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Sustainability within food cold chain sectors in Norway

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ABSTRACT

Food processing, storage, and distribution demand a considerable amount of energy and raw materials. Processes that are especially energy demanding includes cooling, freezing, drying and heating, but they are also necessary to ensure the quality and shelf life of the products. All actors within the food value chain are aware of the climate changes and the need for more sustainable activities and development. Many companies annually report their sustainability initiatives, reduction targets, goals towards carbon neutrality and evaluate their performance based on key performance indicators (KPIs). This paper presents results from a review done on Norwegian actors within dairy, meat, fish, fruit, and vegetable sectors. The companies set their goals according to the Paris Agreement to reduce their emissions significantly toward 2030 and become climate neutral by 2050. Some sectors such as meat and dairy have most of their emissions in the pre-processing stage (at farm level) and have significant challenges in meeting the Paris Agreement goals if the market demand continues to grow. However, it is more likely to achieve the reduction targets from post-harvest to retail stages. There are significant challenges in packaging, transport and the source of electricity and these challenges are addressed in research projects HighEff and ENOUGH. Solutions found within these two large consortiums with relevance for the Norwegian food value chain are also presented in the paper.

Keywords: food cold chain, energy efficiency, natural refrigerants, sustainability, greenhouse gas emission

1. INTRODUCTION

Food production, processing and distribution requires a considerable amount of energy and other resources. For the second year in a row, the world is no longer making progress on achieving the UN Sustainable Development Goals (SDGs), and major challenges remain. Norway faces its greatest challenges in SDG 2 (zero hunger), 12 (responsible consumption and production), 13 (climate action) and 15 (life on land) (Sachs et al., 2022). All of these can be related to the food chain. This study has reviewed the sustainability reports of the largest companies in the main food sectors, i.e., dairy, meat, fish, seafood, fruits and vegetables, focusing on the companies' measures to reduce direct emissions, indirect emissions, and energy consumption.

The agricultural sector in Norway is responsible for about 9.4% of the total national CO_2-eq emissions per year, which is about 4.5 Mt CO_2-eq (Animalia, 2022). The emissions from postharvest processing were 535 000 tonnes CO_2-eq in 2020 and have been more or less stable over the years (Statistics Norway, 2022). Most of these emissions are related to the energy use in processing and storage. The degree of food self-sufficiency in Norway is about 46 %, defined as (consumption-import)/consumption, while the degree of coverage is 87% (consumption + export - import)/consumption. The high degree of coverage is mainly due to the significant seafood export, and the self-sufficiency rate would be higher if the average Norwegian diet contained more local seafood.

This study has been conducted to get an overview of the Norwegian food industry's efforts to reduce energy demand and emissions. The selection of the food value chain actors has been within farm gate and retail gate as shown in Figure 1. However, many companies do not give specific numbers for these stages hence numbers related to other stages are also included in the findings.

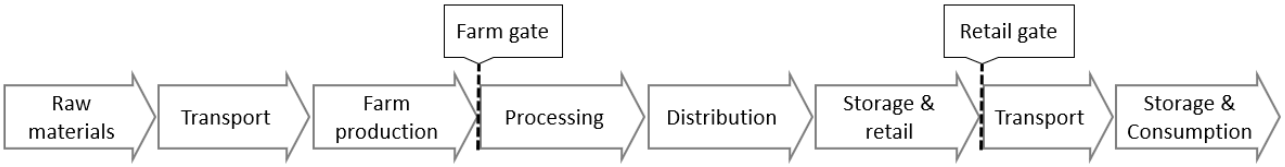

Figure 1. Overview of the different parts of a food value chain.

The EU-project ENOUGH (European food chain supply to reduce GHG emissions by 2050) started in 2021 and aims to bring together industry actors and provide road maps to assist the process on reaching the goal of net zero emissions in 2050. Becoming net zero is an enormous challenge, and the cross-sectional project will demonstrate the best technology available, test new novel concepts, and share experiences to help the industry make the best decisions and allow knowledge transfer.

2. METHODS

The study included the sectors meat (beef, pork, poultry, sheep, goat), dairy, seafood, fruits and vegetables. Some sectors were reviewed at a company level, while others have larger organizations representing the industry. These organizations have an overview of the size of the largest industries in each sector. The selected companies in this study were the largest, excluding smaller food industries. In the meat and dairy sector, companies with at least 5% market share in their segment were included while in in seafood sector stock listed companies operating in Norway were included. In the fruit and vegetable sector, there were mainly two parallel chains supplying the grocery stores, including some industries.

The investigation was carried out by reviewing publicly available information on the company websites, product web pages and annual sustainability reports for the companies who have published it. The company profiles and an overview of their sustainability related activities have been retrieved mainly through their websites wherever available.

3. FOOD SECTORS

3.1. Dairy

Norwegian milk and dairy products are processed mainly by TINE, Synnøve Finden, Q-Meieriene and Rørosmeieriet, in addition to some local small-scale producers. TINE dominates the dairy market with a share of 94% of the milk and over 70% of processed dairy products (OECD, 2021). The total volume of dairy products in Norway are shown in Figure 2. The figure includes import numbers, however cheese is the only product with notable import volumes (about 10% of the total in 2021).

The average GHG emissions from milk Norway is 1.2 CO_2-eq/kg, while the global average is 2.6 CO_2-eq/kg (Gerber et al., 2013). There are significant variations between countries, and the main reason for Norway's lower emissions are high animal productivity and feed efficiency (Oort and Andrew, 2016).

TINE and Q-meieriene have sustainability reports with goals to meet the Paris Agreement. One of the largest emission sources in Scope 1 for TINE is the use of natural gas at one of their processing plants, and they are planning to replace parts of the natural gas with wood chips. Another large contributor to the direct emissions is transport and TINE is aiming to shift the use of all transport fuels to renewable fuels by 2030 (TINE, 2022). Q-meieriene have set the ambitious goal of being climate positive by 2030, with plans to reduce emissions in their cold chain (changing transport fuel, installing heat pumps) and invest in external climate positive projects (Q-meieriene, 2020, 2022). Rørosmeieriet also has ambitious goals and have started with CO_2 heat pumps with glycol cooling circuits, solar panels and connections with the district heating network (Rørosmeieriet, 2023; Selvnes et al., 2023). Synnøve Finden work with reducing emissions through packaging and reduction in food waste.

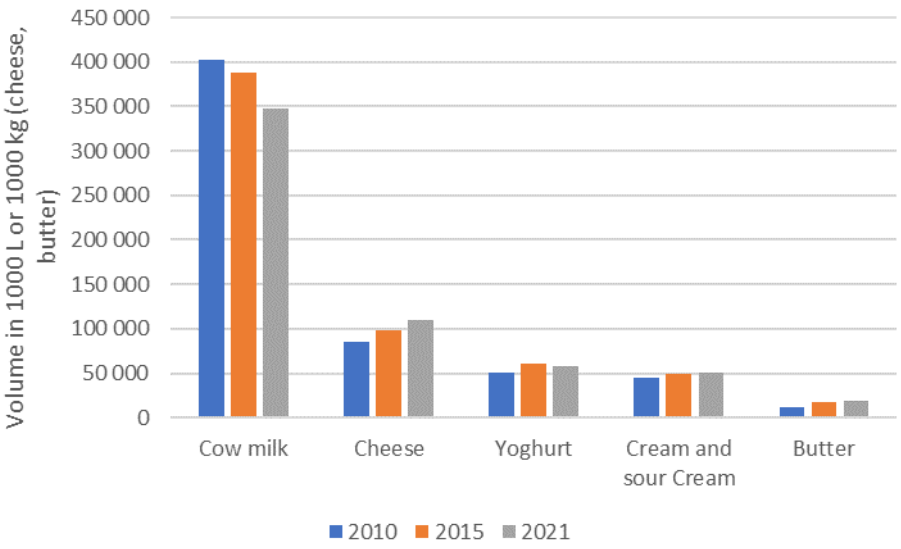

Figure 2. Volume (including import) of dairy products in Norway in 2010, 2015 and 2021, based on numbers from melk.no (Opplysningskontoret for melk, 2022). Numbers for butter in 2010 were not available and are based on 2011 numbers.

3.2. Meat and poultry

The Norwegian meat and poultry industry mainly consists of the cooperative Nortura (owned by 17,100 farmers, have 31 production facilities) and the organization Kjøtt- and fjørfebransjens Landsforbund (KLF, 140 member companies and 150 facilities) representing the privately owned, independent part of the meat, egg and poultry industry. Nortura and Fatland are the largest meat producers, with a market share above 80% for pork, cattle, and sheep. Production volumes are given in Figure 3 (Animalia, 2021a). In the poultry industry, the largest actors are Nortura, Den Stolte Hane, Norsk Kylling and Ytterøykylling. The main volume is chicken (about 106k tonnes in 2021), but there is also some turkey (8.6k tonnes) and duck (0.6k tonnes) production (Animalia, 2022).

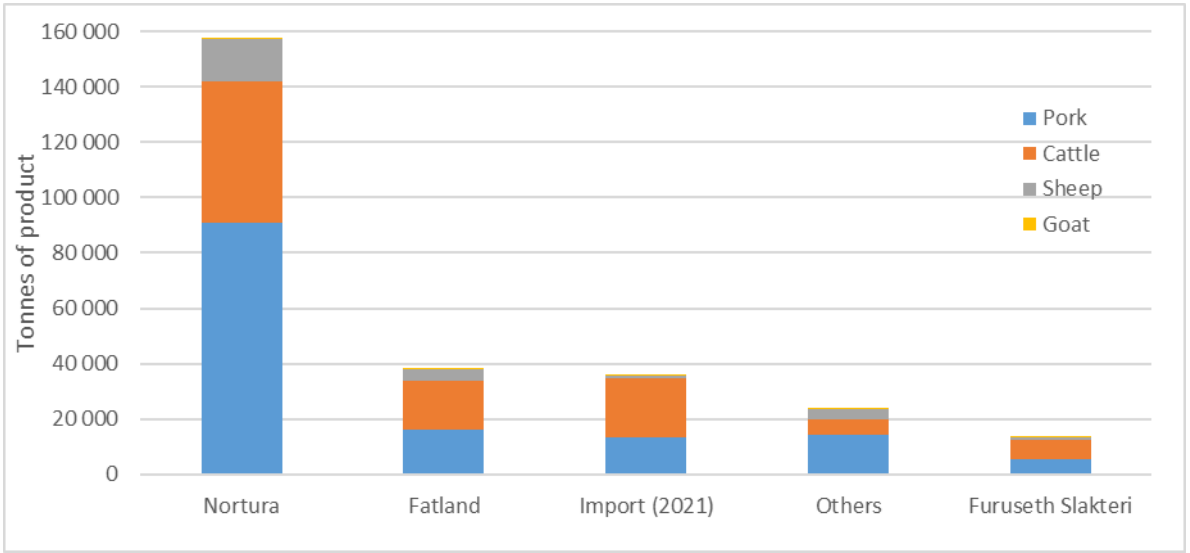

Figure 3. Production volume of the actors in the meat industry based on a report from Animalia (2021)

Animalia is a neutral industry player owned by Nortura (66%) and KLF (34%). According to their websites, there are no official numbers for emissions from meat produced in Norway, but the intensities of emissions from all steps in the production have been calculated in various studies as highest for beef (17-22 CO_2-eq/kilo) and sheep (16-26 CO_2-eq/kilo), and lower for pork (3 CO_2-eq/kilo) and chicken (2-3 CO_2-eq/kilo). Eggs are responsible for about 1.5 kg CO_2-eq/kilo (Animalia, 2021b).

Nortura has a sustainability report stating to use only fossil free energy, reduce food waste from factories by 80%, reduce transport emissions with 80%, and make all food packaging recyclable by 2030. Several measures are mentioned covering scope 1 and 2, in addition to some parts of scope 3 (transport, electricity) (Nortura, 2022). For the meat companies with a market share of 5% or less, there was not found sustainable reports, or any information related to emissions on their website. Norsk Kylling have sustainability reports available on their website. Den Stolte Hane and Ytterøykylling do not have sustainability reports but have parts of their web page dedicated to sustainability.

3.3. Fish and seafood for human consumption

The Norwegian fish sector can be divided into aquaculture and wild-caught fish. The aquaculture sector consists of roe hatcheries, smolt facilities and sea cages, in addition to actors responsible for wellboats, slaughtering and processing (Winther et al. 2020). In 2021, 166 companies had permission to produce salmon, trout and rainbow trout (Fiskeridirektoratet, 2022). Large producers are Mowi, Lerøy, SalMar, Grieg seafood and Austevoll. The total volume of salmon, trout and rainbow trout sold in 2021 was 1 657 473 tonnes (Fiskeridirektoratet, 2022).

For marine fisheries, there are about 5 600 vessels in the Norwegian fishing fleet (Fiskeridirektoratet, 2023), ranging from small vessels to factory trawlers. The fisheries can be divided in two main categories, whitefish (e.g. cod, saithe and haddock) and pelagic fish (e.g. herring and mackerel). There are about 280 primary whitefish processing facilities and 30 pelagic fish processing facilities spread across the Norwegian coastline (PWC, 2019). Central actors are Austevoll Seafood and Lerøy Seafood Group.

Winther et al., (2020) quantified GHG emissions for some Norwegian seafood species at landing. Pelagic fisheries were found to have the lowest emissions (1.1-1.4 kg CO_2eq/kg), and farmed salmon the highest (6.5-8.4 kg CO_2eq/kg). Factors affecting these numbers were packaging, transport mode and distance, in addition to the extent of by-product utilization. For the fisheries, fuel use and the impact of refrigerants also had a great impact on the emissions.

Austevoll seafood and Lerøy have sustainability reports and their aim is to select renewable energy solutions where possible and limit the environmental footprint throughout all operations. Reporting of GHG emissions are strongly encouraged to set targets for emission reductions (Austevoll Seafood ASA, 2021). Lerøy operate several parts of the chain of both fish farming and catches of whitefish. Their main goal is to reduce GHG emissions by 46% by 2030 (2019 base year). Some of their measures are switching from diesel to electric power on most feed barges and investing in an efficient and modern value chain at factories.

Of the aquaculture companies, Mowi aims to reduce its total (Scope 1, 2, and 3) GHG emissions by 35% by 2030 and 72% by 2050 (MOWI ASA, 2020). Examples of measures are reducing feed conversion ratio, switching from diesel to electrical power onshore, maximizing transport efficiency, energy efficient equipment and improving fillet yield. Norway Royal Salmon aims to electrify the feed barges using partly batteries charged by fossil fuel (hybrid) and partly batteries charged with electricity from the onshore power grid either hybrid (Norway Royal Salmon, 2022). SalMar has targets for scope 1 and 2 are a minimum 46% reduction in GHG emissions by 2030 (2019 as reference) and a 42% reduction from 2020 to 2030 for scope 3. Their focus are electrification of sea farms and boats and utilisation of surplus energy.

3.4. Vegetables and fruits

The largest actor in Norway's vegetable, fruits and berries market is Gartnerhallen, a cooperative owned by over 1000 Norwegian producers. Gartnerhallen purchases products from the producers and sells them to the industry and BAMA. The sales in 2020 were more than NOK 2.9 billion and a 65% market share of Norwegian-produced green products. The industry and BAMA sell the products to Norgesgruppen and REMA, which has about 65% market share of grocery stores. There is also a separate product chain supplying COOP, where Nord-grønt is the link between producers and COOP.

Norway's cold climate is only suitable for growing certain fruits and vegetables and it is necessary to import many products to meet consumers demands. Table 1 shows production volumes of the main categories.

Table 1. Production volumes in tonnes 2021. (Opplysningskontoret for frukt og grønt, 2022)

[tonnes]	Produced in Norway	Import
Berries	4 972	14 599
Fruits	12 228	325 000
Vegetables	146 249	131 000
Potatoes	73 738	24 276

Many products are grown in greenhouses, including tomatoes, cucumbers, and multiple types of lettuce and herbs. There has been a shift in energy use within greenhouses in recent years. Energy costs make up 25-40% of the total costs for the companies. Norsk Gartnerforbund's long-term energy advisory work has yielded both economically and climate-positive results for the greenhouse industry. Investment support through Enova and Innovasjon Norge schemes has contributed to many greenhouse companies investing in new energy technology, hence reducing CO_2 emissions by 58% since 1999, see also Figure 4. However, there is significant use of natural gas in the greenhouses. The natural gas is combusted, and the CO_2 is pumped into the greenhouse to increase the concentration of CO_2 in the air. This promotes plant growth and provides heating during colder seasons. Other energy saving measures in the greenhouse industry include replacing lights with modern, efficient LED, heat pumps for cooling and heating and closed greenhouses to reduce concentrated CO_2 from escaping into the environment (Landbruksdirektoratet, 2020).

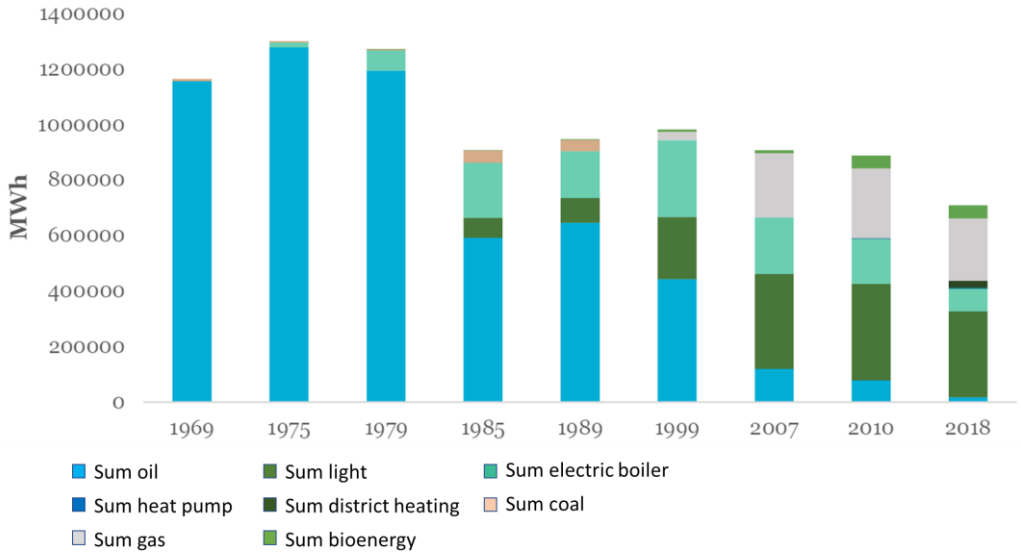

Figure 4. Energy consumption in greenhouses from 1969 to 2019. (Landbruksdirektoratet, 2020)

The post-harvest storage of fresh food and vegetables is also energy demanding. Knowledge of storage temperature and humidity is essential for maintaining quality and reducing food loss and new technology is constantly being developed to optimize storage conditions for fresh products. Newer systems maintain constant temperature internally in the warehouse with sensors and automatic control systems, even during long-term storage, avoiding product losses.

The actors within this sector work towards more sustainability by reducing energy demand and fossil fuel use, reducing use of fossil fuelled boilers, installing solar panels, investing in renewable certificates, optimizing logistics and utilizing rest raw material. They will also reduce emissions related to high GWP refrigerants in cooling systems in transportation and industry plants.

4. SOLUTIONS TO REDUCE CARBON EMISSIONS AND INCREASE SUSTAINABILITY

4.1. Energy

As presented earlier, a majority of the emissions from post-harvest activities are related to energy consumption. Norway has a relatively low emission factor per unit of electricity, 0.008 kg CO2eq/kWh in 2020 (Norges vassdrags- og energidirektorat, 2022), compared to other parts of the world due to the large share of renewable energy. To ensure lowest possible emissions from electricity use, companies can ensure that the energy they use is from renewable sources by buying a guarantee of origin. Also, investment in solar panels at industry facilities has been more economically profitable with the recent technological advancements. There is also an increased focus on industrial symbiosis to utilize waste heat and bioenergy from one production system to another. A transition towards greener energy sources and replacing fossil fuels with alternative sources like electricity, hydrogen fuel cells and so on is a priority for aquaculture farms. The main focus for many companies today is to reduce energy consumption, especially the energy consumption per unit produced.

4.2. Transport

Transport is a crucial part of the food industry, either in the early stages of the value chain or transport to the market. Norway being one of the largest exporters of seafood, transport to global markets by air, sea, and road is one of the stages with the highest direct emissions from fuel use. Refrigeration during transport also contributes to the emissions due to additional fuel use and potential refrigerant leakages. Therefore, reducing emissions from transport has become a key factor in meeting the Paris Agreement goals. Some companies carry out the transport themselves, while others outsource the transport to third parties. Some technical challenges make the transition to low emission transport difficult. However, transport technology is rapidly developing toward electrification and less carbon-intensive fuels like bioenergy and hydrogen fuel cells. Logistics and route optimisation can also be a solution where transition to alternative fuels is not possible.

4.3. Refrigerants

Today's refrigerants in the market can be divided into three groups; saturated, unsaturated and natural working fluids (Hafner et al., 2019). The saturated CFCs, HCFCs and HFCs affect the climate and the environment, and are therefore part of phase-out programs. The unsaturated HFCs are flammable and have toxic decomposition products (even without a fire) when leaking and the long-term effects of new refrigerants are not yet fully known. In Norway, a successful transition from ozone depleting refrigerants (with high global warming potential) to climate friendly natural refrigerants has been made during the last decades. Although there can be some issues with the natural refrigerants, the continuous research and development has been beneficial both for climate- and environment, and the efficiency and the adaptation for different use. Natural refrigerants have also been known for more than a century. The ozone depleting potential (ODP) and global warming potential (GWP) for some selected refrigerants are shown in Table 2.

Table 2 ODP and GWP for some selected refrigerants (Smith et al., 2021)

Refrigerants	Type	ODP	GWP_{100} (AR4)
R12 (freon)	CFC	1	10 910
R22	HCFC	0.055	1810
R404A	HFC	0	3920
R134a	HFC	0	1430
R32	HFC	0	675
R1234yf (HFO)	HFC	0	4
R1234ze (HFO)	HFC	0	6
R744 (CO_2)	Natural	0	1
R717 (ammonia)	Natural	0	0
R290 (propane)	Natural	0	3

4.4. Packaging

Although packaging can increase shelf life of food products, its production can be related to high emissions. The carbon footprint of producing and recycling 1 kg of food packaging is between 1-13 kg CO_2-eq (Weihe et al., 2020). Plastic has a footprint of about 3 kg CO_2-eq and has other environmental challenges. Recycling plastic reduces the quality each time and requires virgin plastic to maintain the quality of the plastic, in contrast to some other materials like aluminium that can be recirculated repeatedly. Many companies are now developing improved product packaging with increased use of recirculated plastic and minimizing the use of plastic, claiming that they are ready to exchange plastic with new materials if alternatives meet health and safety requirements and are reasonably priced.

4.5. Food loss and waste

Food loss is food discarded postharvest due to quality issues or lack of proper infrastructure for handling and storage, while food waste is discarded by the consumers themselves (Lemaire and Limbourg, 2019). Globally, about 31% of the food is lost or wasted in the value chain, representing large amounts of resources going to waste giving the resource intensity of food production (FAO, 2023). The food industries have set goals to reduce the food loss in their part of the value chain but are also involved in measures to reduce food waste at the consumer stage. Food is lost in production and harvesting, postharvest handling, processing, distribution and consumption, but for medium- and high-income countries, food is mostly wasted by the consumer (Widell et al., 2019). Measures aimed at reducing consumer waste could be improved serving-sized portions, packaging improving shelf life, or information about how to store the product. Reducing loss in the value chain could be done by improving the cold chain, implementing new technology to increase shelf life, and utilising more of the rest raw materials (Thakur et al., 2021). Climate changes are expected to cause temperature fluctuations and the Norwegian warehouses need to be rebuilt from being based solely on cooling by outdoor air to installing cooling systems. Although this will increase the energy consumption, food waste due to spoilage and shrinkage will be significantly reduced.

An important aspect of progress towards the emissions goals will be tracking data from the process. The data availability on Scope 1 emissions is easier to track than scope 2 and 3 emissions as they require information from suppliers and sub-suppliers. Registration and tracking of the data can provide an overview of the yearly progress and help to create road maps for achieving emission goals. Monitoring GHG emissions from the product supply chain also helps in benchmarking the products with other products in the market. Norwegian seafood companies are in the top three positions on the Coller FAIRR Protein Producer Index, which has ranked a range of global companies producing meat, fish, and dairy (FAIRR, 2022). Several certification schemes like Aquaculture Stewardship Council Standard also require the companies to report the GHG emissions from their activities regularly and must meet the standard's requirements.

4.6. CO_2 emissions compensation

Some companies also opt to offset their emissions by carbon compensation to meet the zero-emissions goals. Wherever there are unavoidable emissions or the investment to reduce the emissions is too high, carbon compensation could be a good alternative. While for the consumer, CO_2 emissions compensation may be a misleading term. The company may buy their way to net-zero emissions with CO_2 emissions compensation but at the same time have significant emissions along the production. In the end, the consumer will pay for the CO_2 emissions compensation through the price tag, so why not use this money to remove the emission from the actual production?

5. CONCLUSIONS

Most of the companies investigated in this report have published sustainability reports for their operation, and some companies are also updating them annually. The companies have set ambitious goals according to the Paris Agreement, thereby seeking to reduce their emissions significantly by 2030 and become climate neutral by 2050. Some food industries, such as meat and dairy, have most of their emissions in the food chain's pre-processing part (at the farm level) and will have significant challenges in meeting the Paris

Agreement goals. However, it is more likely to achieve the reduction targets from postharvest to retail stages. Pushing companies to make roadmaps for how they will meet the goals they are setting may help the consumer and the industry. Science-based targets can provide companies with a clear path on how to reduce the emissions. Large companies may have the resources to employ staff to work with sustainability in the company, smaller companies may not have the resources.

Here is a summary of the suggested solutions for the different sectors:

- Dairy sector: change from fossil fuel to renewable energy sources in processing and transport, using heat pumps for heating and cooling, changing packaging and reduction in food waste.
- Meat sector: make packaging more environmentally friendly, reducing energy demand, reducing food waste and changing from fossil fuel to renewable energy sources.
- Fish and seafood sector: change fuel for transport of the ships (to for example ammonia or electricity), maximizing transport efficiency (for example use of superchilling instead of ice), improving packaging solutions, and more energy efficient processing.
- Fruits and vegetables sector: work to reduce GHG emissions, but they are less clear on their goals toward climate neutrality. Actions to reduce GHG emissions are increasing energy efficiency in processing, shifting from refrigerants with high GWP to lower GWP fluids, changing from fossil fuel to renewable energy, and more efficient transport.

In further work, it is possible to include more details on the whole food value chain. Another approach for further work is to go into more detailed development and descriptions of activities to reduce the GHG emissions for each industry actor, with a successful collaboration between research institutes, universities, industry and food organizations. Another subject to be evaluated is the footprint of major fish meal and fish oil processing industries, which to some extend has already been done.

Many solutions for how the food value chain should reduce their emissions and become climate neutral will be developed and disseminated from the EU-project ENOUGH (European food chain supply to reduce GHG emissions by 2050). The project will demonstrate the best technology available, test new novel concepts, and share experiences.

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