the greatest contributor to global warming in previous studies on the total life cycle of fish, is not included in the study and the focus is on the cold storage, processing and transportation of the fresh product. The fresh demersal fish is stored and processed at a processing plant where the fish is packed in EPS boxes with 5 kg of fresh fish loins per box and 400 g of ice. The EPS box is produced in Iceland but the polystyrene granulates are imported from Europe. The packed EPS boxes are loaded on EURO pallets and transported in cooled containers by trucks to harbour or airport. The fish is then transported by a containership or with air freight to Europe. In the containership the fish is still in the same container as was used in the land transport in Iceland. During the flight the fish is not in a cooler. In Europe the product is again transported in cooled containers to a retailer in Boulogne sur Mer, France. During the transportation it is assumed that the product is kept at -1°C and ambient temperatures are assumed to be average temperature in March. During the truck transport in Europe the fish is assumed to be kept in the refrigerated containers at -1°C during stops. In Figure 15 a schematic view of the processes examined are shown with the relevant material and energy in- and outputs for each process.

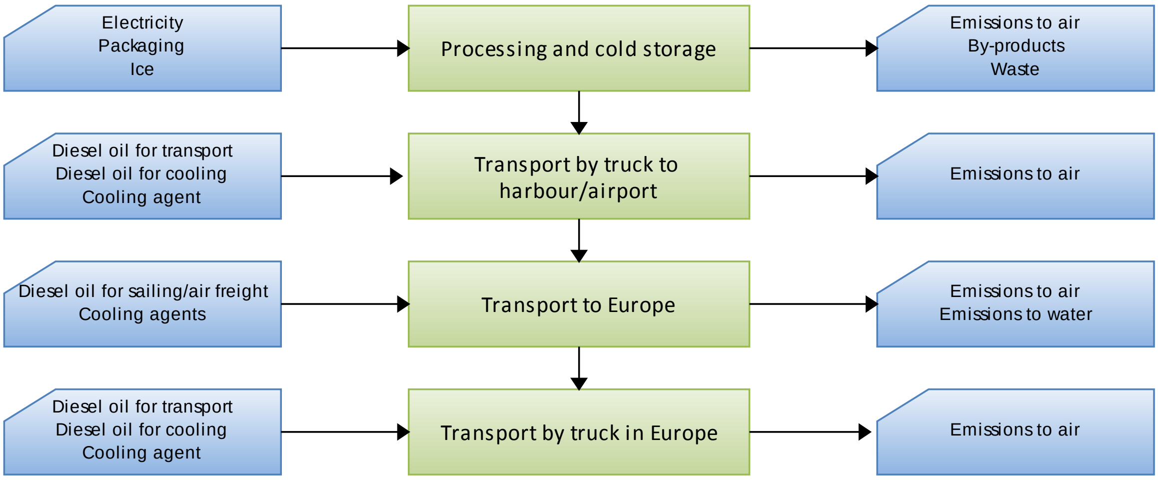


Figure 15: Schematic view of the system boundaries in the study along with the relevant material and energy for in- and outputs

The different timelines used for both transportation modes are shown in Figure 16. The total time of the cold chain is 144 hours and covers 2,787 km for the sea transport and 45 hours and 3,063 km for air freight. The actual timelines and chain boundaries from the mapping in March 2010 used for the sea freight cold supply chain can be seen in Appendix I.

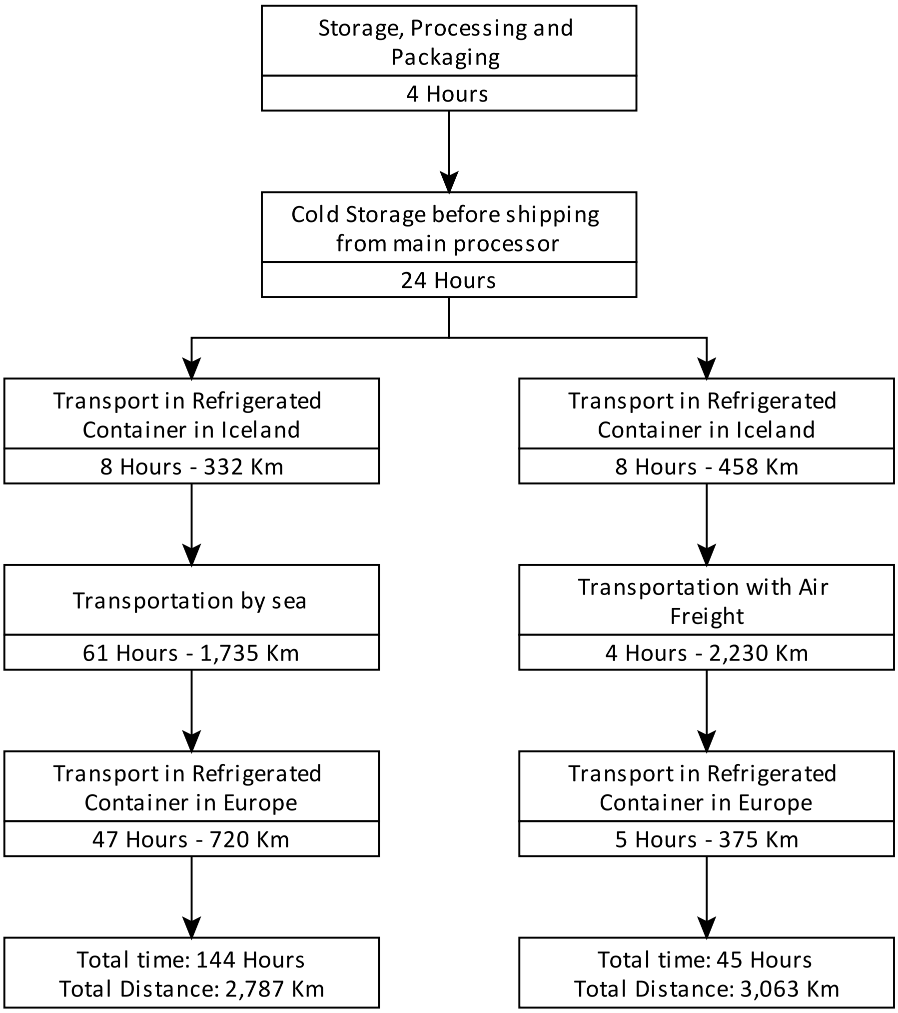


Figure 16: Timeline and distance for the different transportation modes, with sea transport on the left and air freight on the right (Anon., 2010)

4.2 Inventory Analysis

Data was collected for all life cycle processes within the system boundaries that compose the analysed system. Input and output quantities for each unit process were collected, including materials, energy and emissions to air. A compiled list for data collection, assumptions and description of individual phases of the life cycle is given in Appendix II.

4.2.1 Methodology and data collection

The product is one pallet (540 kg) of fresh demersal fish processed and packed in Iceland and transported to Europe by:

a) container ship
b) air freight.

The ´gate to gate` analysis includes the production of EPS boxes, processing, cold storage, transportation of materials and the transportation of the final product to Europe. The gathering of data for each of the life cycle phases is described below.

4.2.1.1 Packaging

The packaging consists of an EPS box manufactured in Iceland where the expandable polystyrene (PS) is imported from Europe. The data on the expandable PS granulate is taken from ELCD/Plastics Europe database in Gabi. Information on the manufacturing of EPS boxes was gathered from an Icelandic EPS box manufacturer. Transportation of the expandable PS granulate from Europe includes transportation by barge in Europe, cargo ship from Rotterdam to Reykjavík, drive from harbour in Reykjavík to the manufacturing plant and the transportation of the EPS boxes by a truck to the fish processing plant. Files used for the transportation processes including the production of fuel were taken from the PE Gabi Database.

4.2.1.2 Processing and Cold Storage

The processing is assumed to be located in northern Iceland. Data on a processing plant was obtained from a producer of fresh and frozen demersal fish fillets. At the fish processing plant the fork lift, ice production and coolers are all operated using electricity. Furthermore, for the freezing and ice production the cooling agent is ammonia (NH_3) which has a zero GWP and is therefore not accounted for in the calculations (International Institute of Ammonia Refrigeration, 2010). Cleansing materials are excluded from the calculations as their main impacts would be on emissions to water through wastewater but not on atmospheric GHG emissions. The data used for the processing plant is therefore electricity which was calculated as kWh per kg of processed demersal fish at the plant in 2009. As the plant manufactures fresh and frozen fish fillets, it can be assumed that for the fresh fillets the energy use is slightly overestimated as more energy is needed for freezing.

4.2.1.3 Electricity in Iceland

The electricity for packaging and processing was modelled using the ELCD/PE database in Gabi on Icelandic power grid mix. The database in Gabi calculates that for each gigawatt-hour (GWh) produced and used in Iceland 23 tons of CO_2 equivalents are released to the atmosphere.

From the Icelandic National Inventory Report on the emissions of GHGs in Iceland it was found that the average GHG emissions from energy production are 13 tons CO_2 equivalents per GWh (Hallsdóttir, Harðardóttir, Guðmundsson, Snorrason, & Þórsson, 2010). Gabi is thereby estimating around 43% higher emissions than found in the literature. This discrepancy can be explained by various factors related to the inventory analysis and the input data which would need to be compared and evaluated. However, such task is beyond the scope of this project, but should be taken into consideration in future work. This confirms what has been pointed out by others that standardization of methodologies, inventory analysis and data sources for different product categories is very important

4.2.1.4 Transportation

The transportation is in three steps and includes transportation by truck from the processing plant to harbour in Eastern Iceland or to the airport in Keflavík, transport to Europe by a container ship or air freight and transportation by truck in Europe to the retailer. As for the packaging, the files used for the truck and container ship including the production of fuel were taken from the PE Gabi Database. The file for a cargo jet and the R134a coolant was taken from the LCI database from the Center for Environmental Assessment of Product and Material Systems, at the Chalmers University of Technology, Sweden (http://www.cpm.chalmers.se/CPMDatabase/Scripts/AdvGeneral.asp).

A 15 year lifetime of the refrigerated container was assumed with a total annual operational time equal to 120 days. Annual refrigerant charge for R134a of 5 kg and a leakage of 10% of the annual charge was used (Heap & Lawton, 1999). The energy use of the chilled containers was calculated using Figure A 2 in Appendix III assuming the ambient temperatures are average temperatures in Iceland, Denmark and France in March, see Table A 3 in Appendix III. In addition it was assumed that each 40 foot container is loaded with 23 EURO pallets. For comparison, in a report by Magnussen, 1993 a refrigerated container is said to require on average approximately 0.2 L diesel oil for 10 km for chilled cargo. The amount of diesel oil used for the refrigerated containers in the study, keeping the product at -1°C varies between 0.12 L/10 km in Iceland to 0.32 L/10 km in Europe. The difference in diesel oil use can for example be explained by the higher ambient temperatures in Europe than in Iceland. The two LCA studies on frozen cod caught and processed in Iceland suggest that the environmental impacts of the chemical compounds in the antifouling paint is negligible during the sea freight to Europe. Based on these results the antifouling paint is not considered in this study.

4.3 LCA Results and Discussions

The cold transportation chains of fresh fish were modelled in Gabi where the various processes of the life cycle were divided up in order to compare the different operations. Only processes that contribute to the carbon footprint of the transportation chains were modelled as the impact category analysed in this study is solely the global warming potential. In Figure 17 - 18 the modelled processes of the two cold chains are shown. Figure 17 and 16 showing the production of EPS boxes and the fish processing plant are mutual for both transportation chains. Figure 19 shows transportation of fresh fish by container ship and Figure 20 the transportation by air.

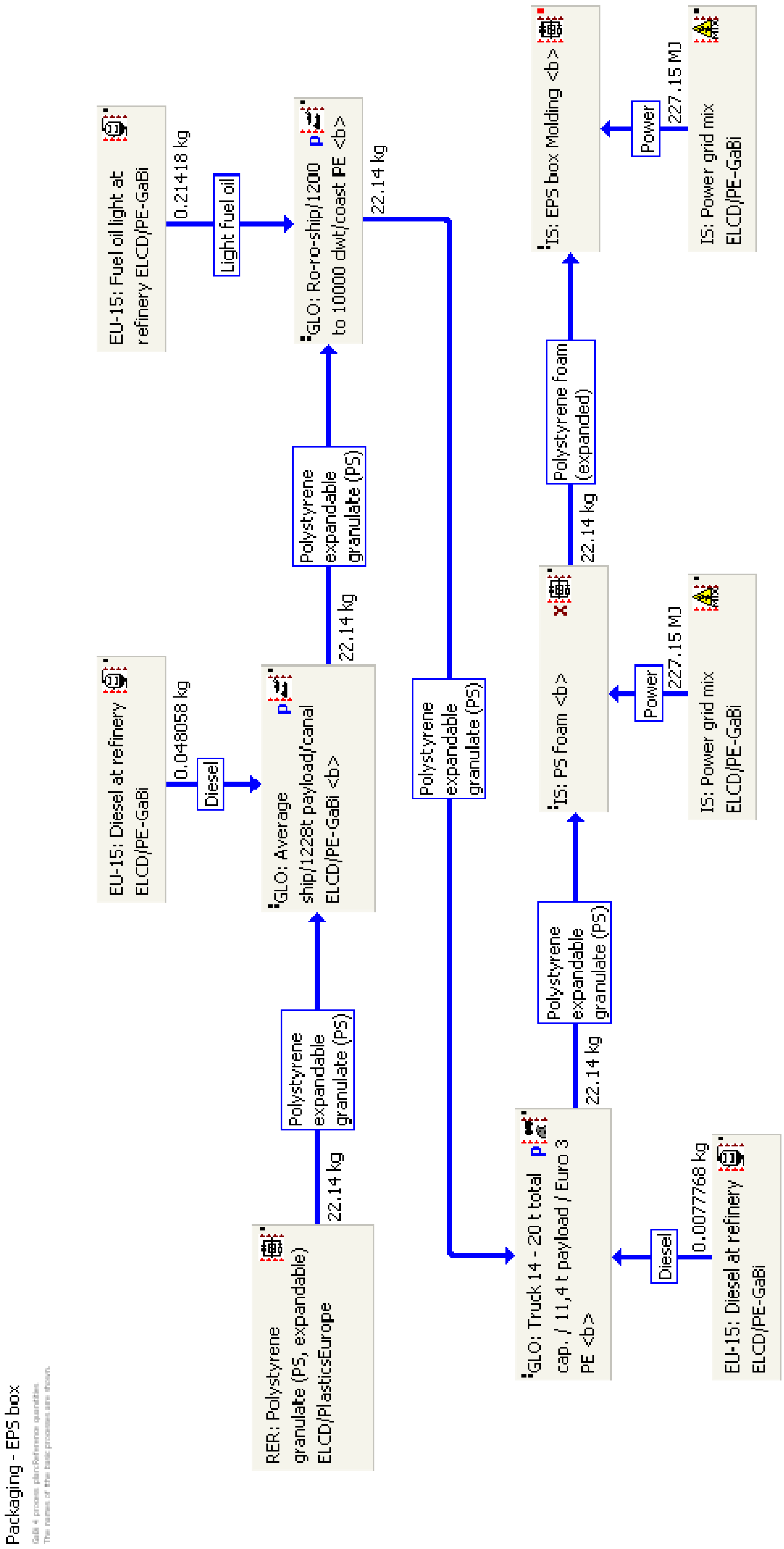


Figure 17: Screen shot from Gabi. The manufacturing of the EPS packaging and the PS granulate, including transportation

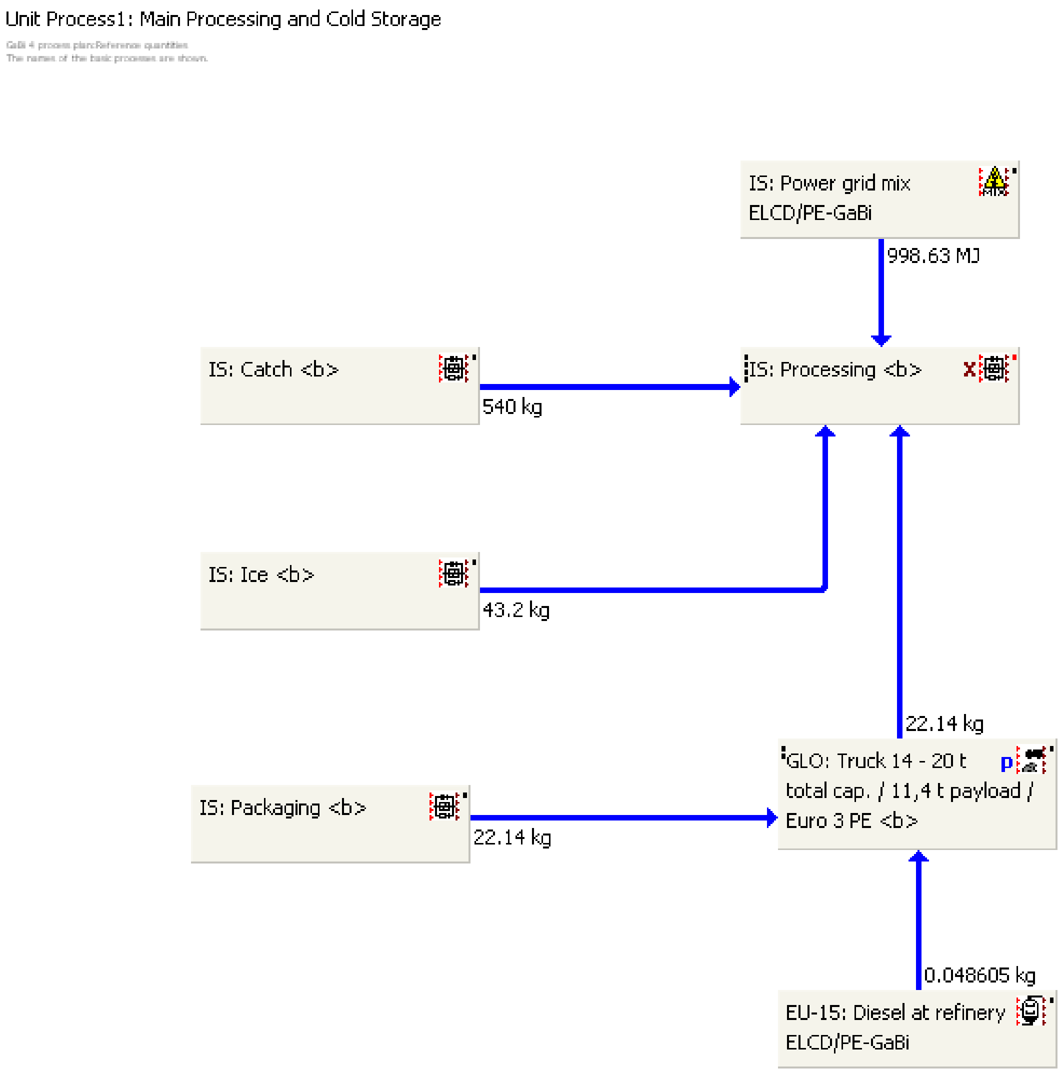


Figure 18: Screen shot from Gabi. The processing plant and the cold storage

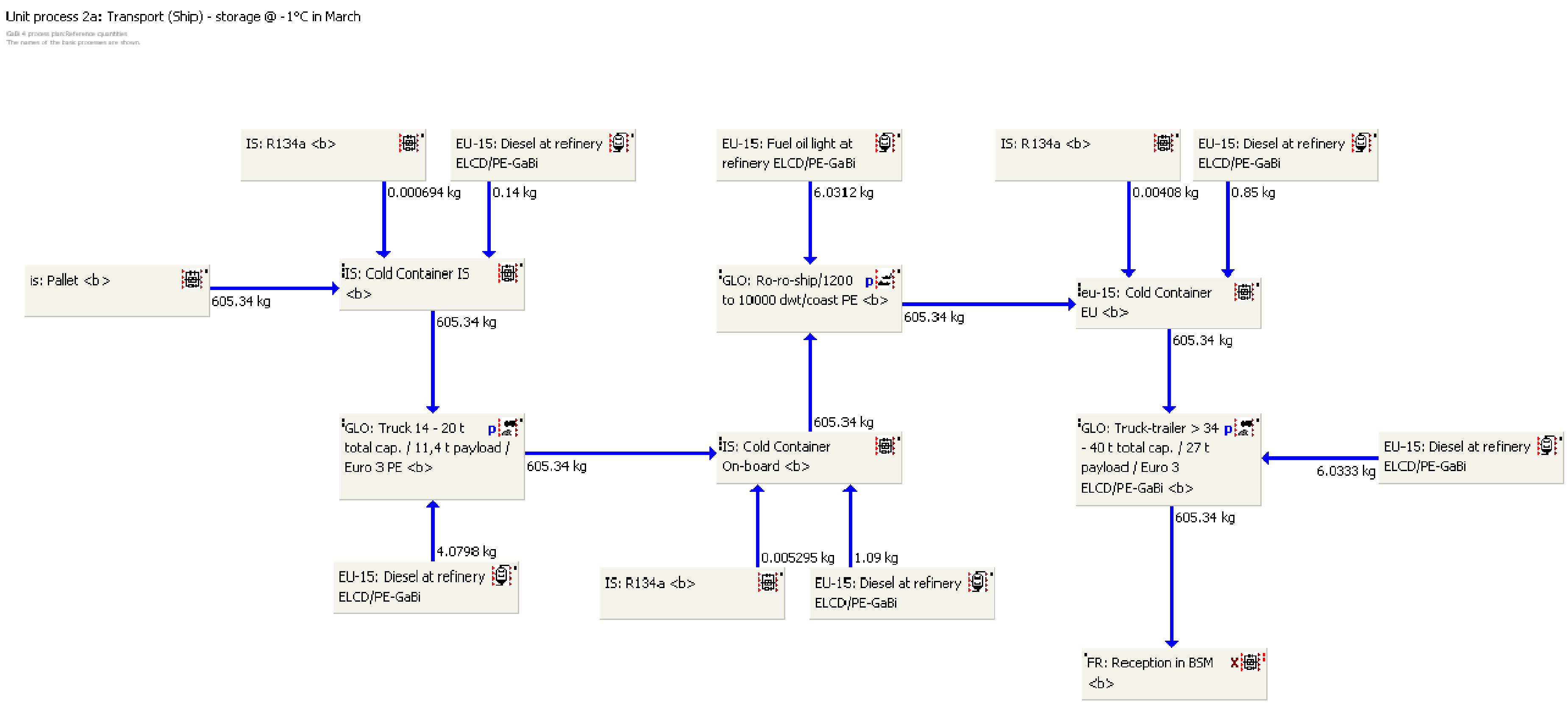


Figure 19: Screen shot from Gabi. The transportation of the FU by sea freight from Iceland to Europe

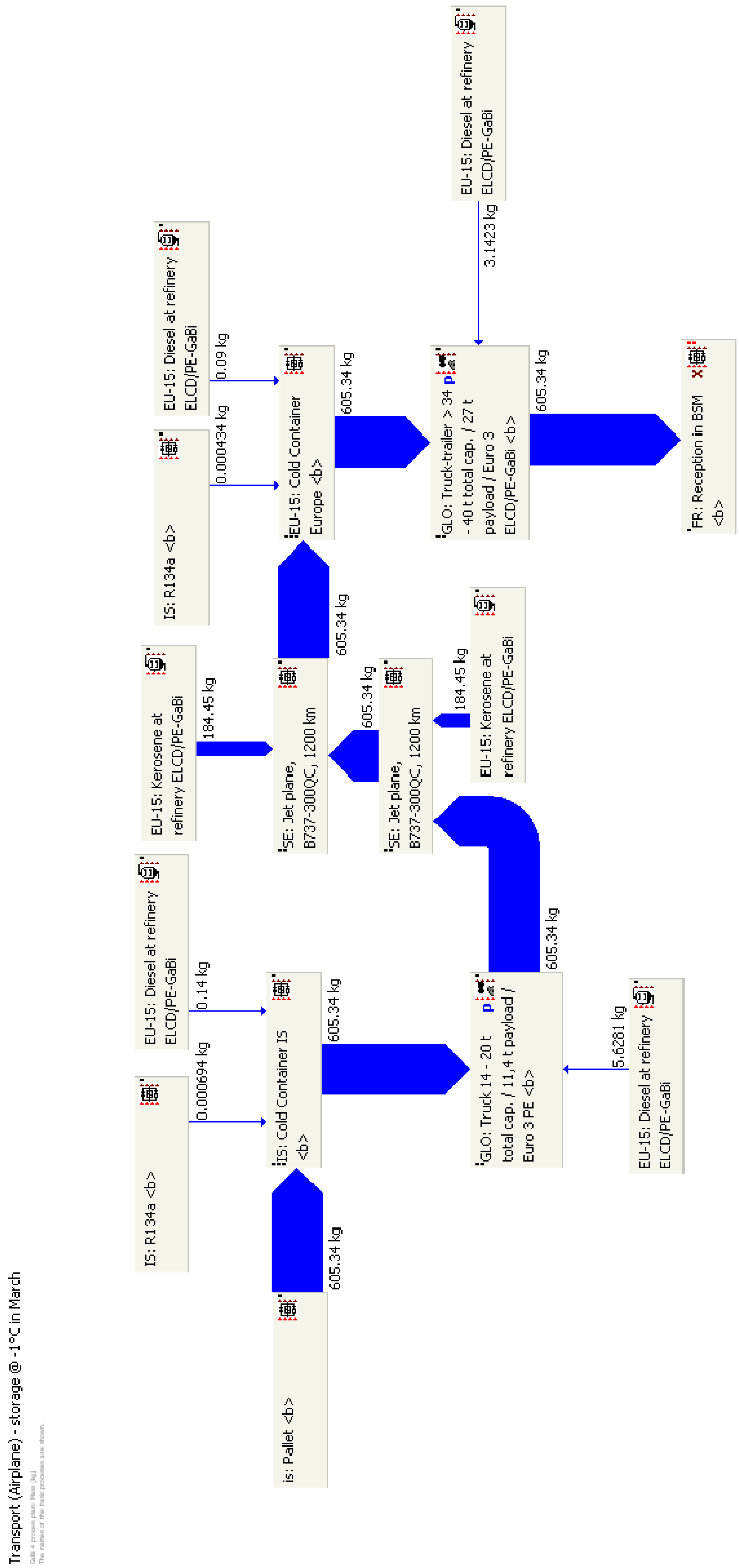


Figure 20: Screen shot from Gabi. The transportation of the FU by air freight from Iceland to Europe

4.3.1 Carbon Footprint

The results of the calculations of overall CO_2 emissions per functional unit from sea- and air freighted cold transportation chains show that there is a significant difference in CO_2 emissions (Figure 21).

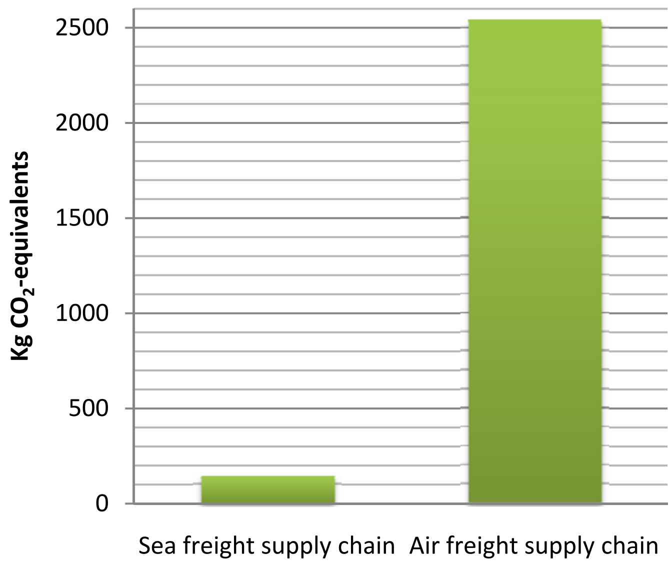


Figure 21: Total emissions of CO_2 equivalents in kg per functional unit (1 pallet with 540 kg fresh demersal fish) for the two cold supply chains

The total emissions for the functional unit processed, packed and transported by ship from Iceland to Europe is 145 kg CO_2 equivalents but when transported by air freight the emissions are found to be 2,542 kg CO_2 equivalents. The carbon footprint of air freighted fresh fish is therefore found to be almost 18 times larger than for the fish transported by ship.

The carbon footprint for the processing and transportation of 1 kg of fresh demersal fish from Iceland to Europe is found to be:

Sea freight:	0.3 kg CO_2 equivalents/ kg demersal fish
Air freight:	4.7 kg CO_2 equivalents/ kg demersal fish.

To further analyse the transportation chains, the contributions to the carbon footprint from the different processes, manufacturing of packaging, processing of fish and the transportation are shown in Figure 22.

As mentioned above, Guttormsdóttir (2009) found that the carbon footprint for the entire life cycle of bottom trawled and long lined cod transported by sea freight to Europe are 5.14 and 1.58 kg CO_2 equivalents respectively. Assuming that the sea freighted cold supply chain analysed here can be translated into these results it is found that the carbon footprint of the fisheries, consumption and final disposal for bottom trawled cod is 4.84 kg CO_2 equivalents and 1.28 kg CO_2 equivalents for long lined cod. Where the major contribution to the footprints are related to the fisheries phase. The carbon footprint of the entire life cycles of bottom trawled and long lined cod, transported by air freight to Europe can then be calculated as 9.54 and 5.98 kg CO_2

equivalents correspondingly. Regarding the entire life cycle it is not only the transportation mode that matters but also the fishing method.

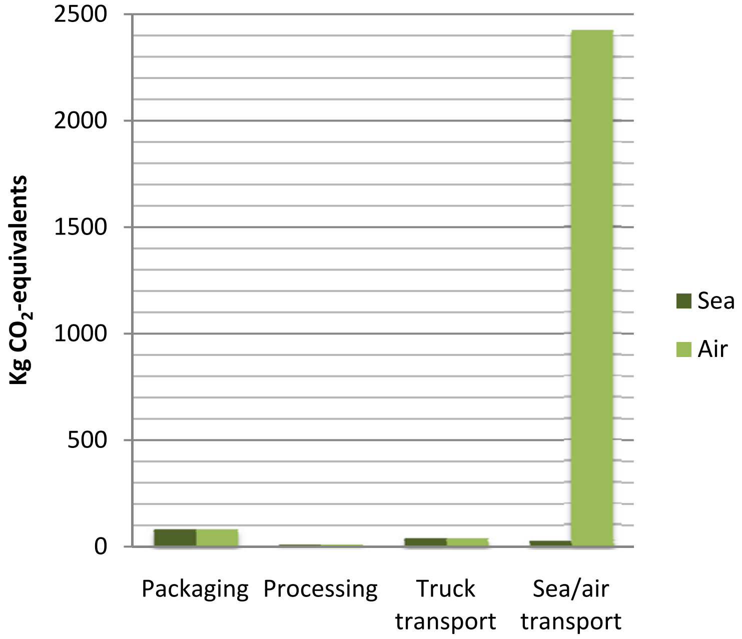


Figure 22: Emissions of CO_2 equivalents in kg per functional unit (540 kg fresh demersal fish) from the different processes of the cold supply chains, sea freight in dark green and air freight in light green

The transportation by air plane is by far the dominating factor of the air freight transportation chain, with 95% of the emissions (see Figure 22). The packaging accounts for 3%, the truck transport for 1% and the processing less than 1%. For the sea freight the manufacturing of the EPS packaging gives the highest environmental impact contributing 54% to the carbon footprint. The transportation by truck contributes 25%, the sea transport 16% and the processing 5%. In Table 4 the CO_2 equivalents emitted from each of the different processes of the cold supply chain for the functional unit is shown.

Table 4: The CO_2 equivalents emitted from each process of the cold supply chains, for 1 functional unit, 540 kg fresh demersal fish

	Sea Freight Supply Chain [CO_2-equivalents]	Air Freight Supply Chain [CO_2-equivalents]
Packaging	78.9	78.9
Processing	6.6	6.6
Truck transport	36.7	31.6
Sea/Air transport	22.6	2425.4
TOTAL:	144.9	2542.5

4.3.1.1 THE PACKAGING

As the EPS boxes alone have a carbon footprint of 79 kg CO_2 equivalents for the functional unit or 0.15 kg CO_2 equivalents per kg demersal fish and contribute significantly to both supply chains it is interesting to look at the manufacturing of the packaging. Figure 23 shows where the particular emissions derive from for the EPS boxes.

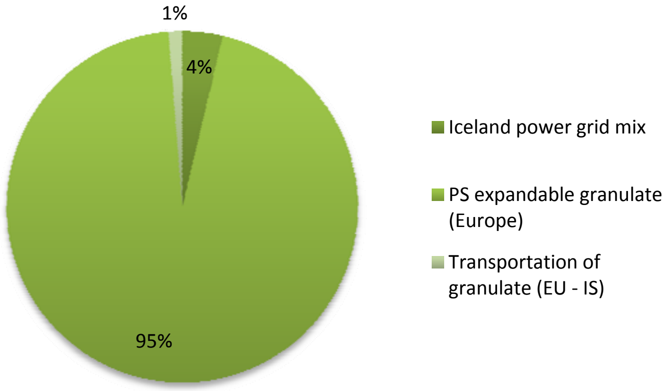


Figure 23: The contribution of the different processes of the manufacturing of EPS packaging to the carbon footprint of the packaging

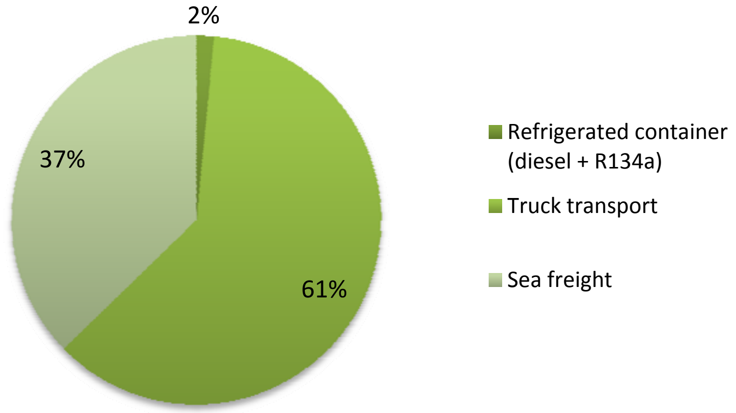
In Figure 23 it can be seen that the manufacturing of the polystyrene expandable granulate in Europe is the main contributor to the carbon footprint of the packaging, with 95% of the emissions. The EPS granulate is transported to Iceland mostly by water and sea transport with 1% of the carbon footprint and the manufacturing in Iceland corresponds to 4% of the footprint.

4.3.1.2 The Transportation

Looking at only the transportation part of the two supply chains it was found that the Carbon footprint of keeping the refrigerated containers at -1°C during the transportation stages was insignificant, see Figure 24. For the sea freighted cold supply chain the refrigerant R134a and the diesel used to run the container were found to contribute to 2% of the total transportation footprint and 0.004% for the air freighted fish and therefore even less for the entire cold supply chains where packaging and processing are included.

Although the truck transport of the sea freighted cold supply chain is proportionally the larger contributor to the overall footprint than in the transport of the container ship, the carbon footprint value is similar for the truck transport in both air and sea freight modes. However, when comparing the total transportation phase as illustrated in Figure 24 it can be seen that the truck transport is responsible for 61% of CO_2 equivalents released to the atmosphere from the sea freighted supply chain. The container ship contributes 37% of the carbon equivalent emitted from the total transportation phase (Figure 24a). The scenario is very different for the transportation phase of the air freighted cold supply chain where the air freight itself contributed to 99% of the carbon equivalent releases and the truck transport to 1%, see Figure 24 b).

a)



b)

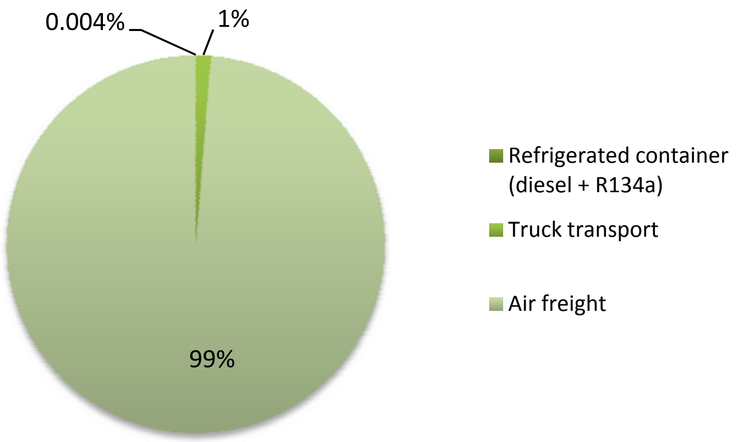


Figure 24: The relative contribution to the carbon footprint of different processes within the transportation phase of a) the sea freighted transportation chain and b) the air freighted transportation chain

4.3.2 Energy Consumption

The fuel needed to operate the cold supply chains was calculated. For the sea freighted cold supply chain the energy consumption was found to be 790 MJ and for the air freighted chain 17,500 MJ. The fuel needed to drive the air freighted chain is therefore 22 times the fuel needed for the sea freighted chain.

The energy consumption for the processing and transportation of 1 kg of fresh demersal fish from Iceland to Europe is found to be:

Sea freight:	1.5 MJ/ kg demersal fish
Air freight:	32 MJ/ kg demersal fish.

It is therefore clear that the air freighted fresh fish requires manifold the amount of fuel needed for the sea freighted fresh fish. Taking into account fuel prices the air freight is a significantly more costly transportation mode.

4.3.3 Electricity and Emissions from Refrigerated Containers

The contributions to the carbon footprint of the functional unit from the processing and the refrigerated containers can be seen in Figure 25. As mentioned earlier, the processing and the refrigerated containers did not have significant effect on the entire supply chains studied. However, the processing does play an important role when the total amount of demersal fish (cod, haddock, saithe and redfish) processed in Iceland in 2008 is analyzed. The carbon footprint for the processing of one functional unit (540 kg demersal fish) is found to be 6.6 kg CO_2 equivalents. The total amount of demersal fish processed in Iceland in 2008 (land freezing and fresh, iced fish exported by air) was 142,358 tons (Statistics Iceland, 2010). In total for the year 2008 the carbon footprint for the processing of demersal fish was 1,746,225 kg CO_2 equivalents, or 0.05% of Iceland's total GHG emissions.

Below is a discussion on the processing and refrigerated containers.

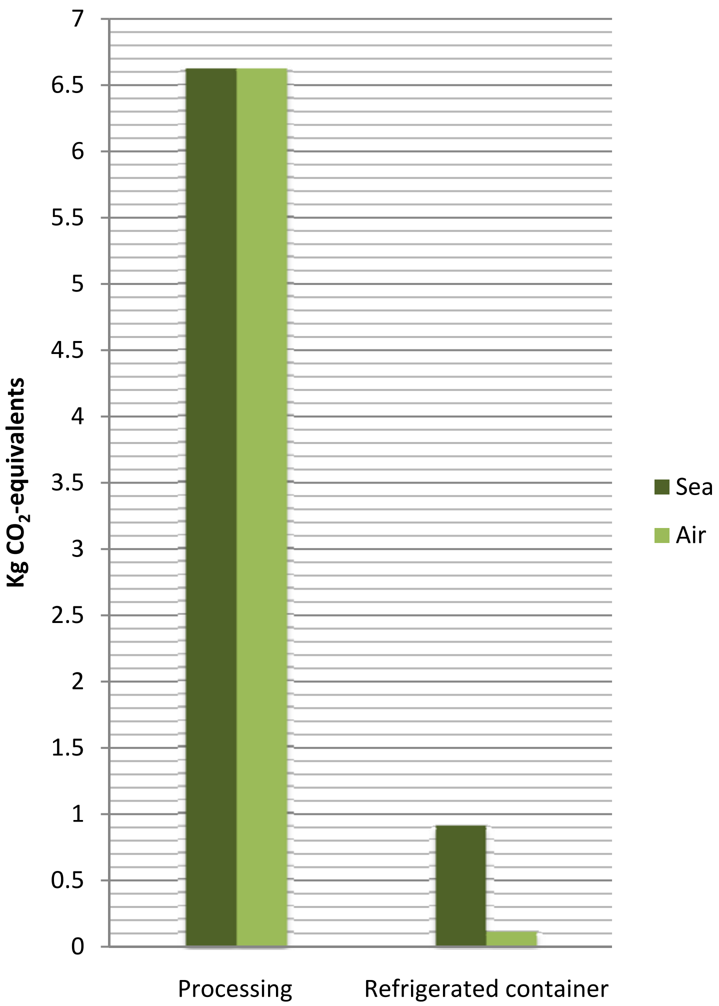


Figure 25: The CO_2 equivalents emitted related to the processing and the operation of the refrigerated containers

4.3.3.1 ELECTRICITY

As mentioned above, Gabi and the National Inventory Report differ by around 43% on the emissions of CO_2 equivalents calculated for the electricity production in Iceland. The carbon equivalents emissions from the processing plant as calculated in Gabi with the Icelandic power grid mix compared to the emissions calculated using the data from Iceland's National Inventory Report is shown in Figure 26. If the carbon footprints of the cold supply chains are calculated again using the National Inventory Report data it is found that overall the footprints decrease by 2.9% for the sea freight and 0.2% for the air freighted supply chain. For the overall conclusions this does not have any major effects, however for the manufacturing of EPS boxes in Iceland and the processing plant this reduces these processes emissions by almost half.

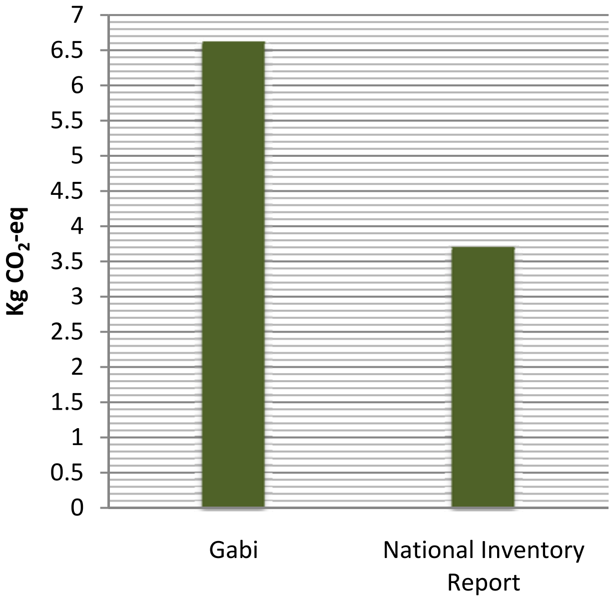


Figure 26: The difference in calculated CO_2-equivalents emissions from the processing based on Icelandic power grid mix in Gabi compared to Iceland's National Inventory Report

This difference in recorded CO_2 equivalents emissions for the electricity production shows that accurate inventory analysis is of vital importance. The reliability and quality of the data must be evaluated and its origin be properly documented as the accuracy of the results and the interpretation is dependent on their use. In the case of the Gabi dataset and the National Inventory Report, both sources are reliable sources. However, it would be interesting to analyze where the difference in the dataset lies. Such analysis is beyond the scope of this project.

4.3.3.2 Refrigerated container

The emissions from the refrigerated containers are around nine times higher for the sea freighted cold supply chain than the air freighted chain. The main reason for this is the long operational time of the refrigerated container during the sea freight and that the fish is not in the container during the flight. For the containers, almost 90% of the emissions are because of diesel oil used to operate the containers while the 10% is from the refrigerant, R134a.

For the refrigerated containers the environmental effect in terms of CO_2 emissions of transporting the fresh fish at -1°C and 4°C were compared. The fuel needed to maintain -1°C and 4°C in the containers was calculated for the truck transport of the sea freighted cold supply chain using the same ambient temperatures as before. In Table 5 below the amount of diesel oil needed and the corresponding CO_2 emissions are shown. The difference between transporting at -1°C or at 4°C is 15%.

In order to be able to compare the energy needed and the amount of CO_2 emissions from transporting fresh and frozen seafood at -18°C data from Magnussen, 1993 was used. According to Magnussen, 1993 the average amount of diesel oil needed to maintain a temperature of -18°C in the container is 0.5 L/10 km. This corresponds to 140 kg CO_2 equivalents during the truck transport of the sea freighted cold supply chain, or almost double the amount of CO_2 compared to transporting fresh at -1°C.

Table 5: The amount of diesel oil needed to maintain the preferred temperatures in the refrigerated containers and the corresponding CO_2 emissions

	Fresh products		Frozen products
Temperature	**-1°C**	**4°C**	**-18°C**
Diesel oil used in truck transport (L)	27	23	53
CO_2 emissions [kg CO_2 – eq.]*	72	61	140

*calculations based on IPCC guidelines (IPCC, 2006)

Although the refrigerated container does not have a significant impact on the cold supply chains it is clear that the cost of keeping the refrigerated container at -18°C is around double the cost of operating at -1°C and almost 2.3 times the cost of operation at 4°C in terms of the cost of diesel oil.

4.4 LCA Conclusions

The results from the computation of the carbon footprints of the two cold supply chains show that the transportation mode is the most important factor, with the carbon footprint of air freight being 18 times that of sea freight. This is in accordance with the findings of Freidberg, 2009 and Tyedmers, Walker, & Sonesson, 2010. In addition, the air freighted cold supply chain uses significantly more fuel than the sea freighted supply chain. This does not only result in considerably higher CO_2 emissions but also increased costs.

Not only does the transportation mode matter, but also to decrease as much as possible the distances and time travelled by heavy vehicles. For the sea freighted supply chain the truck transport in Iceland and Europe give higher environmental impact than the sea transportation itself, although the distance travelled by ship is almost double the distance driven. It must be noted that vehicle traffic also contributes to traffic congestion. Alternative transportation modes to heavy duty vehicles should be considered or the use of alternative fuels, e.g. methane. Food transport by rail or barge would reduce the carbon footprint significantly as would coastal shipping in Iceland.

For both supply chains the processing is an insignificant factor to the overall carbon footprint while the EPS packaging is an important factor. The reasons for the high impact from the packaging can be related to the use of fossil fuels during the manufacturing of the polystyrene granulate. In addition it is manufactured in Europe where electricity and heating is generated using fossil fuels but not renewable energy resources. It has been found that numerous seafood companies in Europe are currently focusing on more environmental friendly packaging than EPS boxes and are looking into solutions with reusable boxes.

It was found that transporting frozen seafood in cooled containers at -18°C emitted almost two times the amount of CO_2 than when transporting fresh seafood at -1°C. These results do not change the overall conclusions as it has been shown that the transportation mode is the most important factor. Frozen products allow for more environmentally friendly transportation mode like sea freight or rail transport, although more time consuming than air freight. Frozen products are therefore preferable, since emissions from the refrigerated containers have been found to have negligible effect in the overall cold supply chain. Increasing the production of frozen seafood will however require considerations of other factors, for example the need for larger freezers.

5 SURVEY ON ENVIRONMENTAL AWARENESS OF STAKEHOLDERS IN THE CHILL CHAIN

5.1 INTRODUCTION

The environmental awareness of retailers and consumers is increasing worldwide which is followed by increased demand for sustainable and environmentally friendly products. It is important for producers to keep up with this new demand in order to not lose the current market share and to increase the possibility to get share at new markets. The opinions of European fish supply chain stakeholders were surveyed by performing interviews at the Brussels Seafood Exhibition (Ólafsdóttir et al., 2010) in relation to the European CHILL-ON project. Environmental issues were rated as the least important drivers (out of four choices: regulations, consumer-, economic-, and environmental values) for implementation of electronic based information systems and supply chain management systems. However, environmental labels were considered as very important marketing tools for seafood. The environmental awareness of Icelandic fish supply chain stakeholders has not been analyzed before and therefore it was considered of interest to perform a survey to get an indication on the environmental awareness and the attitude of Icelandic stakeholders of the cold supply chain towards environmental indicators and what factors influenced their selection of transportation modes. Furthermore, the aim was to find out from which markets the demand for environmental indicators and ecolabels of Icelandic seafood products is the highest. This information will give guidelines on what research is needed to strengthen the definition of sustainable food supply chains and can be used as a basis for recommendations on further studies in the field

5.2 METHOD

The methodology applied was an exploratory approach where a questionnaire was designed and sent out to stakeholders of the supply chain. The questionnaire included 14 fully structured questions and one open ended (survey in Icelandic in Appendix IV).

The questionnaire focused on 3 central factors:

1) *the company's knowledge of the environmental impacts of their products and environmental indicators*,

2) *how stakeholders can use information on environmental indicators* and

3) *what kind of environmental information is demanded and from which markets*.

The survey was an internet based online survey which was open from July 14, 2010 to August 23, 2010. The survey application LimeSurvey (www.limesurvey.org) was used to create the web based survey. An internet link was created which gave access to the survey and sent to three organisations which forwarded the survey to its members. The organisations which forwarded the survey were the Federation of Icelandic Fish Processing Plants (Samtök fiskvinnslustöðva), The Icelandic Federation of Trade (Samtök fiskframleiðenda og útflytjenda) and the National Association of Small Boat Owners (Landssamband smábátaeigenda). In addition the survey was sent directly to 112 employees of various companies active in the fish supply chains. Unfortunately it is difficult to verify the exact number of participants that received the survey as some overlapping may have occurred between the organisations and when the survey was sent out directly. Furthermore, in the introductory to the survey the participants were asked to send the survey to other employees that they found fit to answer the survey, i.e. the so-called ‘snowball sampling’ was used.

The snowball sampling method was used to obtain a research sample where the existing study subjects recruited future subjects. This method was chosen in order to reach a representative sample and to reach information-rich informants as the composition of the sample sent out by the organisations was not known. The advantages of using the method is that it makes it possible to include unknown stakeholders in the survey, it increases the number of participants, builds on resources of existing network and experts in the specific field can be located. However, this method does have some weaknesses. These include the fact that the choice of initial contacts is very important and the researcher does not have an idea of the true distribution of the population of the sample. Furthermore some sampling bias can occur as initial subjects tend to nominate people they know well. This gives a high possibility that the subjects share the same traits and characteristic (Department of Sustainability and Environment, 2010).

In total 74 persons started to answer and 19 did not complete the survey. For the results only the fully submitted answers were analysed. As the sample is 55 persons the results from the survey can be regarded as an indication of trends but not as concrete results on the status on environmental awareness of cold supply chain stakeholders. A larger sample size is needed for a more accurate survey results.

5.3 RESULTS

5.3.1 Demographics

Information on the background of the companies was collected. As the sample size is small the results were not analyzed specifically based on the different background information. From Figure 27 it can be seen that 80% of the respondents work for fish processing plants and 65% in fishing and export companies. In fact, 60% of the companies are both in fishing and processing with 38% covering fishing, processing and export. The category ‘other’ included fish auctions, shrimp processing plants, fish shop and a company selling standards.

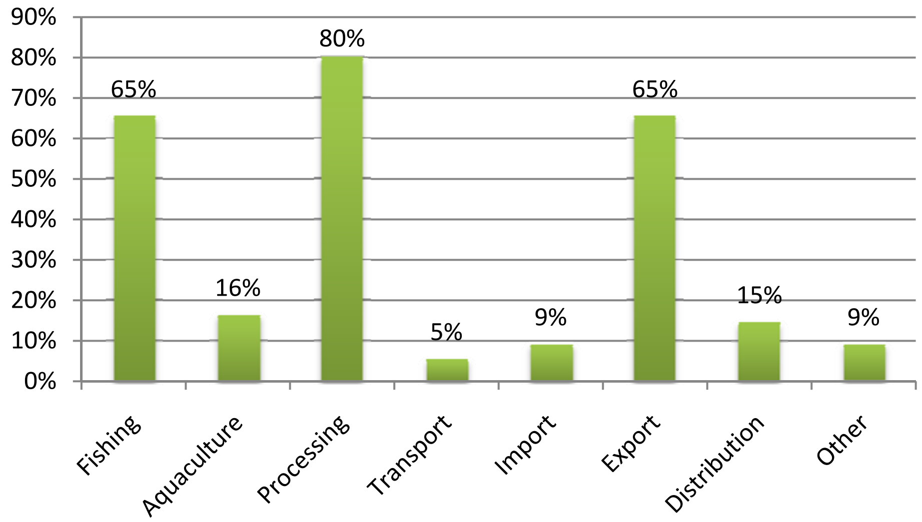


Figure 27: The type of companies participating in the survey

The main products traded are frozen and fresh products with 84% and 80% share respectively, see Figure 28. Thereof, 73% are producing fresh and frozen products. Salted products also have a considerable share (47%) as well as dried products. A few participants also mentioned the production of fishmeal and fish oil.

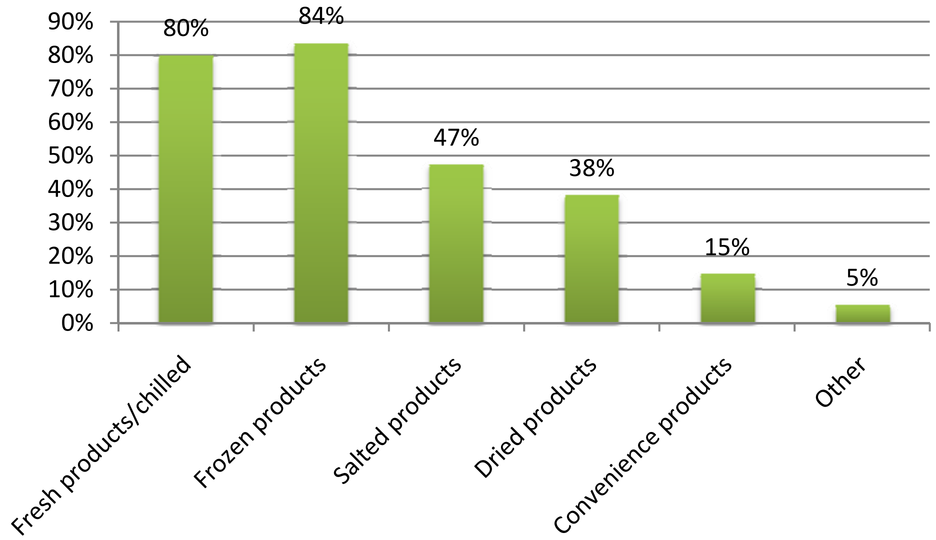


Figure 28: The type of products

The company sizes range from being of micro size, with less than 10 employees to large companies with more than 250 employees. Almost half of the respondents or 49% work for large companies and 33% for medium-sized companies Figure 29. Only 18% of the respondents are working for micro or small sized companies.

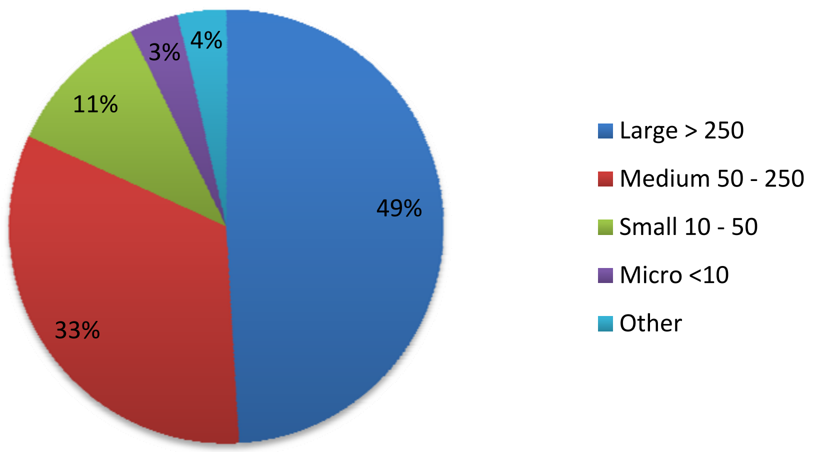


Figure 29: The size of the company with regards to number of employees

The position in the company was also asked for and can be seen in Figure 30. It must be noted that the respondents can be responsible for more than one of the categories as a number of respondents selected more than one category. The participants were 37% management staff, 26% were in sales and marketing, 20% in production and processing and 16% in product development and quality management.

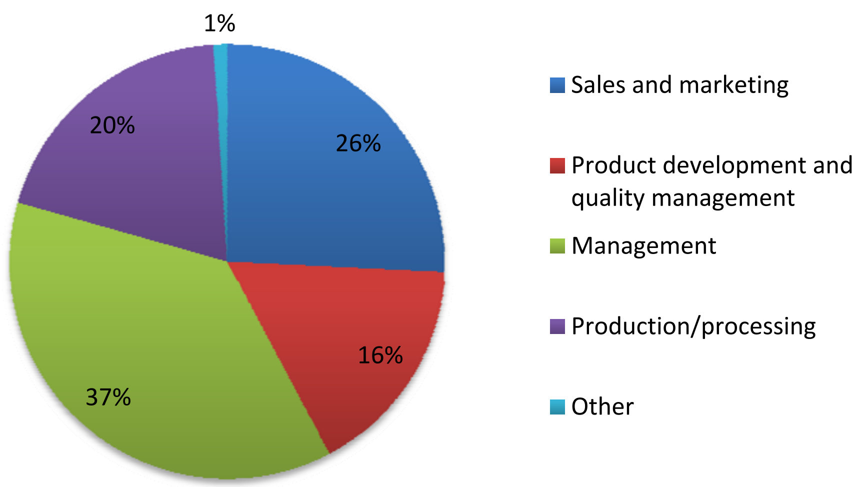


Figure 30: The respondent's position in the company

It is interesting to see that 44% of the companies do have an environmental policy although environmental management systems have not been implemented as extensively (Figure 31). In total 20% have the International Food Standard (IFS) certification and 15% have the British Retail Consortium (BRC) certification, where obvious interest in the BRC was noticed in the 'other' category. Many respondents also mentioned HACCP and the producers of fishmeal mentioned FEMAS as their management schemes.

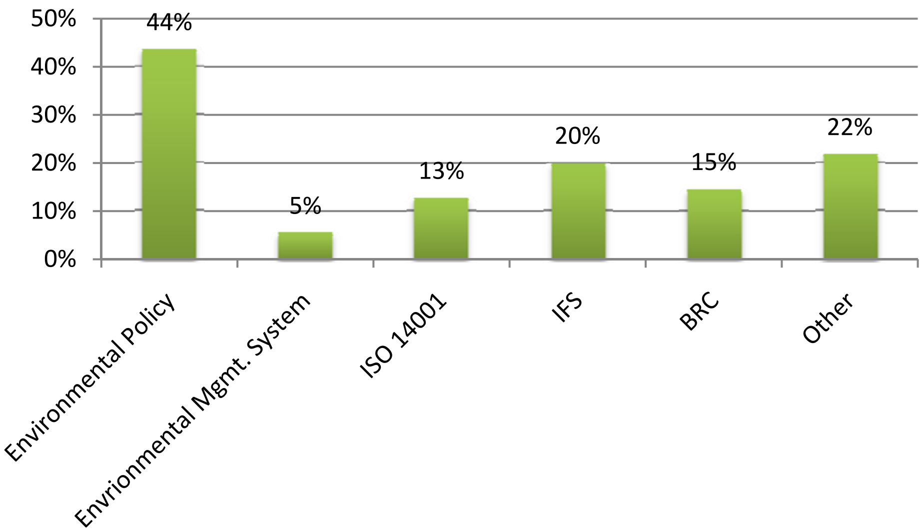


Figure 31: Certification and management schemes for the companies

From the demographics above it can be said that a representative sample was obtained although the sample size is not sufficient to come up with statistically significant results. Rather an indication of a trend can be presented from the survey's results.

5.3.2 Environmental awareness and attitudes of stakeholders of the cold supply chain towards environmental indicators

The respondents were asked if their company recognises the environmental impacts of their product system. That is the environmental impacts of the entire supply chain, from manufacturing and transport to the markets. More than half, or 58% answered that the company does have knowledge of its environmental impacts. A fifth responded that the company does not have knowledge on the impacts caused by their products life cycle, see Figure 32. For large and medium sized companies 62% of the respondents felt that the company does have knowledge about their environmental impacts while 16% of respondents of these company sizes did not feel that the knowledge is available. For the small and micro sized companies half stated that the knowledge was existing and the other half not.

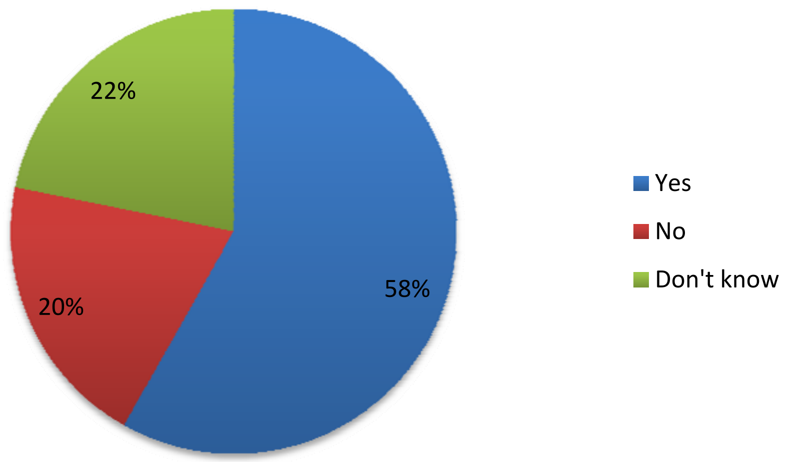


Figure 32: Does the company recognize the environmental impacts from the products life cycle?

Those who responded that the company does have knowledge on its environmental impacts were asked where and how this knowledge is used in the company's operation. The knowledge is used differently for different firms but as can be seen from Figure 33 that there is no specific purpose that overall is more important than the other. One respondent mentioned fewer losses.

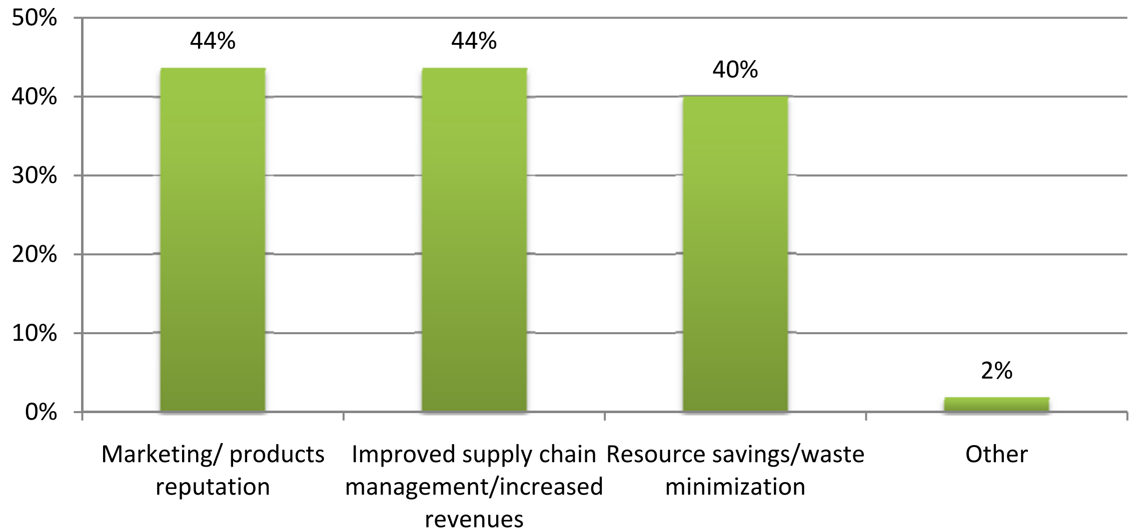


Figure 33: Where/how is the knowledge on the company's environmental impacts used?

A few commented that environmental management in the fishing industry has improved during the last decade. Also, that most of the larger companies in Iceland have the people and the ambition to further improve the environmental performance and the image of these companies. It was also stated by several respondents that they feel that their company is doing better today in terms of environmental management and one mentioned that a board has been formed to follow up on these matters. It was pointed out that more of the raw material is now landed and used for different by-products instead of being thrown into the sea. In addition, one respondent commented that although things were getting better for the large companies, this was not the case for smaller companies in rural areas; especially those located in very small communities.

Furthermore, it was argued that middle aged and older employees have more difficulties in adapting to new procedures.

The respondents were asked if they knew the environmental indicator carbon footprint. Almost half of the respondent said that they recognised the indicator or 46%, see Figure 34. The rest or 54% did not know or did not understand the question. It was found out after the survey had been published that the term carbon footprint caused some confusion. This is because there is not a single term accepted and used in the Icelandic language, but at least three different variations: sótspor, kolefnisspor and CO_2 - fótspor.

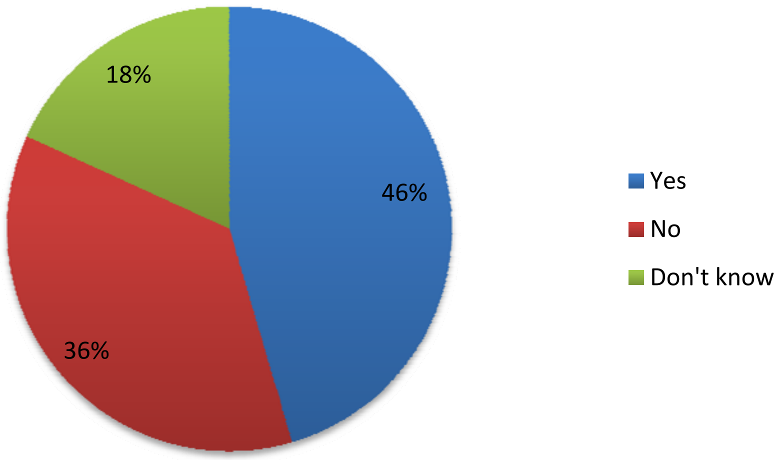


Figure 34: Do you recognize the measure carbon footprint?

The same proportion of respondents that know what carbon footprint is, think that environmental indicators can have a significant value for the Icelandic seafood industry, see Figure 35. As many respondents do not know if environmental indicators can have significance. It is interesting to note that of the respondents that know carbon footprint 72% said that environmental indicators can have significance for the industry, but 8% of those do not believe that the indicators can be of any significance. Furthermore, 25% of respondents that do not know carbon footprint think that environmental indicators can be of significance.

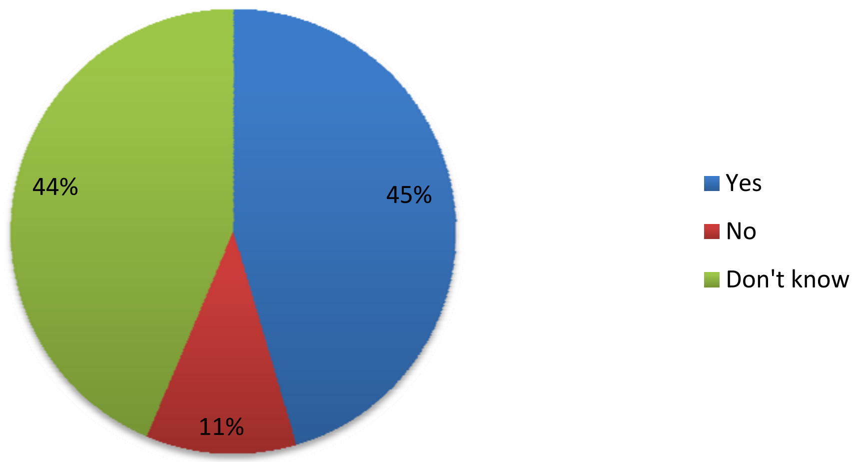


Figure 35: Can environmental indicators have a significant value for the Icelandic seafood industry?

Those who believe that environmental indicators can be of significance were also asked where that significance lies. Figure 36 shows that the respondents believe that information on environmental indicators can primarily have significance in marketing purposes and for their products and the company's reputation. Secondly it is believed that the indicators can assist with resource savings and waste minimization. The improvements of the supply chain management and the increase in revenues is the category given the least significance, i.e. it is found that environmental indicators are not believed to assist in operational improvements.

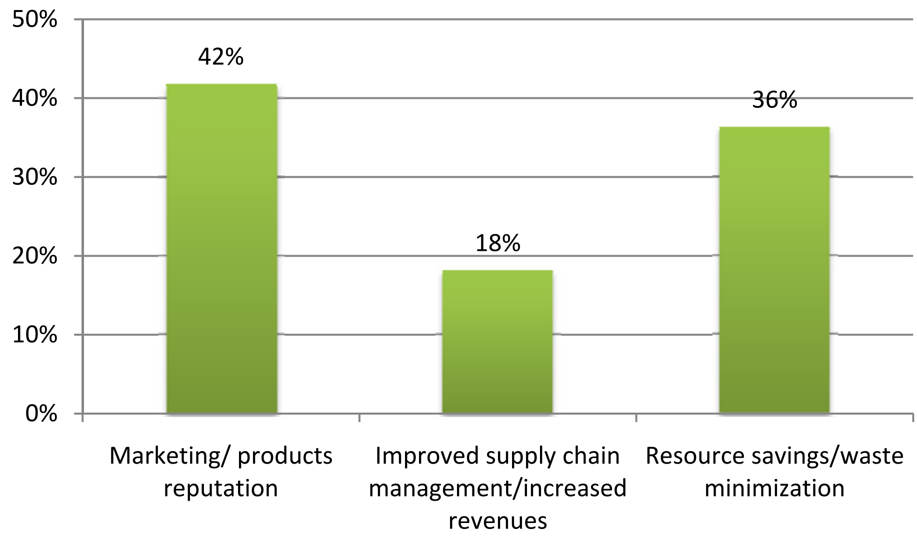


Figure 36: Where does the significance of environmental indicators lie?

This is in accordance with what was found from a survey administered at the Seafood Exposition in Brussels, April 27th – 29th 2010 within the European project CHILL-ON. The respondents in Brussels considered environmental factors primarily as marketing tools. LCA and carbon footprint were mentioned of interest for labelling purposes as environmental labels support user friendly marketing approaches for the industry (Ólafsdóttir et al., 2010).

There is obviously a demand from buyers on the environmental impacts of the products they are trading, see Figure 37. In total 44% of the supply chain actors feel that there is a demand from their clients, while the same proportion or 45% do not currently observe this demand.

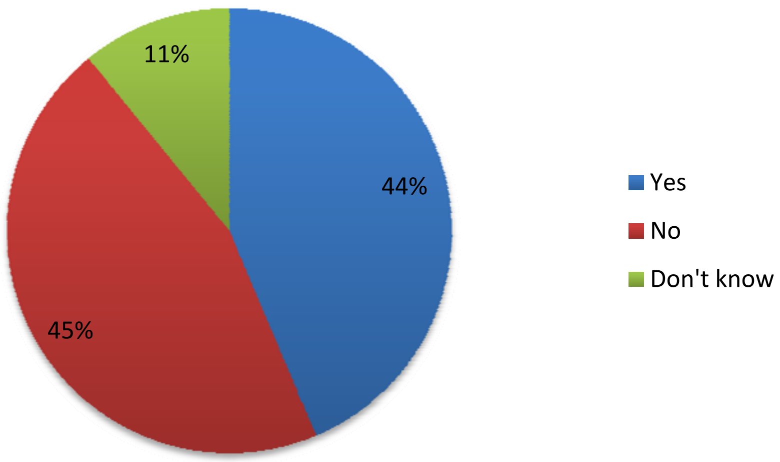


Figure 37: Is there a demand on information about the environmental impacts of your products?

It was commented that buyers, both Icelandic and foreign are increasingly demanding improved operational procedures from the seafood industry and price elasticity is observed. This is in accordance with the findings from the survey conducted in Brussels where it was found that the environmental labels are mainly of interest as marketing tools and retailers were considered to benefit most from implementation of electronically based information systems on product´s characteristics (Ólafsdóttir et al., 2010). Retailers are currently pushing for environmental labels however the consumers are less aware (EU, 2009).

Information about what kind of environmental information is required is shown in Figure 38. It can be seen that there is equal demand for the Iceland – Responsible Fisheries logo and certificate of origin. With 85% of respondents that identified demand for the Icelandic Logo for Responsible Fisheries also identified a demand for certificate of origin. But the Icelandic logo is meant to identify *Icelandic seafood products*, produced from catches in Icelandic waters and indicates *product origin* in Iceland *from responsible fisheries*. There is also a considerable demand for sustainable products and 70% of those who identified sustainable production also identified the Icelandic logo. It is noteworthy that 24% of respondents identify a demand for the Marine Stewardship Council (MSC) environmental label.

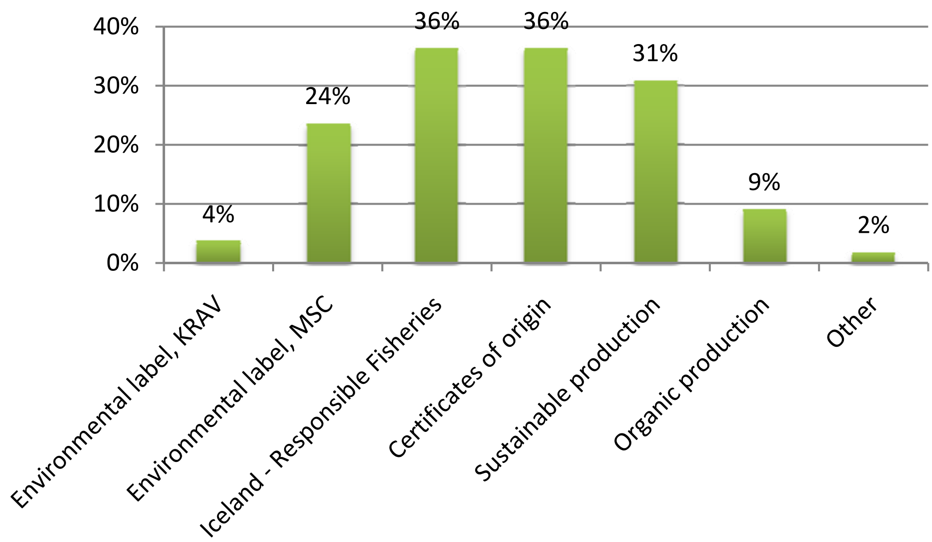


Figure 38: What kind of information is being asked for?

One respondent commented that the fishing industries most important environmental matter is to be able to confirm to the customers that the product being sold comes from a well managed stock that is being used sustainably. The results from the survey conducted in Brussels indicate that environmental labels such as MSC, Save/Friends of the Sea and sustainability indicators are gaining interest as marketing tools (Ólafsdóttir et al., 2010b).

It is clear that the strongest demand for environmental information for Icelandic seafood products is from Northern Europe (Figure 39). Some demand is also identified from Southern Europe and North America. A few respondents identified Eastern Europe and Asia. Unfortunately the market share of each of the identified markets was not found from the survey. It would be interesting to know which of these identified markets is the largest and be able to study the demand further based on these information.

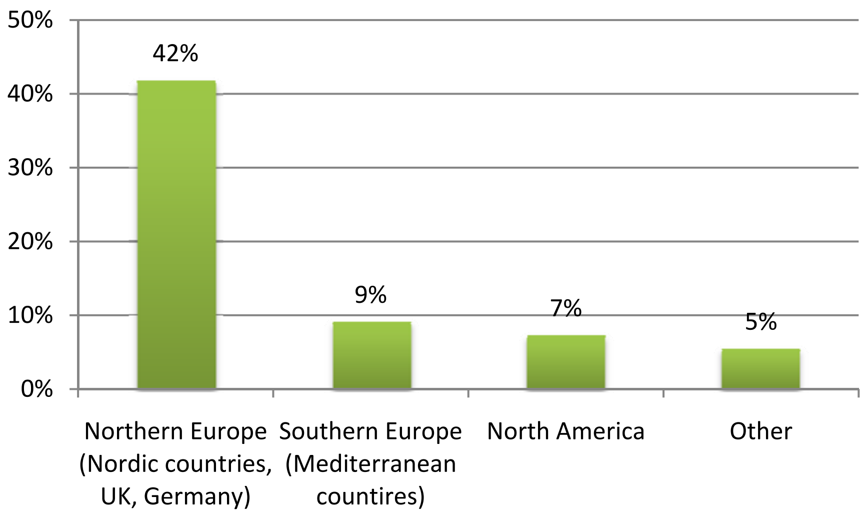


Figure 39: Markets where information on the environmental impacts is demanded

This is in accordance with what was stated in the Brussels survey. There it was commented that sustainability demand and certification is of primary interest for northern Europe, Germany, UK, France, Norway and Sweden. In South Europe, Spain and Portugal for example, there is not as much interest in environmental certification (Ólafsdóttir et al., 2010b).

The respondents were asked to rank the importance of six different factors when deciding on the transportation mode of the cold supply chain to markets abroad. The factors were:

1. Short delivery time
2. Quality of the product/ shelf life
3. Cost
4. Consumer demand
5. Environmental considerations
6. Traceability

The factors that were identified as the most important when deciding on the transportation were: the quality of the product and the costs, see Figure 40. Short delivery time and consumers demand also scored considerably in the first place. It must be noted that no one selected environmental considerations as number one.

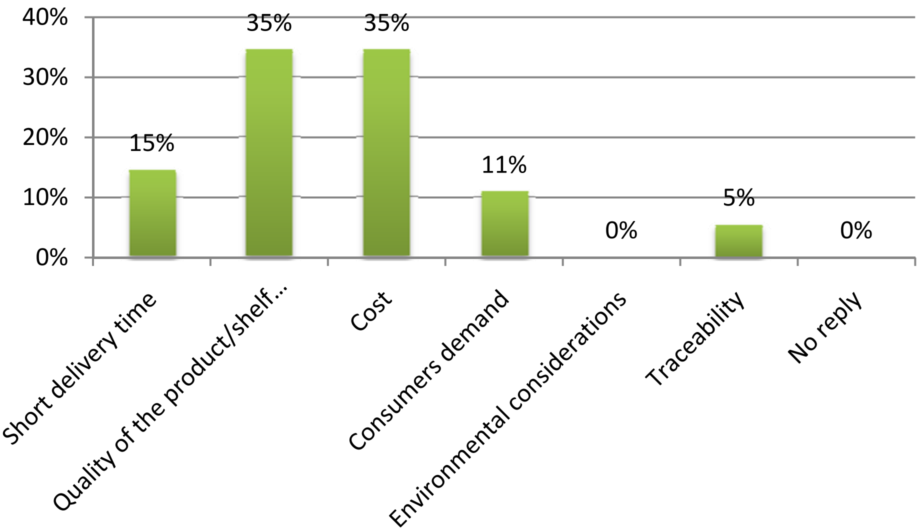


Figure 40: The factors identified as most important (rank 1) when the transportation phase in the cold supply chain is chosen

The graphs with the results for the ranking, 2nd to 5th place of importance are shown in Appendix V. The second most important factor identified was the consumers demand followed by the short delivery time. Other factors, such as cost and the products quality were also identified. Again, none of the respondents chose environmental considerations. In the third rank the quality of the product was found to be the most important factor followed by the cost and consumers demand. Traceability started to score significantly and 2% of respondents chose environmental considerations. In the fourth rank the consumers demand and short delivery time were found the most important factors, with other factors scoring similarly and 13% ranking environmental considerations as choice number 4. For the fifth factor traceability was the most significant factor, followed by environmental considerations and other factors scoring below

11%. For factor number six, the least important factors for the choice of transportation in the supply chain, environmental considerations scored almost 50% with other factors all scoring below 10%. This shows that environmental factors are today not truly considered when the transportation phase is decided, (Figure 41).

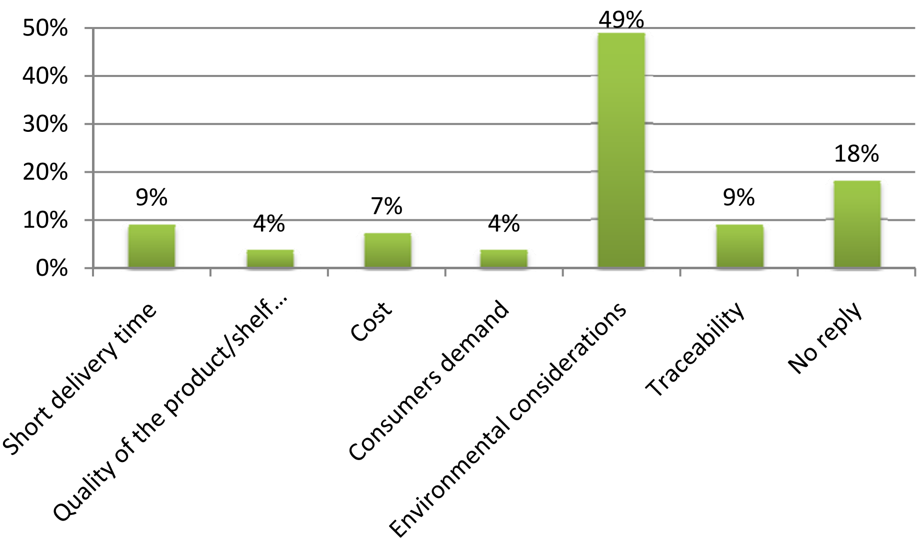


Figure 41: Environmental considerations scored the highest only for the least important factor (rank 6) when the transportation phase of the cold supply chain is chosen

As the respondents were asked to rank six different factors it was found that many stopped ranking after ranking one or more of the factors. Ranking six factors is possibly too many for such a survey or perhaps the available factors are by some stakeholders of the cold supply chain not taken into account at all. It was also commented for this question that as many of the companies are both exporting frozen and fresh products the ranking can be different for these different product types. It is mentioned that fresh products require short delivery time while the frozen product has extended shelf life which influence the choice of transportation mode. Frequency tables for the full responses from the survey can be seen in Appendix VI.

Respondents were free to comment on environmental issues in the fishing industry. The full responses in Icelandic are shown in Appendix V. It was stated that the discussion on environmental issues in the fishing industry has been harmed because of abuse of the subject caused by exaggerations and the hope of profit. Another respondent stated that environmental issues are on the wrong track and extensive education is needed and awareness must be raised. Especially it was pointed out that more knowledge and consciousness is needed on what is being thrown away.

5.4 Survey Conclusions

As mentioned earlier, a representative sample was obtained but too few completed answers to be able to confirm the trend for Icelandic cold supply chain stakeholders. However, an indication on the trend has been obtained.

More than half of the respondents felt that their company recognizes the environmental impacts caused by their production system. It was commented that larger companies have a better understanding of their environmental performance than smaller companies do. The survey found that almost two thirds of the larger companies recognize their environmental impacts while half of the small and micro sized companies claimed to have this knowledge. It must however be noted that while 82% of respondents work for medium and large sized companies only 18% are employees of micro and small sized companies. Based on these answers, knowledge of the environmental performance of the seafood industry in Iceland is fair.

The responses indicate that knowledge of the environmental impacts is used for improvements in marketing and the supply chain management. The knowledge is also found to be important for resource savings and waste minimization. The general consensus seems to point to the fact that environmental considerations are increasing in the industry.

Almost half of the respondents recognised the environmental indicator carbon footprint. As mentioned earlier, it is thought that the question has caused some confusion as there does not exist a single term in the Icelandic language for carbon footprint. This shows the need to get an acceptance of a single term which can be introduced to industries and the public. Less than half of the respondents believe that environmental indicators can be of any significance for the Icelandic seafood industry. The majority of those who recognise carbon footprint see the potential of utilizing environmental indicators. The opportunity to use the indicators is mostly seen in marketing purposes which is in accordance with the findings of Ólafsdóttir, et al. 2010b. Another significance is found in resource savings and waste minimization while the indicators are not found as important for the supply chain management.

The survey indicates that truly there is a demand on information about the environmental impacts of the seafood products. There seems to be a trend of increasing demand from buyers on environmentally sound operational procedures especially as the environmental awareness of retailers is increasing, rather than the public’s. The markets demand certificates of origins (mandatory), sustainable fisheries and to some extent environmental labels, with MSC as the most demanded environmental certification label. With almost half of the respondents feeling the demand for environmentally labelling it is a clear indication that environmentally friendly production is now demanded on mainstream markets, not only on niche markets. The survey results show that the main market to demand the environmental information is in northern Europe. This supports the findings of Ólafsdóttir, et al. (2010b).

When respondents were asked which factors where most important when it came to chose the transportation phase of the supply chain the results were clear. Quality of the product and the cost are of highest importance for most of the supply chain actors. Importance of other factors varied throughout the ranking process with a clear insignificance of environmental considerations through the ranking until the least important factor for the transportation phase was chosen. There the environmental considerations scored significantly highest indicating the current low importance of environmental considerations in the transportation phase.

6 OVERALL CONCLUSIONS AND DISCUSSIONS

The calculations of the carbon footprint for the two cold supply chains show that the transportation mode matters. The air freighted transportation chain was found to emit manifold the amount of GHGs than if the fresh fish was transported by container ship. The conclusions support the findings of previous studies that compared air and sea freight, where it has been stated that 'fish should swim, not fly'. Consumer's attitude is a very important aspect if change in transportation mode is to be achieved. When making food choices consumers need to not only think about where the product was produced but also how it was produced and transported.

According to consumer studies reviewed (chapter 2.6.1), there are good marketing opportunities for frozen fish products. The problem is that people believe that fresh is better than frozen although the experiments conducted during the two studies point to the fact that people like eating the frozen products. There is a clear need to educate consumers worldwide on the quality characteristics of frozen fish as well as the overall environmental gains from consuming frozen fish. Furthermore, studies on the prolonged shelf life of fresh seafood products could be enhanced, thereby allowing for a more time consuming and enviromentally friendly transportation mode.

The results from the survey on the environmental awareness in the cold chain, stakeholders indicate that environmental indicators can be of significance for Icelandic seafood products. Primarily the environmental indicators are seen as marketing tools. This follows the fact that there seems to be an increasing interest in environmentally certified products, especially from northern Europe. The same trend was observed in a previous survey conducted in Brussels in March 2010.

Currently the seafood industry is aware of the local environmental impacts caused by the fisheries themselves. While sustainable fisheries are a very important consideration in the industry there is a need to look beyond these localized impacts. The results from the survey point to the fact that currently environmental considerations are not taken into account at all when the cold transportation chain is chosen. The main emphasis is on the quality of the products and the costs of transportation. In order to be able to offer the customers environmentally friendly products there is a need to include the entire life cycle of the seafood products from cradle to grave. This means new way of thinking in the industry and expanding the environmental considerations already taking place.

6.1 RECOMMENDATIONS

Recommendation from this study are based on the results of LCA where only environmental impact was taken into account, but economic and socioeconomic factors need to be considered as well. Some suggestions addressing these issues are recommended. In order to achieve the modal shift in transportation and a more environmentally friendly cold supply chain a few steps could be taken:

- Consumers should be educated on the characteristics of fresh and frozen fish, emphasising the environmental benefits of choosing frozen rather than fresh and the quality of frozen seafood products.
- Make the consumers aware of the limitation of their geographical location, i.e. if they live in-land, far from fishing grounds the environmental impact of transport of the fresh seafood will be significant.
- Research on the application of alternative fuels for heavy duty vehicles and other transportation modes are under way and should be seriously considered for future supply chains.
- Currently the refrigerants used for cooled containers have an extensive GWP. New refrigerants are being developed with close to zero GWP and will hopefully be in general use sooner than later.
- Ecolabels and environmental certification schemes for seafood should promote sustainable seafood from a life cycle perspective. The certification schemes should be further developed to include the full life cycle of the products from 'cradle to grave'.
- It is necessary to perform total LCA of seafood products including socio-economic impacts where the quality of life is considered and consumer´s preferences. In western world societies it is considered quality of life to be able to have access to a variety of products produced in different parts of the world.
- The carbon footprint can be useful for marketing purposes if communicated correctly. Presenting the exact value and direct comparison between products can be misleading if taken out of context and can be confusing for consumers.
- Standardized methodologies for the development of carbon footprints of products must be prepared to ensure reliability, quality and consistency among labelled products.
- Consumers must be educated on what the carbon footprint stands for and acceptable footprints must be communicated to consumers.
- Some retailers are currently presenting lowering of products carbon footprint. Data behind such statements must be substantiated with the standardized methods in order for consumers to make informed purchasing decisions.

7 LIST OF ABBREVIATIONS

ASCS	Applied Supply Chain Systems Research
BRC	British Retail Consortium
CBC	Combined Blast and Contact
CFC	Chlorofluorocarbons
EEA	European Economic Area
EPS	Expanded Polystyrene
EU	European Union
FAO	Food and Agriculture Organization
FEMAS	Federation of European maritime Associations of Surveyors
GHG	Greenhouse Gas
GWh	Gigawatt-hour
GWP	Global Warming Potential
HACCP	Hazard Analysis & Critical Control Points
HCFC	Hydrochlorofluorocarbon
HDV	Heavy Duty Vehicle
HFCs	Hydrofluorocarbon
IFS	International Food Standard
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
MSC	Marine Stewardship Council
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substances
PFC	Perfluorocarbon
PS	Polystyrene
PSR	Pressure State Response
UNFCCC	United Nations Framework Convention on Climate Change
WWF	World Wildlife Fund

8 REFERENCES

Agriculture and Agri-Food Canada. (2005). Fish and seafood sector profile, The Netherlands, March 2003. Canadian Embassy in the Hague, Netherlands. Retrieved from: http://www.ats.agr.gc.ca/europe/3911_e.htm.

Andersen, O. (2002). Transport of fish from Norway: energy analysis using industrial ecology as the framework. *Journal of Cleaner Production*, *10*(6), 581-588. doi: 10.1016/S0959-6526(01)00057-9.

Anon. (2010). CHILL-ON Deliverable. D.5.2.A-FISH Allocation of Chill-on technologies in supply chains. Chapter 5.5 Report on the field trial in the COD CBC (IS-FR) March 2010. CHILL-ON:FP6-016333-2

Birgisdóttir, H., & Ólafsdóttir, R. (2009). Kolefnisspor Landsvirkjunar - Loftslagsbókhald 2008. Retrieved from http://www.landsvirkjun.is/media/umhverfismal/Kolefnisspor_Landsvirkjunar_2008.pdf.

Carbon Trust. (2010). Carbon footprinting. Retrieved on August 31 from: http://www.carbontrust.co.uk/cut-carbon-reduce-costs/calculate/carbon-footprinting/pages/carbon-footprinting.aspx

Common, Michael and Stagl, Sigrid. (2005). *Ecological Economics. An Introduction.* University Press, Cambridge.

Davíðsdóttir, B., Loftsdóttir, Á., Hallsdóttir, B., Skúladottir, B., Kristófersson, D. M., Rúnarsson, G., et al. (2009). Möguleikar til að draga úr nettóútstreymi gróðurhúsalofttegunda á Íslandi. Niðurstöður sérfræðinganefndar 2009.

Department of Sustainability and Environment. (2010). Snowball Sampling. The State of Victoria. Retrieved from: http://www.dse.vic.gov.au/dse/wcmn203.nsf/linkview/d340630944bb2d51ca25708900062e9838c091705ea81a2fca257091000f8579.

Estrada-Flores, S. (2008). The Environmental Dimension of Food Supply Chains. *Chain of Thought: The Newsletter of Food Chain Intelligence*, *1*(2), 1-17. Retrieved from http://www.food-chain.com.au/FCI_enews2.pdf.

Eyjólfsdóttir, H. R., Yngvadóttir, E., Jónsdóttir, H., & Skúladóttir, B. (2003). Vistferilgreining á þorskafurðum/ Environmental Effects of Fish on the Consumer's Dish - Life Cycle Assessment of Icelandic Frozen Cod Products. Retrieved from http://www.matis.is/media/utgafa//Verkefnaskyrsla0603.pdf.

EU. (2009). Environment: Commission and retail sector launch Retail Forum to promote more sustainable consumption. Retrieved from: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/339.

Euronews. (2010). Euronews documentary, Food - Sea to plate: a cool route http://www.euronews.net/2010/06/03/sea-to-plate-a-cool-route/ released 03/06 08:59 CET.

FAO. (2005). Guidelines for the Ecolabelling of Fish and Fishery Products from Marine Capture Fisheries. Retrieved from: http://www.fao.org/docrep/008/a0116t/a0116t01.htm#bm1.

Freidberg, S. (2009). Hotspots in a Cold Chain: A Life Cycle Assessment of Loki Fish. Retrieved from http://lokifish.com/freidbergpaper.pdf.

Garðarsson, Finnur. (2010). Íslenska merkið og vottunarferlið. Sjávarútvegsráðstefnan 2010 – Hafsjór tækifæra, Grand Hótel Reykjavík, 6 – 7 September 2010. Retrieved from: www.sjavarutvegsradstefnan.is.

Guttormsdóttir, A. B. (2009). Life Cycle Assessment on Icelandic cod product based on two different fishing methods. Environmental impacts from fisheries.

Hallsdóttir, B. S., Harðardóttir, K., Guðmundsson, J., Snorrason, A., & Þórsson, J. (2010). Emissions of greenhouse gases in Iceland from 1990 to 2008. National Inventory Report 2010. *Environment*. Reykjavík.

Harris, J. (2000). *Basic principles of sustainable development*. *Working Paper 00-04* (pp. 0-25). Retrieved from http://www.ciaonet.org/wps/gdae002/gdae002.pdf.

Heap, R. D., & Lawton, A. R. (1999). Calculation of TEWI for Refrigerated Freight Containers. In *20th International Congress of Refrigeration, IIR/IIF* (Vol. IV). Sydney.

Hoffman, Andrew J. (2000). Competitive Environmental Strategy. A Guide to the Changing Business Landscape. Island Press, Washington D.C.

International Institute of Ammonia Refrigeration. (2010). Ammonia: The Natural Refrigerant of Choice (An IIAR Green Paper). Retrieved on August 11 2010 from: https://www.iiar.org//aar/aar_green2.cfm?.

IntraFish. (2010). EU Key Role to Play for Sustainable Fishing. Retrieved on July 16th from: www.intrafish.no/global/news/article273324.ece

IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 3: Mobile Combustion*. (S. Eggelston, L. Buendia, K. Miwa, T. Ngara, & K. Tanabe)*Energy* (pp. 1-78). Institute for Global Environmental Strategies (IGES) for the IPCC. Retrieved from www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf.

James, S., & James, C. (2010). The food cold-chain and climate change. *Food Research International*, 1-13. Elsevier Ltd. doi: 10.1016/j.foodres.2010.02.001.

Jensen, P., & Schroten, A. (2006). Indicator Fact Sheet TERM 2006 13b – Modal split in freight transport. Retrieved from http://www.eea.europa.eu/data-and-maps/indicators/freight-transport-demand-by-mode-3/term_2006_13b___modal_split_in_freight_transport_final_version.pdf/at_download/file.

Jensen, P., & Schroten, A. (2006). Indicator Fact Sheet. TERM 2006 13a – Freight transport volume by mode and group of goods. *Transport*. Retrieved from http://www.eea.europa.eu/data-and-maps/indicators/freight-transport-demand-by-mode-

3/term_2006_13a___freight_transport_volume_by_mode_and_group_of_goods_final_version.pdf/at_download/file.

Jeswani, H. K., Azapagic, A., Schepelmann, P., & Ritthoff, M. (2010). Options for broadening and deepening the LCA approaches. *Journal of Cleaner Production*, *18*(2), 120-127. Elsevier Ltd. doi: 10.1016/j.jclepro.2009.09.023.

Jónsdóttir, A.B., Margeirsson, B. and Arason, S. (2009). Temperature mapping and assessment of supply chains including CBC chilling. In CHILL-ON Deliverable D5.4.A. FISH Field Trial Scenario and Mapping Summary Report Chapter 2. Cod-CBC IS-FR Annex 1. CHILL-ON:FP6-016333-2.

Karlsen, H., & Angelfoss, A. (2000). Transport of frozen fish between Ålesund and Paris - a case study. *Aalesund College, Aalesund, Norway*. Retrieved from http://research.dnv.com/marmil/lifecycle/case report frozen fish.pdf.

Körner, O. and Madsen, B.E. (2009). Global Warming Potential of Smoked Trout Fillet. AgroTech, Århus, Denmark.

Magnussen, O. (1993). *Energy consumption in the cold chain* (pp. 171 - 177). Refrig. Sci & Tech. International Institute of Refrigeration, 1993, Cold chain refrigeration equipment by design.

Magnussen, O., Haugland, a., Torstveithemmingsen, a., Johansen, S., & Nordtvedt, T. (2008). Advances in superchilling of food – Process characteristics and product quality. *Trends in Food Science & Technology*, *19*(8), 418-424. doi: 10.1016/j.tifs.2008.04.005.

Magnússon, H. and Martinsdóttir, E. (1995). Storage Quality of Fresh and Frozen-thawed Fish in Ice. Journal of Food Science, 60 (2): 273 – 278.

Ministry for the Environment. (2007). Stefnumörkun í loftslagsmálum. Reykjavík. Retrieved from http://www.umhverfisraduneyti.is/media/PDF_skrar/Stefnumorkun_i_loftslagsmalum.pdf.

Nielsen, J., Listov-Saabye, F. and Jensen, Kristina N. (2003). L 25. A Consumer View of Frozen Fish. First Joint Trans-Atlantic Fisheries Technology Conference – TAFT 2003. 33rd WEFTA and 48th AFTC Meetings, 11 – 14 June 2003, Reykjavík, Iceland.

Organic Monitor. (2010). Future of Eco-Labels Debated at Sustainable Foods Summit. Retrieved from: http://www.npicenter.com/anm/templates/newsATemp.aspx?articleid=27782&zoneid=2.

Ólafsdóttir, G., Bogason, S., Colmer C., Eden, M., Hafliðason, T. and Kuck, M. (2010a). Improved efficiency and real time temperature monitoring in the food supply chain. In Proceddings of 1st IIR International Cold Chain and Sustainability Conferences, Cambridge, UK, 29th – 31st March 2010. IIF – IIR, France, 2010. ISBN 978-2-913149-75-5.

Ólafsdóttir, G., Bogason, S., Hafliðason, T., Guðlaugsson, E., Guðmundsdóttir, H., Jóhannesson, G. Þ., et al. (2010). Stakeholder views on implementation of information and supply chain management systems in the fish sector. In *40th Anniversary & Annual Meeting of WEFTA Western European and Fish Technologists' Association. Izmir - Turkey on 4 - 7 October*

2010.. Izmir: 40th Anniversary & Annual Meeting of WEFTA Western European and Fish Technologists' Association.

Ólafsdóttir, G., Lauzon, H., Martinsdóttir, E., Oehlenschlager, J. and Kristbergsson, K. (2006). Evaluation of shelf-life of superchilled cod (Gadus morhua) fillets and influence of temperature fluctuations on microbial and chemical quality indicators. Journal of Food Science 71 (2): 97-109.

PE International. (2010). Gabi Software. Retrieved on June 22nd 2010 from: www.gabi-software.com

PE International. (2009). *Handbook for Life Cycle Assessment (LCA) Using the GaBi Education Software Package*. GmbH: PE International.

Pelan, C. (2010). Fresh vs. Frozen. Retrieved on August 12 2010 from: http://www.eatmagazine.ca/article/2010-03-05/freshvsfrozen.

Pelletier, N., & Tyedmers, P. (2008). Life cycle considerations for improving sustainability assessments in seafood awareness campaigns. *Environmental management*, *42*(5), 918-31. doi: 10.1007/s00267-008-9148-9.

Pintér, L., Zahedi, K., & Cressman, D. R. (2000). Capacity Building for Integrated Environmental Assessment and Reporting. *Sustainable Development*. Retrieved from www.iisd.org/pdf/geo_manual_2.pdf.

Remmen, A., Jensen, A. A., & Frydendal, J. (2007). Life Cycle Management. A Buisness Guide to Sustainability.

Roy, P., Nei, D., Orikasa, T., Xu, Q., Okadome, H., Nakamura, N., et al. (2009). A review of life cycle assessment (LCA) on some food products. *Journal of Food Engineering*, *90*(1), 1-10. doi: 10.1016/j.jfoodeng.2008.06.016.

Scholz, A., Sonesson, U., & Tyedmers, P. (2009). Catch of the Freezer. *New York Times*. Retrieved from http://www.nytimes.com/2009/12/09/opinion/09scholz.html.

Statistics Iceland. (2010). Environmental, transport and fisheries statistics. Retrieved on June 30 2010 from: www.hagstofa.is

Sveinsdottir, K., Martinsdottir, E., Green-Petersen, D., Hyldig, G., Schelvis, R., Delahunty, C., et al. (2009). Sensory characteristics of different cod products related to consumer preferences and attitudes. *Food Quality and Preference*, *20*(2), 120-132. Elsevier Ltd. doi: 10.1016/j.foodqual.2008.09.002.

Tassou, S., De-Lille, G., & Ge, Y. (2009). Food transport refrigeration – Approaches to reduce energy consumption and environmental impacts of road transport. *Applied Thermal Engineering*, *29*(8-9), 1467-1477. Elsevier Ltd. doi: 10.1016/j.applthermaleng.2008.06.027.

Thrane, Mikkel. (2005). LCA of Danish Fish Products. New methods and insights. Department of Development and Planning, Aalborg University, Denmark.

Thrane, M., Ziegler, F., & Sonesson, U. (2009). Eco-labelling of wild-caught seafood products. *Journal of Cleaner Production*, *17*(3), 416-423. Elsevier Ltd. doi: 10.1016/j.jclepro.2008.08.007.

Tyedmers, P., Walker, S., & Sonesson, U. (2010). Global Salmon LCA - Press Release. *Ecotrust*. Retrieved from http://www.ecotrust.org/press/lca_20091120.html.

UNEP. (2009). *Guidelines for social life cycle assessment of products*. (C. Benoît & B. Mazijn)*United Nations Environmental*. United Nations Environment Programme. Retrieved from http://en.scientificcommons.org/45759105.

Valdimarsson, Grímur. (2010). Leiða umhverfismerkingar til betri fiskveiðistjórnunar? Sjávarútvegsráðstefnan 2010 – Hafsjór tækifæra, Grand Hótel Reykjavík, 6 – 7 September 2010. Retrieved from: www.sjavarutvegsradstefnan.is.

Wongwises, S., & Chimres, N. (2005). Experimental study of hydrocarbon mixtures to replace HFC-134a in a domestic refrigerator. *Energy Conversion and Management*, *46*(1), 85-100. doi: 10.1016/j.enconman.2004.02.011.

Ünal, V. (2006). Profile of fishery cooperatives and estimation of socio-economic indicators in marine small-scale fisheries; case studies in Turkey. Retrieved from http://www.gemub.com/pdf/unal.pdf.

Ziegler, F., Nilsson, P., Mattsson, B. and Walther B. (2003). Life Cycle Assessment of Frozen Cod Fillets Including Fishery-Specific Environmental Impacts. International Journal of LCA *8*(1) 39-47.

APPENDIX I: TIMELINE AND BOUNDARIES FOR SEA FREIGHT MAPPING

Figure A 1: Actual timelines and chain boundaries for the March 2010 cod Field Trials. From: D.5.2.A-FISH Allocation of Chill-on technologies in supply chains. Chapter 5.5 Report on the field trial in the COD CBC (IS-FR) March 2010. CHILL-ON:FP6-016333-2. The LCA study includes the steps in the supply chain from main processing storage until reception in Bs/M (shaded).

Timeline overview of the scenario	Timeline of the mapping		Duration (h)	Time from catch		Time from packaging	
	Start time	End time	Hours	Hours	Days	Hours	Days
Catch + pre-processing on board	8.3.2010	8.3.2010		24	1,0		
Storage and transport at sea	8.3.2010	8.3.2010	8	32	1,3		
Landing and transport to main processing storage	9.3.2010 08:00	9.3.2010 09:00	1	33	1,4		
Main processing storage	9.3.2010 09:00	9.3.2010 11:00	2	35	1,5		
Main processing	9.3.2010 11:00	9.3.2010 11:30	0,5	35,5	1,5		
Packaging and palletization	9.3.2010 11:30	9.3.2010 11:45	0,25	35,75	1,5	0,25	*0,0*
Cold storage before shipping from main processor	9.3.2010 11:45	10.3.2010 10:00	22,25	58	2,4	22,5	*0,9*
Containerization	10.3.2010 10:00	10.3.2010 12:00	2	60	2,5	24,5	*1,0*
Transport in container in Iceland	10.3.2010 12:00	10.3.2010 20:00	8	68	2,8	32,5	*1,4*
Sea and land transport IS-DK	10.3.2010 20:00	13.3.2010 09:00	61	129	5,4	93,5	*3,9*
Domestic transport Denmark	13.3.2010 09:00	13.3.2010 13:00	4	133	5,5	97,5	*4,1*
Storage Padburg	13.3.2010 13:00	14.3.2010 04:00	15	148	6,2	112,5	*4,7*
Transport Padburg / BSM	14.3.2010 04:00	15.3.2010 08:00	28	176	7,3	140,5	*5,9*
Storage in BSM	15.3.2010 08:00	16.3.2010 09:00	25	201	8,4	165,5	*6,9*
Reception at Conegan in BSM	16.3.2010 09:00	16.3.2010 11:00	2	203	8,5	167,5	*7,0*
Total - supply chain				**203**	**8,5**	**167,5**	**7,0**

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APPENDIX II: INVENTORY TABLE

Table A 1: The data inventory for the cold supply chain where fish is transported by container ship.

Transport	Material input	Amount per functional unit	Comments, boundary conditions and assumptions	References, source of information
	Truck in Iceland	201 tKm	Domestic transport in Iceland is 332 km, using 14 - 20 ton truck with 11.4 ton payload	Truck 14 - 20 t total cap./11.4 t payload/Euro 3 PE Gabi Database
	Transport by cargo ship	1050 tKm	Sea transport is 1,735 km. Load in ship: 70%.	Ro-ro ship/ 8630 dwt/coast PE Gabi Database
	Truck in Europe (Esbjerg - Padburg, Padburg - BSM)	436 tKm	Transport is 720 km, using 34 - 40 ton truck wit total payload of 27 ton	Truck-trailer > 34 - 40 t total cap. / 27 t payload/ Euro 3. ELCD/PE Gabi database
Fuels	Diesel oil for trucks	10.1 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
	Fuel oil for cargo ship	4.72 kg		EU-15: Fuel oil light at refinery ELCD/PE Gabi Database
	Diesel for refrigerated container	2.08 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
Cooling agent	Cooling agent in truck, R134a	0.004774 kg	In container in Iceland the use of R134a is 0.000694 kg and in Europe 0.00408 kg	http://www.cpm.chalmers.se/CPMDatabase/Scripts/sheet.asp?ActId=VolvTU010-8/18/99-341
	Cooling agent in ship/container, R134a	0.005295 kg		

Storage and processing	Material input	Amount per functional unit	Comments, boundary conditions and assumptions	References, source of information
Electricity	Electricity Iceland	999 MJ	Data on electricity use gathered from a producer of fresh and frozen demersal fish fillets.	IS: Power grid mix from Gabi
	Truck in Iceland	7.5 tKm	14 - 20 ton truck with 11.4 ton payload. EPS boxes are transported 338 km from the manufacturer to the processing plant	Truck 14 - 20 t total cap./11.4 t payload/Euro 3 PE Gabi Database
Fuel	Diesel oil for truck	0.104 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
Packaging	**Material input**	**Amount per functional unit**	**Comments, boundary conditions and assumptions**	**References, source of information**
EPS box	Polystyrene granulate (expanded)	22.14 kg	Each box contains 5 kg of cod loins and 0.4 kg ice	Polystyrene granulate (PS, expandable) ELCD/Plastics Europe Gabi database
	Transport within Europe by barge	6.6 tKm	The polystyrene granulate is transported 300 km	Average ship/1228 t payload/canal ELCD/PE-Gabi database
	Transport by cargo ship	45.3 tKm	Sea transport is 2046 km	Ro-ro ship/ 8000 dwt/coast PE Gabi Database
	Truck in Iceland	0.35 tKm	14 - 20 ton truck with 11.4 ton payload. Granulate transported 16 km from harbour to manufacturing.	Truck 14 - 20 t total cap./11.4 t payload/Euro 3 PE Gabi Database
Fuels	Diesel oil for barge	0.048 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
	Fuel oil for cargo ship	0.214 kg		EU-15: Fuel oil light at refinery ELCD/PE Gabi Database
	Diesel oil for truck	0.008 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
Electricity	Electricity	454 MJ	Manufacturing in Iceland.	IS: Power grid mix from Gabi

Table A 2: The data inventory for the cold supply chain where fish is transported by air freight.

Transport	Material input	Amount per functional unit	Comments, boundary conditions and assumptions	References, source of information
	Truck in Iceland	277 tKm	Domestic transport in Iceland is 458 km, using 14 - 20 ton truck with 11.4 ton payload	Truck 14 - 20 t total cap./11.4 t payload/Euro 3 PE Gabi Database
	Transport by air plane	1350 tKm	Distance trawelled is 2,230 km	http://www.cpm.chalmers.se/CPMDatabase/Scripts/sheet.asp?ActId=CPMXFRTOOL2000-01-04835
	Truck in Europe (Cologne, Germany - Boulogne sur Mer, France)	227 tKm	Transport is 375 km, using 34 - 40 ton truck wit total payload of 27 ton	Truck-trailer > 34 - 40 t total cap. / 27 t payload/ Euro 3. ELCD/PE Gabi database
Fuels	Diesel oil for trucks	8.8 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
	Kerosene for air plane	368.9 kg		EU-15: Fuel oil light at refinery ELCD/PE Gabi Database
	Diesel for refrigerated container	0.23 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
Cooling agent	Cooling agent in truck, R134a	0.001128 kg	In container in Iceland the use of R134a is 0.000694 kg and in Europe 0.000434 kg	http://www.cpm.chalmers.se/CPMDatabase/Scripts/sheet.asp?ActId=VolvTU010-8/18/99-341
Storage and processing	**Material input**	**Amount per functional unit**	**Comments, boundary conditions and assumptions**	**References, source of information**
Electricity	Electricity Iceland	999 MJ	Data on electricity use gathered from a producer of fresh and frozen demersal fish fillets.	IS: Power grid mix from Gabi
	Truck in Iceland	7.5 tKm	14 - 20 ton truck with 11.4 ton payload. EPS boxes are transported 338 km from the manufacturer to the processing plant	Truck 14 - 20 t total cap./11.4 t payload/Euro 3 PE Gabi Database
Fuel	Diesel oil for truck	0.104 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database

Packaging	Material input	Amount per functional unit	Comments, boundary conditions and assumptions	References, source of information
EPS box	Polystyrene granulate (expanded)	22.14 kg	Each box contains 5 kg of cod loins and 0.4 kg ice	Polystyrene granulate (PS, expandable) ELCD/Plastics Europe Gabi database
	Transport within Europe by barge	6.6 tKm	The polystyrene granulate is transported 300 km	Average ship/1228 t payload/canal ELCD/PE-Gabi database
	Transport by cargo ship	45.3 tKm	Sea transport is 2046 km	Ro-ro ship/ 8000 dwt/coast PE Gabi Database
	Truck in Iceland	0.35 tKm	14 - 20 ton truck with 11.4 ton payload. Granulate transported 16 km from harbour to manufacturing.	Truck 14 - 20 t total cap./11.4 t payload/Euro 3 PE Gabi Database
Fuels	Diesel oil for barge	0.048 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
	Fuel oil for cargo ship	0.214 kg		EU-15: Fuel oil light at refinery ELCD/PE Gabi Database
	Diesel oil for truck	0.008 kg		EU-15: Diesel at refinery ELCD/PE Gabi Database
Electricity	Electricity	454 MJ	Manufacturing in Iceland.	IS: Power grid mix from Gabi

APPENDIX III: DATA FOR INVENTORY ANALYSIS

Data used for the inventory analysis is shown below.

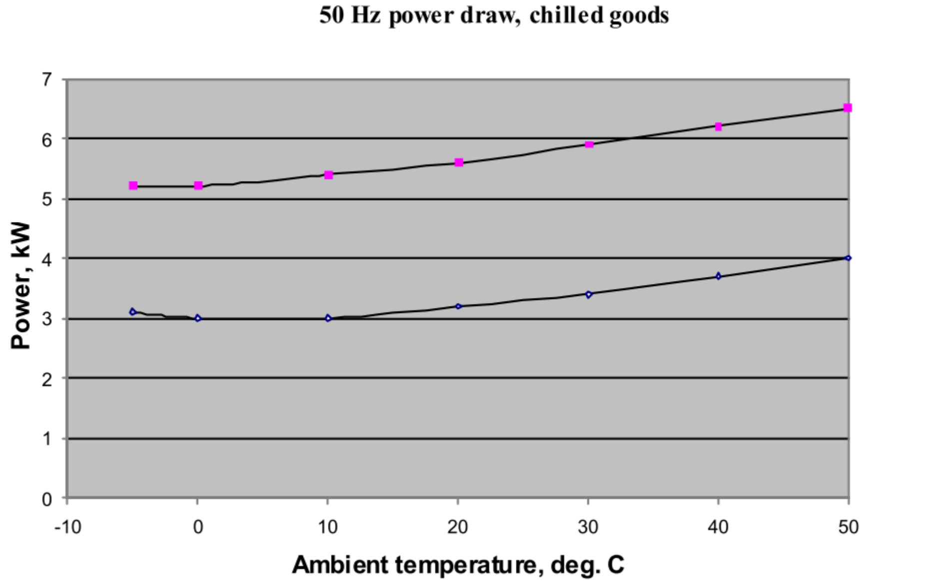

Figure A 2: ***Power draw range for refrigerated containers of various designs at steady temperature conditions, 50 Hz operation, -1 to +13°C cargo temperatures*** **(Heap & Lawton, 1999).**

Table A 3: The average ambient temperatures for the different locations during the cold supply chain.

Location	Average ambient temperature - March		Source
Iceland	-1.3	°C	http://www.vedur.is/Medaltalstoflur-txt/Reykjavik_001_med6190.txt
Ship	0	°C	Estimated
Denmark	2.1	°C	http://www.dmi.dk/dmi/index/danmark/klimanormaler.htm
France	7	°C	http://comprendre.meteofrance.com/content/2009/8/21006-48.pdf

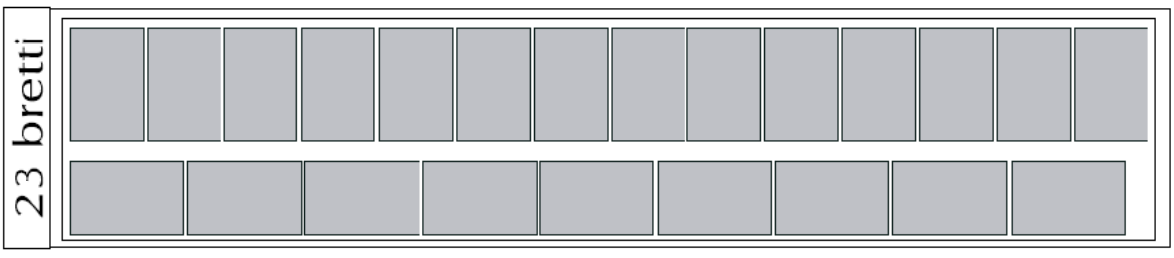

Figure A 3: ***Number of EURO pallets in a 40 foot chilled container (http://www.eimskip.is/PortalData/1/Resources/documents/Eimskip_frystigamabaeklingur_low.pdf)***

Appendix IV: Survey

Below is the survey on the environmental awareness and the attitude of stakeholders of the cold supply chain towards environmental indicators sent out (in Icelandic).

Könnun á umhverfisvitund og viðhorfum á umhverfisgildum sjávarafurða

Ég er nemandi í framhaldsnámi í umhverfis- og auðlindafræðum við Háskóla Íslands og er að vinna að verkefni um umhverfisáhrif framleiðslu- og flutningaferla sjávarafurða. Tilgangur þessarar könnunar er að athuga umhverfisvitund og viðhorf hagsmunaaðila í virðiskeðju sjávarafurða til umhverfisgilda. Einnig að kanna hvaðan eftirspurn eftir umhverfisgildum og/eða umhverfismerkingum koma. Svör þín eru mikilvægt innlegg í upplýsingaöflun fyrir íslenskan sjávarútveg.

Það tekur um það bil 5 – 10 mínútur að svara könnuninni. Könnunin er nafnlaus og þriðja aðila verða ekki afhentar niðurstöður hennar. Ef þú telur að annar starfsmaður innan fyrirtækisins sé betur til þess fallinn að svara könnuninni vil ég vinsamlegast biðja þig um að áframsenda könnunina á viðeigandi starfsmann.

Verkefnið er styrkt af Nýsköpunarsjóði námsmanna og Rannsóknarstofu í hagnýtum vöruferlum við Verkfræði- og náttúruvísindasvið Háskóla Íslands (www.ascs.is) í samvinnu við EFLU verkfræðistofu (www.efla.is).

Kærar þakkir

Gyða Mjöll Ingólfsdóttir

Umhverfisgildi (e. environmental indicator) er mælanleg stærð sem gefur upplýsingar um umhverfisáhrif ýmissa afurða. Umhverfisgildi nýtast til að gefa viðmið um hvort áhrif úrbóta í framleiðslu- og flutningaferlum tiltekinna afurða sé jákvæð fyrir umhverfið.

Hér er leitað eftir upplýsingum um þekkingu og viðhorf á umhverfisgildi sjávarafurða. Vinsamlegast svarið eftirfarandi spurningum.

---

1. Hver er starfsemi fyrirtækisins sem þú starfar hjá/rekur? Merkið við allt sem við á.

- ❒a Fiskveiði
- ❒b Fiskeldi
- ❒c Fiskvinnsla
- ❒d Flutningar
- ❒e Innflutningur
- ❒f Útflutningur
- ❒g Dreifing til smásala/stóreldhúsa
- ❒h Annað, hvað?____

2. Hvers konar afurðir verslar fyrirtækið með? Merkið við allt sem við á.

- ❒a Ferskar afurðir/kældar
- ❒b Frosnar afurðir
- ❒c Saltaðar afurðir
- ❒d Þurrkaðar afurðir
- ❒e Fullunnar afurðir/tilbúnir réttir
- ❒f Annað, hvað?____

3. Hver er stærð fyrirtækisins með tilliti til fjölda starfsmanna?

- ❒1 Stórt, fleiri en 250 manns
- ❒2 Meðalstórt, frá 50 til 249 manns
- ❒3 Lítið, frá tíu til 50 manns
- ❒4 Smátt, færri en tíu manns

4. Hvert er starfssvið þitt innan fyrirtækisins?

- ❒1 Sala og markaðssetning
- ❒2 Vöruþróun og gæðamál
- ❒3 Stjórnun og rekstur
- ❒4 Framleiðsla/vinnsla/tækni
- ❒5 Annað, hvað?____

5. Merkið við viðeigandi:

Fyrirtækið er með:

- ❒e Umhverfisstefnu (e. Environmental policy)
- ❒f Umhverfisstjórnunarkerfi (e. Environmental Management System)
- ❒f ISO 14001
- ❒f IFS vottun (International Food Standard)
- ❒f BRC vottun (British Retail Consortium)
- ❒f Annað, hvað? ____

Næstu spurningar snúa að umhverfisvitund og viðhorfum til umhverfisgilda sjávarafurða.

6. Býr fyrirtækið yfir þekkingu á umhverfisáhrifum framleiðslu- og flutningsferlum afurðanna?

- ❐1 Já
- ❐2 Nei
- ❐77 Veit ekki

6a. Ef já við spurningu 6: Hvar nýtist sú þekking í starfsemi fyrirtækisins?

- ❐a Markaðssetningu afurða/ bættri ímynd fyrirtækisins (Neytendavægi)
- ❐b Bættri stýringu virðiskeðjunnar/ meiri hagnaði (Hagræn gildi)
- ❐c Minni úrgangi/ betri nýtingu (Umhverfisgildi)
- ❐d Öðru, hverju?

____

7. Þekkir þú til mælieiningarinnar sótspor/kolefnisspor (e. CO_2 footprint)?

- ❐1 Já
- ❐2 Nei

8. Telur þú að <u>umhverfisgildi</u> (t.d. kolefnisspor, matarmílur (e. food-miles) o.s.frv.) geti haft vægi fyrir íslenskar sjávarafurðir?

- ❐1 Já
- ❐2 Nei
- ❐77 Veit ekki

8a. Ef já við spurningu 8: Í hverju felst það vægi?

- ❐a Markaðssetningu afurða/ bættri ímynd fyrirtækisins (Neytendavægi)
- ❐b Bættri stýringu virðiskeðjunnar/ meiri hagnaði (Hagræn gildi)
- ❐c Minni úrgangi/ betri nýtingu (Umhverfisgildi)
- ❐d Öðru, hverju?

____

9. Er eftirspurn eftir upplýsingum um umhverfisáhrif afurða ykkar frá kaupendum?

- ❐1 Já
- ❐2 Nei
- ❐77 Veit ekki

9a. Hvers konar upplýsingum? Merkið við allt sem við á.

- ❐a Umhverfismerkingu, KRAV
- ❐b Umhverfismerkingu, MSC
- ❐c Íslenska upprunamerkinu
- ❐d Upprunavottorði
- ❐e Sjálfbærni
- ❐f Lífrænni framleiðslu
- ❐g Öðru, hverju? ____

9b. Frá hvaða markaðssvæðum er eftirspurnin? Merkið við allt sem við á.

- ❒a Norður-Evrópu (Norðurlöndunum, Bretlandi, Þýskalandi)
- ❒b Suður-Evrópu (Miðjarðarhafslöndum)
- ❒c Norður-Ameríku
- ❒d Öðrum svæðum, hverjum?____

10. Til hvaða þátta er helst litið við val á flutningsleiðum afurða á markaði? Vinsamlega raðið eftir mikilvægi.

- ❒a Stuttur afhendingartími
- ❒b Gæði vörunnar/geymsluþol
- ❒c Kostnaður
- ❒d Kröfur kaupenda
- ❒e Umhverfisgildi
- ❒f Rekjanleiki afurða

11. Viltu bæta einhverju við?

Bestu þakkir fyrir að svara spurningalistanum

APPENDIX V: SURVEY RESULTS

Answers to question number 10 in the survey for ranking 2 – 5 are shown in Figures A3 – A6 below.

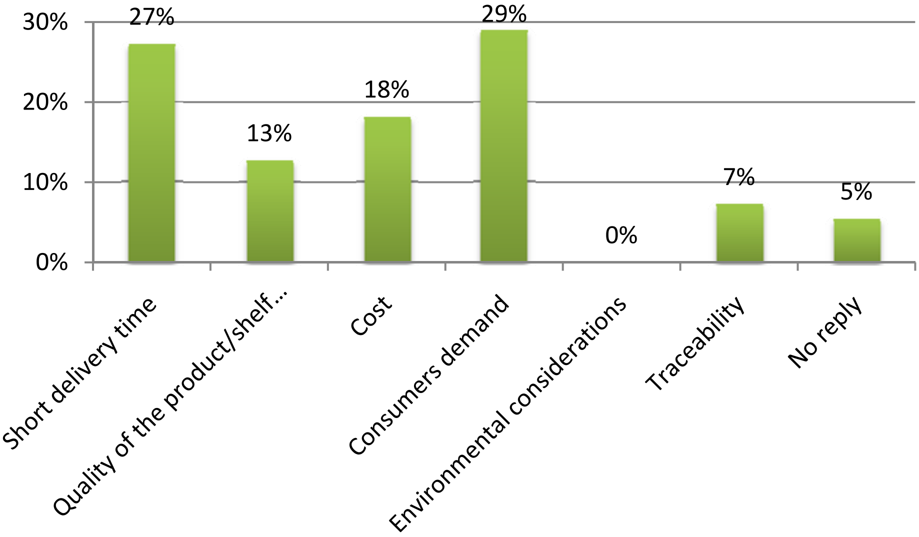

Figure A 4: The second most important factors considered for the transportation chain (rank 2).

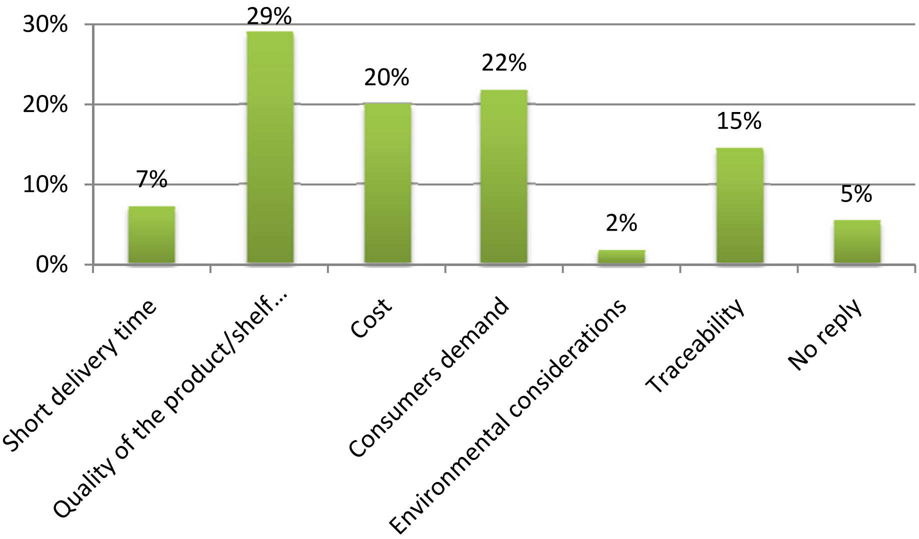

Figure A 5: The third most important factors considered for the transportation chain (rank 3).

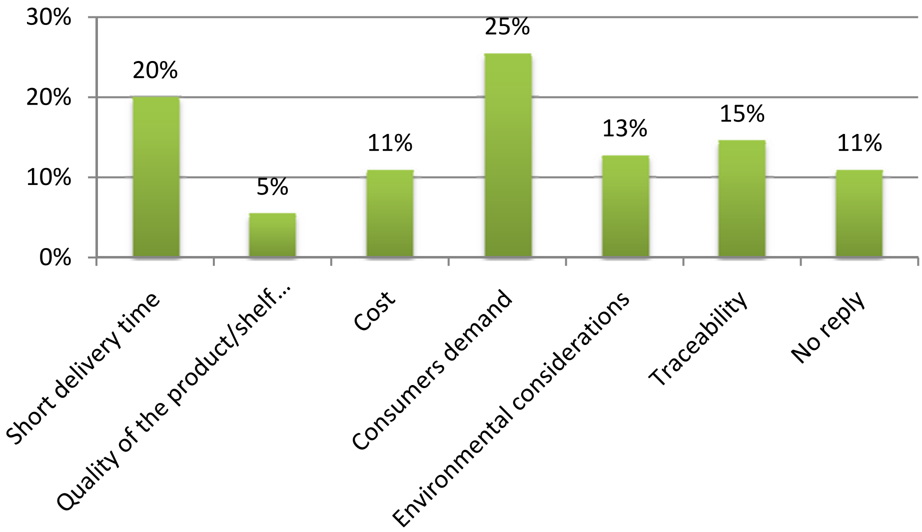

Figure A 6: The factors ranked as the number four for the selection of the transportation chain (rank 4).

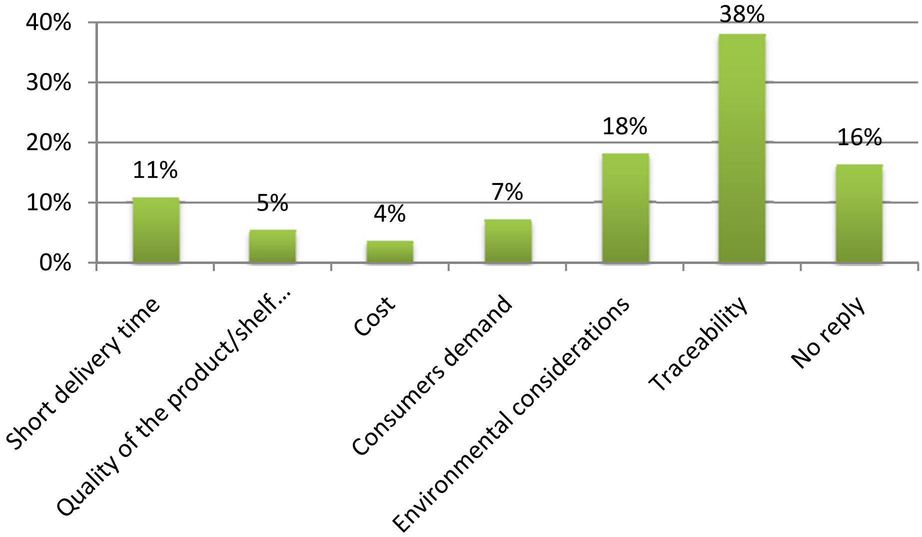

Figure A 7: The second least important factors for the selection of the transportation chain (rank 5).

Comments from participants of the survey are shown in Table A4, in total seven comments were posted.

Table A 4: The comments posted by the participants of the survey.

	Comments
1	Umhverfismál í sjávarútvegi hafa skánað mikið á undanförnum áratug. Flest stærri fyrirtæki landsins virðast hafa innanbúðar fólk sem hefur metnað til að bæta umhverfi og ímynd fyrirtækjanna. Kaupendur, bæði innlendir og erlendir gera sífellt auknar kröfur á veiði- og vinnslufyrirtækin um bætta meðferð vörunnar og virðist verðteygni vera þar á milli. Á hinn bóginn virðast umhverfismál vera ekki í jafn góðu lagi í smærri samfélögum úti á landi og versnar umhverfisvitund eftir því sem að samfélagið er smærra sem fyrirtækið vinnur í. Afar erfitt er að snúa hugsanahætti starfsmanna sem eru um miðjan aldur og eldri og virðast þeir eiga afar erfitt með að hækka þrifstandard og gæði.
2	Tel að þau hafi batnað mjög mikið síðustu ár þar sem komið er með meira af afurðum í land í stað þess að henda þeim í sjóinn, eins og t.d. hausar og sló sem farið er að nýta í afurði.
3	Varðandi svar við spurningu 10, þá getur uppröðun þátta orðið mismunandi eftir því hvaða vöruflokk við er átt. Ferskvara þarf t.d. stuttann afhendingartíma og á meðan frosin afurð hefur lengri lífttíma sem hefur áhrif á val flutningsleiða. Umræða um umhverfismál í sjávarútvegi hefur orðið fyrir miklum skaða vegna öfgaafla og gróðavonar þeirra sem þá umræðu misnota. Sem dæmi eyðir stór togari sem veiðir uppsjávarfisk mikilli olíu en ef þú deilir lítrunum niður á afurðakg er olíueyðslan hverfandi og í ljós kemur að díselhákurinn er í raun afar umhverfisvænn kostur við hráefnisöflun til matvælaframleiðslu, svona niðurstöður fá ekki mikla umfjöllun, miklu meira spennandi að sýna mynd af dökkum reyknum frá vélinni og telja lítrana.
4	Að svo stöddu ekki, en ég tel okkur vera mjög á réttri leið
5	Mun meiri áhersla á umhverfismál og félagið hefur sett upp sérstaka innri nefnd til að fylgja eftir þeim áherslum
6	Stærsta og mikilvægasta umhverfismál sjávarútvegsins er geta staðfest við sína viðskiptavini a varan komi úr fiskstofnum sem eru nýttir á sjáflbæran hátt og ekki sé gengið á stofnana.
7	Eru í bulli, þarf víðtækari fræðslu og vekja fólk til vitundar, sérstaklega varðandi það sem er verið að henda

APPENDIX VI: SURVEY FREQUENCY TABLES

1. What type of company do you work for?

	Count [n]	Percent [%]	Percent of cases [%]
Fishing	36	25%	65%
Aquaculture	9	6%	16%
Processing	44	30%	80%
Transport	3	2%	5%
Import	5	3%	9%
Export	36	25%	65%
Distribution	8	5%	15%
Other	5	3%	9%
Total	**146**	**100%**	**265%**

2. What are the types of products?

	Count [n]	Percent [%]	Percent of cases [%]
Fresh products/chilled	44	30%	80%
Frozen products	46	31%	84%
Salted products	26	18%	47%
Dried products	21	14%	38%
Convenience products	8	5%	15%
Other	3	2%	5%
Total	**148**	**100%**	**269%**

3. Size of company (no. of employees)

	Count [n]	Percent [%]
Large > 250	27	49%
Medium 50 - 250	18	33%
Small 10 - 50	6	11%
Micro <10	2	4%
Other	2	4%
Total	**55**	**100%**

4. What is your position in the company?

	Count [n]	Percent [%]	Percent of cases [%]
Sales and marketing	25	26%	45%
Product development and quality management	16	16%	29%
Management	36	37%	65%
Production/processing	19	20%	35%
Other	1	1%	2%
Total	**97**	**100%**	**176%**

5. The company has:

	Count [n]	Percent [%]	Percent of cases [%]
Environmental Policy	24	37%	44%
Environmental Mgmt. System	3	5%	5%
ISO 14001	7	11%	13%
IFS	11	17%	20%
BRC	8	12%	15%
Other	12	18%	22%
Total	**65**	**100%**	**118%**

6. Does the company recognize the environmental impacts of the product system (from processing, transportation etc.)

	Count [n]	Percent [%]
Yes	32	58%
No	11	20%
Don't know	12	22%
Total	**55**	**100%**

6a. Where/how is this knowledge used?

	Count [n]	Percent [%]	Percent of cases [%]
Marketing/ products reputation	24	34%	45%
Improved supply chain management/increased revenues	24	34%	29%
Resource savings/waste minimization	22	31%	65%
Other	1	1%	35%
Total	**71**	**100%**	**175%**

7. Do you recognize the measure CO2-footprint?

	Count [n]	Percent [%]
Yes	25	45%
No	20	36%
Don't know	10	18%
Total	**55**	**100%**

8. Do you think that environmental indicators can be of significance for the Icelandic seafood industry?

	Count [n]	Percent [%]
Yes	25	45%
No	6	11%
Don't know	24	44%
Total	**55**	**100%**

8a. Where/how can environmental indicators be of significance?

	Count [n]	Percent [%]	Percent of cases [%]
Marketing/ products reputation	23	43%	42%
Improved supply chain management/increased revenues	10	19%	18%
Resource savings/waste minimization	20	38%	36%
Total	**53**	**100%**	**96%**

9. Is there a demand on information about the environmental impacts of the products from your clients/buyers?		
	Count [n]	**Percent [%]**
Yes	24	44%
No	25	45%
Don't know	6	11%
Total	**55**	**100%**

9a. What kind of information?			
	Count [n]	**Percent [%]**	**Percent of cases [%]**
Environmental label, KRAV	2	3%	4%
Environmental label, MSC	13	17%	24%
Iceland - Responsible Fisheries	20	26%	36%
Certificates of origin	20	26%	36%
Sustainable production	17	22%	31%
Organic production	5	6%	9%
Other	1	1%	2%
	78	**100%**	

9b. From which markets is this demand?			
	Count [n]	**Percent [%]**	**Percent of cases [%]**
Northern Europe (Nordic countries, UK, Germany)	23	66%	42%
Southern Europe (Mediterranean countries)	5	14%	9%
North America	4	11%	7%
Other	3	9%	5%
	35	**100%**	**64%**

10-1. What factors are considered when the transportation phase of the cold supply is chosen? Rank 1		
	Count [n]	**Percent [%]**
Short delivery time	8	15%
Quality of the product/shelf life	19	35%
Cost	19	35%
Consumers demand	6	11%
Environmental considerations	0	0%
Traceability	3	5%
No reply	0	0%
	55	**100%**

10-2. What factors are considered when the transportation phase of the cold supply is chosen? Rank 2		
	Count [n]	**Percent [%]**
Short delivery time	15	27%
Quality of the product/shelf life	7	13%
Cost	10	18%
Consumers demand	16	29%
Environmental considerations	0	0%
Traceability	4	7%
No reply	3	5%
	55	**100%**

10-3. What factors are considered when the transportation phase of the cold supply is chosen? Rank 3

	Count [n]	Percent [%]
Short delivery time	4	7%
Quality of the product/shelf life	16	29%
Cost	11	20%
Consumers demand	12	22%
Environmental considerations	1	2%
Traceability	8	15%
No reply	3	5%
	55	**100%**

10-4. What factors are considered when the transportation phase of the cold supply is chosen? Rank 4

	Count [n]	Percent [%]
Short delivery time	11	20%
Quality of the product/shelf life	3	5%
Cost	6	11%
Consumers demand	14	25%
Environmental considerations	7	13%
Traceability	8	15%
No reply	6	11%
	55	**100%**

10-5. What factors are considered when the transportation phase of the cold supply is chosen? Rank 5

	Count [n]	Percent [%]
Short delivery time	6	11%
Quality of the product/shelf life	3	5%
Cost	2	4%
Consumers demand	4	7%
Environmental considerations	10	18%
Traceability	21	38%
No reply	9	16%
	55	**100%**

10-6. What factors are considered when the transportation phase of the cold supply is chosen? Rank 6

	Count [n]	Percent [%]
Short delivery time	5	9%
Quality of the product/shelf life	2	4%
Cost	4	7%
Consumers demand	2	4%
Environmental considerations	27	49%
Traceability	5	9%
No reply	10	18%
	55	**100%**