Manuscript ID: 314814
DOI: 10.18462/iir.iccc.2020.314814

Refrigeration and sustainability in the seafood cold chain.

Tom Ståle NORDTVEDT and Kristina N. WIDELL
SINTEF Ocean, 7465 Trondheim, Norway,
tom.s.nordtvedt@sintef.no

ABSTRACT

Environmental concerns regarding seafood production have been focused on biological impact on target and by-catch stocks as well as ecosystem effects of certain types of fishing gear. Less attention has been paid to the fact that seafood production also contributes to many types of environmental effects above the ocean surface due to modern fishing and fish farming technology. The biological impacts on marine ecosystems have not become less important, quite the contrary. In recent years, however, resource use to produce supply materials and support the production chains of farmed and caught seafood products and resulting emissions to air, water and ground have received increased attention.

To bring seafood from the sea to dinner table its necessary to maintain a low temperature. Sustainable, energy efficient refrigeration systems used in Norwegian fishing vessels and harvest in aquaculture are discussed. Further, systems at the processing facility, storage and transport are presented and discussed.

Keywords: Refrigeration, Sustainability, Energy Efficiency. Seafood

1 INTRODUCTION

To bring seafood from the sea to dinner table its necessary to maintain a low temperature. An estimated 15 % to 50 % of all food is lost or wasted, meaning it is produced but never eaten by humans. The FAO estimates that 35% of fish and other seafood are lost, 30 % of cereals and 45 % of fruit and vegetables (FAO 2012). The UN sustainable development goals address this problem, mainly in target 12.3, which says "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses". Food loss and waste is also linked to other targets in SDG 12 and other goals, such as SDG 2 (zero hunger), SDG 6 (water management), SDG 7 (efficient energy use), SDG 8 (economic growth), SDG 9 (infrastructure), SDG 13 (climate action) and SDG 15 (life on land) (United Nations 2019).

One important measure to reduce sea food losses is to use refrigeration, either chilling or freezing, which prevents food from degrading. Reducing food temperatures improves quality and extends shelf life because it reduces microbiological activity, as well as chemical and physical changes (Singh 2011) (Visser 2006, Magnussen, Haugland et al. 2008). Since refrigeration requires electricity to operate compressors, pumps and fans, increasing the volume of refrigeration systems worldwide would also lead to increased energy consumption unless there is a simultaneous focus on increased energy efficiency for both new and existing systems. Worldwide, the refrigeration sector consumes about 17 % of the total electricity used, including air conditioning (Coulomb, Dupont et al. 2015). Increasing refrigeration during food production, transport and storage will reduce losses, but those systems can also benefit greatly from energy reduction measures. Compared to the cost of developing new energy production plants, increasing energy efficiency is often far less expensive. In 2008, there were at least 100 000 industrial refrigeration plants in Norway, which consumed about 6 TWh per year (Røsvik, Bakken et al. 2008). Focusing on reducing energy consumption in these systems could not only affect total energy use, but also greenhouse gas emissions, both directly (by cutting leakage of high GWP refrigerants) and indirectly (from energy use). Refrigeration worldwide accounts for 7.8 % of global greenhouse gas emissions (Coulomb, Dupont et al. 2017). Indirect greenhouse gas emissions from energy use account for more than two-thirds of these emissions, while direct emissions (refrigerant leakage) account for one-third. (UNEP 2018)

Seafood is extremely sensitive to high temperatures during processing, which means that chilled or frozen handling is almost always necessary. Seafood harvest vessels and processing plants may use different kinds of refrigeration equipment, including:

- Refrigerated seawater (RSW) tanks for chilling
- Tunnel freezers for large batch freezing
- Plate freezers for consumer packages of seafood
- Impingement freezers for individual quick freezing, ready-made products and the like
- Ice machines for chilling fresh seafood during distribution
- Equipment for super chilling
- Cold storage chillers and freezers
- Drying systems for processing and storage of seafood

(Widell and Eikevik 2010, Walnum, Andresen et al. 2011, Stonehouse and Evans 2015, Ates, Widell et al. 2017, Indergård, S. Joensen et al. 2018, Verpe, Bantle et al. 2018)

Although the seafood industry has focused on increasing energy efficiency in recent years, many opportunities for improvement remain. Refrigeration systems are not always dimensioned correctly, or operations may have changed over the years, so that a first step towards improvement could be to undertake measurements, calculations and other analyses. More uniform use of energy during the day could result in lower power peaks and reduced costs. Other investments that can also result in reduced energy use include better regulation of compressors and other components, the use of surplus heat in processing, and the installation of heat pumps and thermal storage.

2 REFRIGERATION IN THE SEAFOOD CHAIN

Seafood consumers are becoming more aware of the environmental consequences of fishing, and the environmental impact of seafood products may influence the market share. They require more information about carbon footprint, environmental impact and traceability. It will be important for the consumers to know, for example, where and how a product has been produced, how the temperature has been during the processing and transport, and the value for the accumulated carbon footprint.

2.1. Refrigeration after harvest at sea

The fishing fleet of Norway consists of a range of different types of vessels, ranging from small boats to large fish factories, in total 6134. All vessels have methods for keeping the fish cold, to preserve fish quality and shelf life. There are mainly three different methods: Store the fish on ice (which is brought from land or produced onboard), chilling in RSW (refrigerated sea water) tanks, and freezing in blocks in plate freezers. A few vessels also have quick freezers for single frozen fillets. Keeping the fish cold is necessary to avoid food degradation and losses, but refrigeration systems require electricity. The Norwegian land-based industry has, during the last decades, had an increasing focus on reducing energy consumption and it is necessary to extend this work to the fishing fleet to improve competitiveness in the world economy.

The Norwegian fishing fleet has a large potential of reducing the total energy consumption, because it consists of many vessels and a high average age. The propulsion system is the main energy user and there are several different actions for reducing its energy consumption. However, the refrigeration systems also consume a great part of electrical energy, which is produced onboard, but with less research focus until now. Furthermore, the direct economic advantage from a lower energy (fuel) consumption will most often be gained by the shipowner, which makes it easier to defend an investment in energy efficiency measures.

Some fishing vessels are planning to use LNG (Liquefied Natural Gas) as fuel for a more environmentally friendly propulsion. LNG is stored at -162 °C and when using it as fuel it is possible to utilize the evaporation heat from the gasification of LNG to cover some portion of the cold needed to freeze the fish. There exists a concept developed for cold recovery on LNG-fueled passenger vessels, used for covering parts of the AC cooling demand. However, since the cooling demand, operational conditions and operation pattern for a fishing vessel differs in many ways from that of a passenger vessel, there is a need for developing concepts adapted to fishing vessels.

In today's vessels, excess heat from the propulsion engines can be used for space and tap water heating but may not be enough for other processes onboard, for example enzymatic hydrolysis, used for utilization of marine raw material as shown is figure 1.

Figure 1: Trawler FV Molnes with bins that keep the fish alive before controlled slaughter process and hydrolysis treatment of the rest raw material. (picture from https://www.nordicwildfish.no/)

For future propulsion systems, such as hybrid or fully electrified systems there are less or no surplus heat available. To provide the required heat, it is possible to utilize surplus heat from the refrigeration system. The surplus heat is normally available at lower temperature levels and the installation of a heat pump, to lift the temperature level, is needed. Heat pump systems with the refrigerant CO2 are brilliant for these cases, since these are compact units and the refrigerant is detectable and therefore not dangerous if there are leakages. These systems are utilized by most Norwegian supermarkets and some industrial process plants but must be adjusted for fishing vessels. For example, the variation in operating conditions and operation profile between different types of fishing vessels are much larger than between supermarket installations.

Furthermore, a refrigeration plant onboard a fishing vessel generally differs from a land-based installation in the following ways;

- the electricity is most often produced in fossil-fuelled generators onboard
- there are higher refrigerant leakage rates due to the harsh environment
- over-dimensioned components/systems and limited space
- more stringent safety regulations regarding e.g. flammability

Carbon dioxide (CO_2) is a natural refrigerant that is, until now, used for chilling and freezing onboard a few fishing boats in Norway. It is reliable and efficient, but not yet well known to this industry, and especially abroad in other fishing regions. The refrigerant currently used onboard Norwegian fishing vessels is ammonia (NH_3), another natural refrigerant. It is the most energy efficient refrigerant, but it can be dangerous if there is a large leakage. With proper training and equipment, it is safe and the vast utilization of these systems in Norway is a good example of this. Natural refrigerants do not affect the climate nor the environment, which synthetic refrigerants like R22 do, which contributes to both global warming and ozone layer depletion. R22 is still the most widely used refrigerant onboard fishing vessels according to International Institute of Refrigeration (De Larminat (2018)). There exists non-ozone depleting synthetic refrigerants (HFCs, HFOs) but these still have a substantial GWP or the decomposition products are toxic. Furthermore, these refrigerants are subject to phasedown and they are likely to be difficult to get in the future, even if they are allowed for temperatures below -50°C for tuna freezing.

2.2. Refrigeration in seafood farming

In the past five years, the annual production of salmon and trout in Norway has been approximately 1.3 million tonnes(https://en.seafood.no/) of round fish. The potential for volume growth is present both for market and production, but the lacking balance between the industry’s environmental footprint and the desire for growth has restricted volume increase. In line with the need for innovation and improvement, the need for modern equipment, monitoring and feed technology has helped to develop a significant supply industry.

95% of the salmon is sold gutted, but amount of fillets and consumer packaging are increasing. Several companies produce their own brands, which they export. Commercial production of salmon and trout in Norway takes place in 11 of the country's counties.

Norway is the largest producer of Atlantic Salmon in the world, with a global production share of 53 % in 2016 (1 233 619 tonnes).There is a large potential in increasing the salmon production in Norway, but there are several biological issues that must be solved first. A rapid and efficient processing of the fish is necessary, both today and with increased future production.

The salmon is produced in sea cages and transported live in well boats to processing plants onshore. Before the salmon is slaughtered it should be kept at least 12 h in holding cages, to reduce stress levels and increase product quality. Processing factories include some main processing and handling stages. The fish are slaughtered by stunning and gill cut.After that it bleeds and die in another chilling tank and is then transported to gutting, before they are either packed as gutted fish into polystyrene boxes or filleted and packed into boxes of expanded polystyrene (EPS) containing >10 % ice. Table 1 shows typical energy use in salmon production.

Table 1: In- and outputs at the salmon slaughter plant affecting energy/carbon footprint per tonne live weight salmon produced (Winther et.al (2009))

Inputs	Amount
Live-weight salmon	1000 kilos
Electricity	81 kWh
Carbon dioxide	0.15 kg
Water	3500 litres
Refrigerant R22	0.45 g
Refrigerant NH3	7.4 g
Ice	207 kg
Outputs	
Salmon, head-on, gutted	822 kilos
Salmon by-products to ensilage	178 kilos

An effective chilling of salmon depends on the temperature difference between fish and chilling water, chilling time, the flow of water, mass of fish and water and of stirring. Dead fish sink to the bottom of the tank, which could result in more cold water passing above the fish, instead of between, resulting in less efficient chilling. It is necessary to have and to develop equipment for effective and rapid chilling of the fish. Figure 2 shows a typical chilling tank at a salmon slaughter plant.

Figure 2: Chilling tank at salmon slaughter plant

Chilling of salmon to a low and stable temperature is important for the quality and the shelf life of the product. A reason for increased shelf life with decreasing product temperature is that the growth of microorganisms is slower when the temperature is low. Another consequence of low temperature is slower protein denaturation and protein degradation.

2.3. Refrigeration in seafood processing

Energy consumption analyses at seafood processing plants have shown that about 70 % of all energy consumption is by the refrigeration system. Energy-saving initiatives that focus on these systems can consequently have a great impact on total energy consumption, but there are also uncertainties associated with making these modifications. Processing plant owners might be reluctant to make changes or stop production for changes that are costly and have a longer or uncertain pay-back time. Research, information and experiences from other systems could be a motivator, together with governmental financial support (Walnum 2010, Ates, Widell et al. 2017, Enova 2019).

Seafood processing plants mainly consist of filleting, trimming and packing for retailers. The refrigeration equipment are cold storage rooms and chilling at freezing equipment. Figure 3 shows frozen mackerel fillets after a belt freezer at a processing plant. A typical distribution of energy demand for a seafood processing plant is shown in figure 4.

Figure 3: Combined blast and contact freezing of mackerel filets

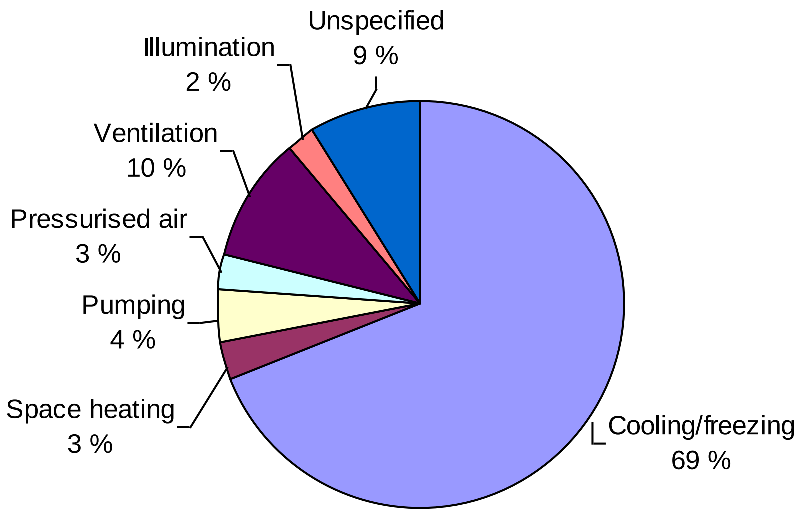

Figure 4: Typical distribution of energy demand at fish processing plants [Helgerud, H.E. 2007]

In table 2, typical energy use for filleting and freezing (the cooling/freezing part in figure 4) at salmon and whitefish plants are shown.

Table 2: Energy use for filleting and freezing (Winther et.al (2009)

Energy use (kWh/tonne product)	Total	Filleting	Freezing
Whitefish plant	794	661	133
Salmon plant	701	568	133
Average	748	615	133

Data regarding the use of by-products was found in Bekkevold and Olafsen (2007), stating that 100% of by-products from farming are used, 39 % of by-products from cod processing and 95 % of by-products from herring processing. This should also be a part of a sustainability measure for seafood.

2.4. Refrigeration in seafood transportation

Transportation of seafood products are with trucks, trains, airfreight or boats. Table 4 shows the greenhouse gas emission from different transport alternatives and it is calculated based on the following assumptions.

Trucks

Frequently used trucks in fish export from Norway are models such as Volvo FH and Scania R500. The total amount of goods that can be loaded per truck is limited to around 24 tonnes. A typical insulated container on these lorries can load 33 euro pallets.

The cooling system contributes with greenhouse gas emissions in two ways 1) through the energy required to power the cooling system and 2) via leakage of cooling agents with high global warming potential. Several sources confirmed diesel consumption to be around 2-4 l/h, varying depending on load and season. Technical specification in table 3 of the two most frequently used systems was obtained from the company dominating the market in Sweden and Norway.

Table 3: Fuel consumption in cooling systems (Winther et.al (2009))

Cooling system temperature	**Fuel (l/h)**				**Average (l/h)**
	SL-200e		**SL-400e**		
°C	**High**	**Low**	**High**	**Low**	**All**
-20	3.27	2.1	4.33	2.2	**3.0**
0	3.62	2.12	4.78	2.05	**3.1**

Leakage of refrigerants was estimated to 5-10 % of refrigerant volume (NTM 2008). The total refrigerant volume in trailers is approximately 6.5kg. Most used refrigerants are R134a and R404A with Global Warming Potential of 3300 respectively 4800. As can be seen in table 3 the fuel consumption is higher for 0°C than for -20°C. This is probably due to less insulation in 0°C cabinets and higher temperature of the cargo load.

Container

Typical cargo flow represents a 40-feet container that is either delivered directly to port or loaded at warehouse near the harbour from a connecting transport as trucks or trains. Fuel use per cargo for container ships origins from Lindstad and Mørkve (2009) and it is assumed that 56 % of the cargo capacity is utilized. In addition to the fuel use for propulsion of the vessel, the electricity demand of refrigerated containers was added in the same way as was done for trucks, but with the container plugged into the ship using 160g diesel per kWh onboard.

Trains

Distances by rail were calculated based on information from Green Cargo (Green Cargo 2009). The round frozen herring is transported in containers from St. Petersburg to Moscow (814 km) a transport estimated to take approximately 12 hours. Energy use for rail freight was between 0.034-0.043 kWh/t*km depending on how hilly the area is (NTM 2008c). Refrigeration of containers was modelled similar to refrigeration on trucks.

Boats

Round frozen fish is transported in bulk on a relatively small ship (loading around 2000 tons of fish directly on an equal amount of euro pallets). This boat was assumed to be 2/3 to 3/4 empty on the way back, depending on the route. The bulk ship was the only case where an empty return transport was added due to the information that these vessels to a large extent actually are empty on the way back. A fuel use of 0.011 l/t*km was used after personal communication with several reefer ship owners.

The chosen ferry data are based on emission data from NTM (2008b) using a "modern" RoRo Cargo ship with specific fuel consumption of 77 kg diesel/km and 3800 lane meters and cargo deck. Emissions were allocated with 58 % to the cargo and 42 % to the passenger according to how much area each of them occupy, as suggested by NTM. The emission rate per semi-trailer was calculated according to the 17 lane meters truck and trailer occupy and the corresponding weight of cargo load.

Airfreight

The distance for airfreight between Oslo and Tokyo was calculated using www.airrouting.com. The air transport has been modelled by using a Boeing 747 400 in the NTM database (NTM 2008b), as the closest match to Boeing 747 400ERS commonly used for salmon exports. These aircrafts are dedicated cargo planes and do not take passengers. A load of 3.5 tonnes of fish is usually loaded in a flight container of 4.5 tonnes including ice and packages (Wesby, SAS, pers. comm. and salmon producer). The data from NTM (2008a) represents a 100 % freight factor with maximum load of 93 tonnes, however a general load factor of 0.7 was used motivated by the general uncertainties related to return flights and sample representativity for the whole fleet. No extra factor for emissions at high altitude was used.

Table 4: Greenhouse gas emissions related to transportation of one tonne of product one kilometre (Winther et.al (2009))

Main Transport Processes	GHG emissions ($g\ CO_2e$/tonne*km)
Airfreight, Boeing 747-400	879
Lorry, Norway rural, 18 tonnes fresh fish	93
Lorry, Norway rural, 22 tonnes frozen fish	91
Lorry, European motorway, 18 tonnes fresh fish	76
Lorry, European motorway, 22 tonnes frozen fish	67
RoRo Car ferry (18 tonnes fresh fish)	52
RoRo Car ferry (22 tonnes frozen fish)	43
Containership (Small, 17knots)	36
Containership (Large Slow, 14knots)	18
Freight train (using Russian electricity)	7
Bulk ship Herring	<35[1]
Truck Cooling	10 222[2]
Truck Freezing	9 919[2]
Boat Cooling	6 129[2]
[1] includes cooling [2] ($g\ CO_2e$/hour of refrigeration needed)	

3 SUSTAINABILITY IN THE SEAFOOD VALUE CHAIN

Traditionally, environmental concerns regarding seafood production have been focused on biological impact on target and by-catch stocks as well as ecosystem effects of certain types of fishing gear. Less attention has been paid to the fact that seafood production also contributes to many types of environmental effects above the ocean surface, due to modern fishing and fish farming technology. The biological impacts on marine ecosystems have not become less important, quite the contrary. In recent years resource use to the production chains of farmed and caught seafood products and resulting emissions to air and water have received increased attention.

In 2009, SINTEF performed an analysis of carbon footprint and energy use for various Norwegian seafood products from origin to wholesaler around the globe. The products stem from capture fisheries for herring, mackerel, cod, saithe and haddock or from aquaculture of salmon. After landing or slaughter fish are processed into a variety of fresh, frozen, round, gutted or fillet products after which they are transported to the respective country and city where the wholesaler is located. The large number of chains assessed using the same methodology, ISO standardised Life Cycle Assessment methodology, following the supply chains from cradle-to-gate, allows for comparison between supply chains illustrating the effect single aspects such as species, transport mode and distance and product form. This investigation was repeated in 2019/2020 and the results will be published in May 2020. The results presented in this paper are from the 2009 investigation.

In general, the products from pelagic fisheries were found to have the lowest carbon footprint while products from demersal (e.g. cod, saithe, haddock) fisheries and salmon were higher and in similar range (Figures 5 and 6. The range in carbon footprint was 1-14 kilos of carbon dioxide (CO2) equivalents per kilo of edible product delivered to the wholesaler, the range in energy use was 16-210 megajoule (MJ) equivalents. The lowest value was achieved by round frozen herring and mackerel taken to Moscow by bulk shipping and train and the highest by gutted, fresh salmon taken to Tokyo by airfreight.

The two categories studied, energy use and carbon footprint, were highly correlated, indicating that the use of fossil fuels dominated the carbon footprint result. The use of the old generation of refrigerants, which were phased out in other applications decades ago, turned out to be the second largest contributor to the carbon footprint for almost all chains originating in demersal fisheries contributing to up to 30 % of the total carbon footprint. The exception to this was cod processed in China where transport was largest, diesel use in fishing second and refrigerants ranked third. Less surprising was that diesel use in fishing was the most important contributor in the other demersal chains, even though all fisheries were relatively fuel efficient compared to literature data. Pelagic fisheries are so efficient already that other activity such as packaging, processing and transportation become more important.

It was shown that processing in Norway is favourable compared to exporting whole fish for processing abroad, since by-products are used to a greater extent in Norway and part of the transport activity is avoided. Freezing or super-cooling of seafood requires some energy, but especially when long distance transportation is involved, the longer shelf-life of frozen or super-cooled fish makes it possible to transport it in a much more efficient manner which is more important for the overall result. Moreover, frozen and super-cooled fish does not require use of ice as does fresh fish which is positive both due to the electricity used for ice production, but more importantly due to the larger amount of fish that can be loaded per pallet, truck and container. While there is a clear effect of transport distance, the factors transport mode and transport time are equally important.

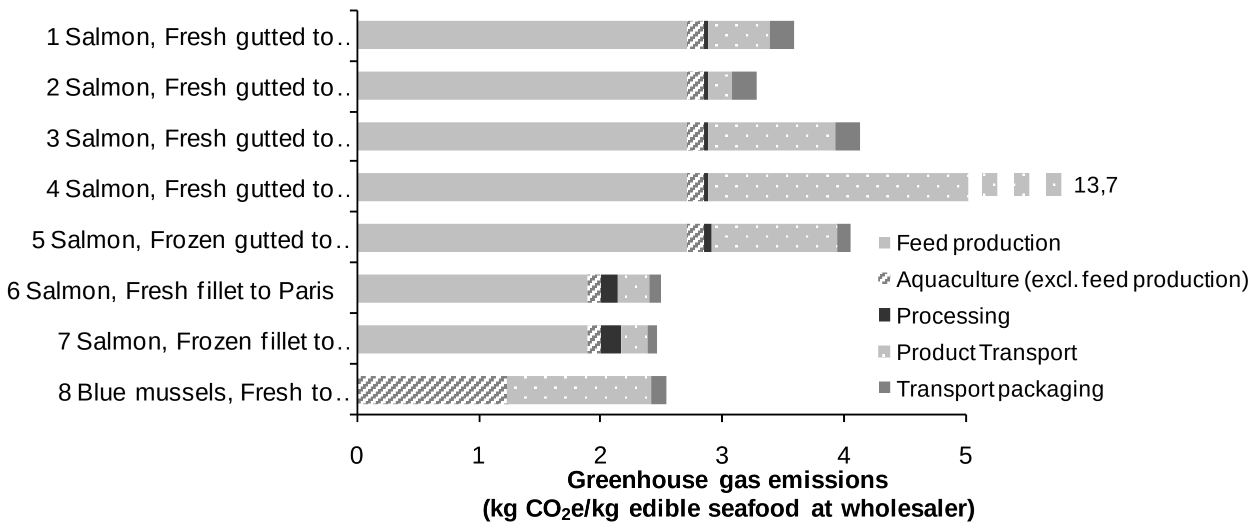

Figure 5: Overall carbon footprint results for products from aquaculture (Winther et.al (2009))

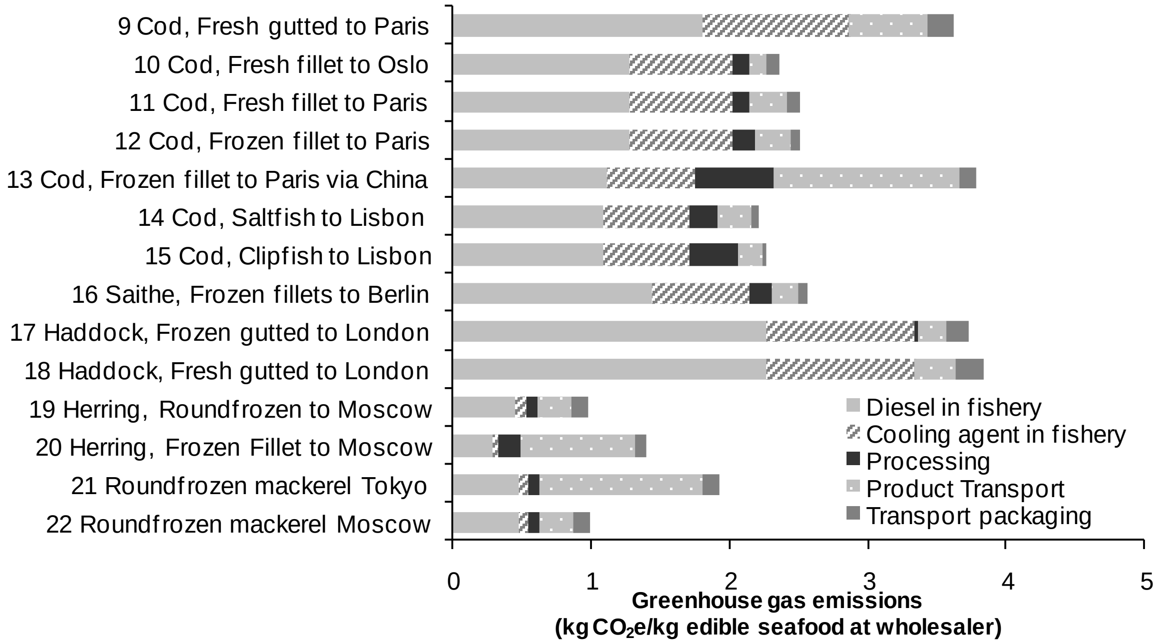

Figure 6: Overall carbon footprint results for products from capture fisheries (Winther et.al (2009))

The results presented above only concern the carbon footprint, but the study included two impact categories – the other one being primary energy use. Primary energy use as calculated by the impact assessment method Cumulative Energy Demand (CED) is, for the studied value chains, highly correlated to the carbon footprint. This result shows that the carbon footprint is largely determined by the use of fossil fuels in the different chains both for fishing, transportation and to some extent production of packaging and electricity. The main differences are that the refrigerants used in the fishing phase almost only contribute to the carbon footprint, hardly to energy use at all. The processing phase contributes more to the impact category energy use than to carbon footprint, since some of the energy used in this phase does not contribute to the carbon footprint. But the overall results for the two categories are very similar as can be seen in Figure 7.

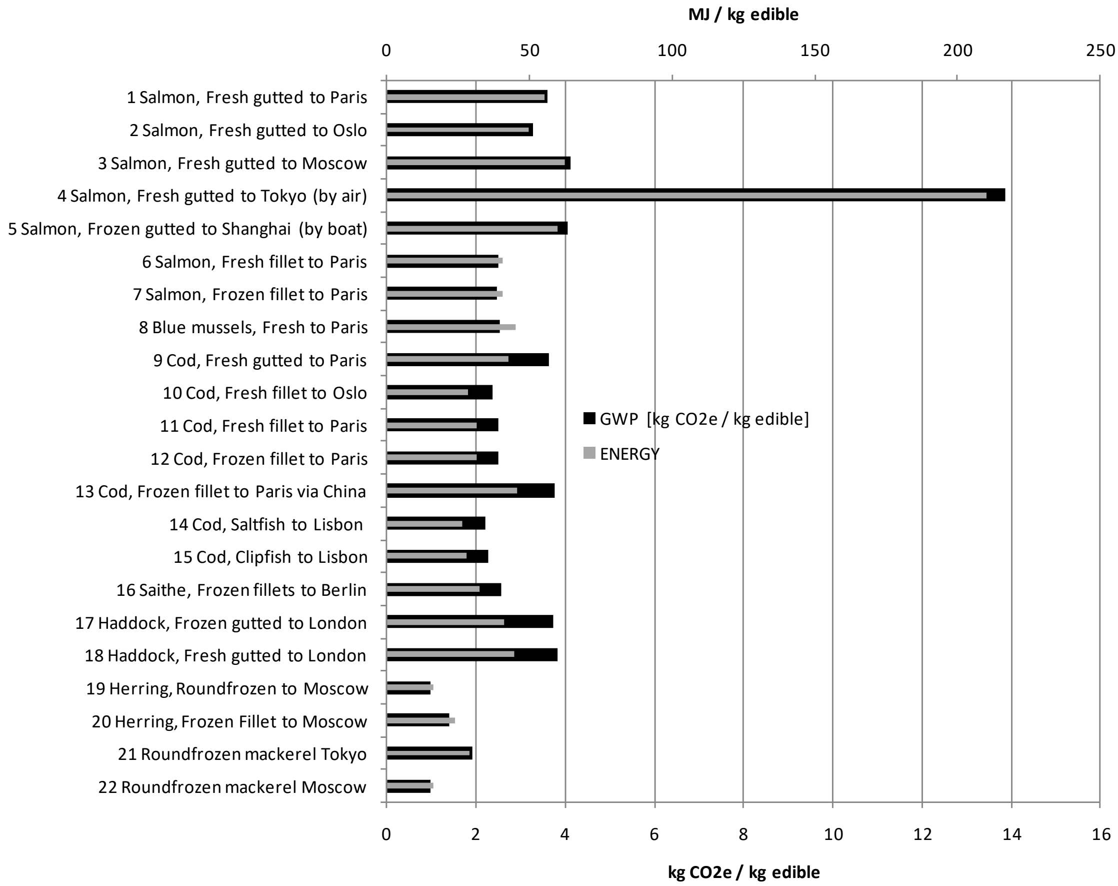

Figure 7: Total results primary energy use and climate impact. Energy use on top axis and climate impact on lower axis. (Winther et.al (2009))

4 CONCLUSIONS

The conclusions from this work include that seafood products are competitive from a carbon footprint and energy use perspective compared to meat products. Important areas to focus on for fisheries are improving the fuel efficiency further and replacing refrigerants with high greenhouse gas emissions used in onboard cooling systems by climate neutral ones. With regard to salmon farming, optimizing feed use and feed composition with regard to climate impact are paramount.

General conclusions for all types of products are that increasing the proportion of frozen seafood to fresh, which in turn decreases the need for air freight and other resource-intensive means of transport, would lead to major improvement.

Increasing the edible yield and use of by-products would likewise lead to lower emissions and processing more seafood before export is advantageous because of better possibilities to make use of by-products and decreased need for transportation when exporting products rather than whole fish.

To reach more realistic results, modelling of the products with higher resolution with regard to which fisheries that deliver fish to individual supply chains would be desirable, that would also allow for more detailed recommendations for improvement.

On the long-term, it is desirable to increase the knowledge of the impact of individual measures in fisheries management in order to be able to optimize the management system also from an environmental point of view. Taking carbon footprint and energy efficiency into account in the design of the fisheries management systems of the future would help making seafood production an even more sustainable and less resource-demanding business.

Seafood products studied are on the right way towards sustainability and have many of the essential elements of sustainable production in place already. However, there are many actions both on the short and long term that can improve the situation further and it is very important to deal with these questions in a proactive way to produce sustainable products.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Research Council of Norway for the financial support for carrying out the present research [NFR project No. 257632/HighEff].

REFERENCES

Ates, M. B., et al. (2017). Energy consumption for salmon slaughtering processes. 7th Conference on Ammonia and CO2 Refrigeration Technology. Ohrid, Macedonia, Internat. Inst. of Refrigeration, ISBN 9782362150210.

Bekkevold, S., Olafsen, T., 2007.(In Norwegian) Marine biprodukter: Råvarer med muligheter (Marine by-products: Raw materials with potential- in Norwegian). RUBIN-project report. Available from rubin@rubin.no

Coulomb, D., et al. (2017). The impact of the refrigeration sector on climate change. 35th Informatory note on refrigeration technologies IIR.

De Larminat, Paul, (2018) Cold chain technology brief, Fishing vessel application, IIR, UN environment, https://goo.gl/2NH9Lh

FAO (2012). "SAVE FOOD: Global Initiative on Food Loss and Waste Reduction." http://www.fao.org/save-food/resources/keyfindings/infographics/fish/en, cited: 2019 06 18.

Helgerud, H.E., Store energipotensialer i næringsmiddelindustrien, in Enova rapport 2007:6. 2007.

Indergård, E., et al. (2018). Optimization of quality and yield of stockfish by end-drying in climatic controlled storage. 5th IIR Conference on Sustainability and the Cold Chain, Beijing, China.

Lindstad, H., Mørkve, O. T. (2009), Methodology to assess the Energy Efficiency and the environmental performance of maritime logistics chains, 10th International marin design conference, IMDC09 Tapir academic press, ISBN 978-82-519-2438-2.

Magnussen, O., et al. (2008). "Advances in superchilling of food - Process characteristics and product quality." Trends in Food Science & Technology.

NTM (2008a), The Network for Transport and Environment (NTM), Environmental data for international Sea cargo transport. Calculation methods, emission factors, mode-specific issues. Version 2008-10-18, www.ntm.a.se

NTM (2008b), The Network for Transport and Environment (NTM), Environmental data for international cargo and passenger air transport. Calculation methods, emission factors, mode-specific issues. Version 2008-10-18, www.ntm.a.se

NTM 2008c. The Network for Transport and Environment (NTM), Rail transport. Environmental data for international cargo transport. Calculation methods, emission factors, mode-specific issues. Version 2008-03-04, www.ntm.a.se

Røsvik, S., et al. (2008). Klimatiltak med relasjon til kuldeanlegg og varmepumper [in Norwegian]. Klimadokument kulde [Technical report].

Singh, R. P. (2011). Computational Modeling in Refrigeration and Freezing of Foods. International Congress of Refrigeration, Prague, Czech Republic.

Stonehouse, G. G. and J. A. Evans (2015). "The use of supercooling for fresh foods: A review." Journal of Food Engineering.

UNEP (2018). Workshop on energy efficiency opportunities while phasing-down hydrofluorocarbons (HFCs), including Briefing papers A, B and C). http://conf.montreal-protocol.org/meeting/workshops/energy-efficiency/presession/.

United Nations (2019). "17 Goals to transform our world." https://www.un.org/sustainabledevelopment/, cited 2019.06.18.

Verpe, E., et al. (2018). Evaluating Plate Freezing of Fish Using Natural Refrigerants and Comparison with Numerical Freezing Model. 13th IIR Gustav Lorentzen Conference, Valencia, Spain.

Visser, K. (2010). An HFC/HCFC free food processing plant: the energy and environmental benefits of a two stage transcritical CO2 refrigeration plant. Gustav Lorentzen conference on natural working fluids. IIR. Sydney, Australia.

Walnum, H. T. (2010). Energy consumption in Norwegian seafood industry. SINTEF Technical Report. ISBN 978-82-594-3438-8.

Walnum, H. T., et al. (2011). "Dynamic simulation of batch freezing tunnels for fish using Modelica." Procedia Food Science 1(0): 698-705.

Walnum, H. T., et al. (2011). Verification of a Modelica-based dynamic simulation model for batch freezing tunnels. International Congress of Refrigeration.

Widell, K. N. and T. Eikevik (2010). "Reducing power consumption in multi-compressor refrigeration systems." International Journal of Refrigeration 33(1): 88-94.

Winther, U., Ziegler, F., Skontorp Hognes, E., Emanuelson, A., Sund, V., Ellingsen, H. "Carbon footprint and energy use of Norwegian seafood products" SINTEF Report SFH80 A096068. (2009) ISBN 978-82-14-04925-1