Norwegian Institute for Sustainability Research

Carbon footprint of broiler breast meat from Nortura

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REPORT NO.
OR 23.21

YEAR
2021

ISBN NO.	ISSN NO.	REPORT TYPE	CONFIDENTIALITY
-	2535-812X	Commissioned report	Closed

NORSUS

PROJECT TITLE

Carbon footprint of broiler breast meat from Nortura

PROJECT NUMBER

3187

COMMISSIONED BY

Nortura

REFERENCE

Atle Løvland

INTERNAL QUALITY CONTROL

Erik Svanes

NUMBER OF PAGES

20

KEY WORDS

Carbon footprint, broiler, Nortura, Carbon Trust

PHOTO FRONTPAGE

Prior

Preface

Climate change has implications for both human and natural systems and could lead to significant impacts on resource availability, economic activity and human wellbeing. In response, international, regional, national and local initiatives are being developed and implemented by public and private sector to mitigate greenhouse gas (GHG) concentrations in the Earth´s atmosphere.

Nortura wants to ensure that customers and the public get a comprehensive picture of their products' carbon footprint and demonstrate that the company is transparent. Nortura has worked to reduce the carbon footprint of their products and implemented measures of own production and at the broiler producers. This applies to e.g., measures to reduce energy consumption, use of renewable energy sources and better utilization of plus products.

The aim of this report is to quantify and document the carbon footprint associated with the life cycle stages of a broiler breast meat, beginning with resource extraction and raw material sourcing and extending through the production, use and end-of-life stages of the product.

Summary

The goal of this study is to quantify and document the climate change (GHG emissions) associated with the life cycle stages from cradle to grave of a broiler breast meat from cradle to grave.

The functional unit is 1 kg of broiler breast meat from Nortura, including consumer packaging. The results show that the carbon footprint for broiler breast meat has been reduced since 2015. The result for 2020 is 3.90 kg CO_2 eq. per kg of broiler breast meat if carbon feedback is included and 3.74 carbon feedback is excluded. Both results are equivalent, depending on the context in which they are to be used.

The sensitivity analysis shows that the results are robust in terms of residual mix for electricity, but data for soy greatly affect the results. This analysis has been carried out with the best available data that follows methodological guidelines and as such is the result are considered valid.

Contents

1 Method

1.1 Products category rules and characterisation method

This carbon footprint is an update of an LCA study from 2017 that was mainly based on GHG protocol (WRI/WBCSD, 2011) while this version is based on Product Environmental Footprint Category Rules (PEFCR) Feed for food producing animals (FEFAC, 2018) and the Product Environmental Footprint Category Rules (PEFCR) for Dairy Products (EDA, 2018). The PEFCR for dairy products is mainly followed for downstream processes because there is no public PEFCR for meat, and these processes are assumed to have the same distribution and purchasing patterns and the same chilling requirements.

Two characterization methods are used in this carbon footprint analysis. The EF (Environmental Footprint) method 3.0 (adapted) v1.00 (Fazio et al., 2018) is chosen because it is adapted for use with PEFCR. This method includes carbon feedback. In addition, the IPCC 2013 GWP 100a (IPCC, 2013) without carbon feedback is used to make the analysis comparable with other studies.

1.2 Goal and scope, functional unit and system boundaries

The goal of this study is to quantify and document the climate change (GHG emissions) associated with the life cycle stages of a broiler breast meat from cradle to grave.

The functional unit is 1 kg of broiler breast meat from Nortura, including packaging.

The system boundaries is from cradle to grave. For packaging the raw materials for primary and secondary packaging are included, for consumer packaging for the end-of-life.

1.3 Allocation procedures

The analysis is calculated using economic allocation for feed production and between edible and non-edible products.

Manure is assumed exported from the farm as a product with no economic value. This means that emissions related to housing and storage of the manure is allocated to the broiler production and that emissions and benefits as fertiliser from application of manure on land are not included.

1.4 Data collection and quality

The analysis is performed in the software SimaPro Developer 9.1.0.11 Multi user version. Data for feed consumption, packaging, slaughter and processing are collected by Nortura. Data for feed composition are from Felleskjøpet, which is calculated on the basis of annual purchases of raw materials. Data for methane and nitrous oxide emissions from chicken production are calculated using emission factors and models in the national inventory report (Norwegian Environment Agency, 2019) and Carbon limit (2018). Data for distribution, wholesale, retail and consumer are based on default values from Product Environmental Footprint Category Rules (PEFCR) for Dairy Products. (EDA, 2018). End of life is based on data from Green

Point Norway. All background processes are either literature data specified in the report or from databases. The ecoinvent 3.6 database (Wernet et al., 2016) is used as the first choice, as it is the most consistent database. If the necessary processes are not found in ecoinvent database, Agri-footprint or Agribalyse processes (Koch & Salou, 2016) have been used (Blonk Consultants, 2017a, 2017b). In the cases where these databases are used, sub-processes such as electricity and diesel have been replaced with Ecoinvent processes.

The reference year for the broiler production at farm, feed composition and manufacturing process is 2020, unless otherwise stated. The time and technology representativeness for the database processes varies, but broadly, the data is representative for the period 1998-2018 and associated technology and satisfies the requirement that generic data from databases can be used. The geographical coverage follows the collected data, using data for country of origin for production of feed ingredients when available. The production plant at Hærland is producing all Priors chicken breast products, hence the data from the production plant at Hærland is representative for the production. Overall, data is considered to be complete, precise, consistent and reproduceable.

For more information regarding data, see chapter 3.

2 Climate change

Climate change is the impact category used in the carbon footprint. The climate change is reported as aggregated value and separately for the sub-indicators "Climate change – fossil", "Climate change – biogenic" and "Climate change - land transformation".

The emission of greenhouse gases measured in CO_2 equivalents, also called global warming potential (GWP). A 100-year time horizon has been selected for the carbon footprint, see Table2.1, as the conventional cut-off time in LCA climate change modelling. See also section 1.1 for description of the characterisation methods.

Table2.1 Characterisation factors used in the study.

		Characterisation factor GWP100	
Emissions	Chemical formula	Incl. carbon feedback[1] EF-method EF 3.0	Excl. carbon feedback IPCC 2013 GWP 100
Carbon dioxide, fossil	CO_2	1	1
Carbon dioxide, biogenic	CO_2	0	0
Carbon dioxide, land transformation	CO_2	1	1
Carbon dioxide, to soil or biomass stock		-1	
Carbon dioxide, to soil or biomass stock	CO_2	-1	-1
Methane	CH_4	36,8	30,5
Methane, biogenic	CH_4	34	27,75
Dinitrogen monoxide	N_2O	298	265

2.1 Fossil and biogenic emissions

Fossil-based systems are assumed to be net contributors of CO_2 emissions, contrary to bio-based systems where CO_2 circulates between the biological system and the anthroposphere, not contributing to increased concentration of CO_2 in the atmosphere.

Biogenic CO_2 is defined as CO_2 released to the atmosphere due to decomposition and combustion of biological material. Traditionally, biomass-based products have in LCA been considered climate neutral because the amount of CO_2 released can be offset by CO_2 sequestration due to regrowth of biomass. The same principle is followed in this study.

[1] The "climate–carbon feedback" refers to the effect that a changing climate has on the carbon cycle, which impacts atmospheric CO_2, which in turn changes further the climate. In concrete terms: when CO_2 is emitted, the atmospheric CO_2 pool increases. A fraction of this excess atmospheric CO_2 is taken up by the ocean and the terrestrial biosphere (the "carbon sinks"), but as long as a part of the excess CO_2 stays in the atmosphere, it warms the climate. In turn, this warming climate slows down the uptake of the atmospheric CO_2 by the sinks. This slowing-down constitutes a positive feedback – i.e. a warming climate is warmed further through the feedback. Rather than a slowing-down of the carbon sinks, it is also possible to view the feedback as a reduction of the carbon sinks uptake efficiency.

2.2 Land Use Change

Land use change is especially important for agricultural and forestry products. When the amount of biomass above and below ground in an area changes due to changes in land use, this will lead to increased emissions or uptake of CO_2. If an area were initially forest, a transition to agricultural land would lead to increased CO_2 emissions, since forests contain more carbon above and below ground than agricultural land. Such a change of land area is named land transformation or land use change, i.e. the change in the purpose for which land is used by humans (e.g. crop land, grass land, forest land, wetland, industrial land) (BSI, 2011). Emissions of CO_2 from direct land use change (LUC) include the example above, change from forest to agriculture. According to IPCC (2006), land use change shall not be accounted for when there has been no change over the last 20 years. If there has been deforestation over the last 20 years, these CO_2 emissions shall be distributed evenly over 20 years. This means that 5% of the effect is added to the crop(s) produced in a year.

Emissions of CO_2 from indirect land use change (ILUC) include offset effects, i.e. a change in one product system leads to a change in another product system. For example, increased bioethanol production based on maize in the United States may mean that more maize for food purposes must be produced elsewhere in the world, which could result in a forest area being converted into agricultural land. The indirect land use change is not included in this study.

3 Inventory

3.1 Production of feed ingredients

Table3.1 provides the annual amounts of the various feed ingredients used in the feed concentrate. These data are more precise than if a standard recipe was used, as the composition varies throughout the year due to variations in the supply of feed ingredients.

Table3.1 Feed ingredients, country of origin, amount and share (%)

Feed ingredients	Country of origin	Total amount 2020	%
Wheat	Norway	8 353 652	33.7 %
Maize grits	Poland 85%, Germany 5%, Argentina 10%	3 183 750	12.9 %
Oat	Norway	2 772 750	11.2 %
Soybean meal	Brazil 75%, Canada 25%	2 154 324	8.7 %
Soybean meal (Hi-Pro)	Brazil	2 114 895	8.5 %
Rapeseed meal	Baltics	1 316 436	5.3 %
Peas	Norway	1 118 644	4.5 %
Triticale	Norway	981 928	4.0 %
Rendered fat	Norway	656 100	2.6 %
Faba beans	Norway	591 011	2.4 %
Enzymes & other	EU, China	300 529	1.2 %
Amino acids	Asia	229 063	0.9 %
Soy oil	Brazil, Canada	177 383	0.7 %
Maize gluten meal	China	154 491	0.6 %
Microminerals & Vitamins	EU, China, India, Mexico	151 919	0.6 %
Monocalcium phosphate	Finland	138 411	0.6 %
Limestone	Norway	134 344	0.5 %
Oil seed	Norway	88 478	0.4 %
Fish silage	Norway	66 308	0.3 %
AX3 ADVANCED (soy protein)	Brazil	54 119	0.2 %
Sodium chloride (rock salt)	Germany	24 565	0.1 %
Fish meal	Norway	10 718	0.0 %
Sodium bicarbonate	China	1 402	0.0 %
Potato protein	Norway, Sweden, Finland	723	0.0 %

For the production of domestic feed ingredients, Norwegian inventory data is used, i.e. oat and wheat including wheat feed quality (A. Korsaeth et al., 2012), faba beans (A. Korsaeth & Roer, 2016). For triticale, i.e. rye-wheat, there is no specific data and therefore data have been used for wheat (65% spring wheat and 65% winter wheat), since that have the same yield level. Rapeseed meal is the by-product of the solvent extraction of oil from rapeseed and economic allocation is used between the coproducts. Data for rendered fat is based on Norwegian site-specific data, using economic allocation between rendered fat and meat bone meal.

In average, 75% of the soybean meal used in animal feed production in Norway is grown in Brazil and the remaining in Canada. Data for soybeans from Brazil is modelled for specific states using the ecoinvent database (Wernet et al., 2016) and the composition is based on each state's share of production (ProTerra

Foundation, 2019). Since the stated regions represented in ecoinvent database comprise only 78% of the production, the proportion has been corrected to add up to 100% (Table 3.2).

Table 3.2 Production share of soybeans in Brazil in different states (%).
Source: https://www.proterrafoundation.org/project/sustainable-soy-production-in-brazil/

	Share of production %	Corrected share of production %	SimaPro-prosess
Mato Grosso	27	35	Soybean BR-MT| soybean production | Cut-off, U
Paraná	17,3	22	Soybean BR-PR| soybean production | Cut-off, U
Rio Grande do Sul	16,1	21	Soybean BR-RS| soybean production | Cut-off, U
Goiás	9,6	12	Soybean BR-GO| soybean production | Cut-off, U
Mato Grosso do Sul	7,6	10	Soybean BR-MS| soybean production | Cut-off, U
Sum	78	100	

Economic allocation is used for soybean meal (63.1%), soybean oil (36.3%) and soy lecithin (0.6%), using international prices for 2018/19 (FAO, 2020). The data basis for processing soybean meal is based on specific data from the supplier Denofa.

Data for the remaining feed ingredients are from ecoinvent, Agri-footprint and Agribalyse.

Production of concentrates is based on Agri-footprint Compound feed broilers, using electricity 0.315 MJ/kg feed and gas 0.135 MJ/kg feed for heat production.

Domestic transport distances have been calculated as a weighted average. The domestic transport of feed ingredients is 129 km weighted distance from grain production areas to feed concentrate facility and 125 km for imported feed ingredients from the nearest port to feed concentrate facility. These distances are calculated by using the amount of Norwegian-produced grain used in concentrate production at all the feed concentrate facilities. This data is collected from the feed concentrate industry. The geographical location of the facilities is assessed against which regions the grain comes from. The same has been done for imported feed ingredients, based on the facilities' distance to the nearest of 3 selected ports. The transport of the feed from the feed concentrate plant to the farm is assumed to be 100 km.

3.2 Broiler production

3.2.1 Parent generation

Table3.3 shows the feed concentrate consumption for broiler mothers. It can be mentioned that a parent hen lays less eggs than a hen in an egg production system.

Table3.3 Consumption of feed concentrate per broiler.

	2015	2020
Feed concentrate per hen in breeding (kg) 0-18 weeks	9,50	8,98
Feed concentrate per hen in hatching egg production (kg) 18-58 weeks	43,41	49,20

Sum (kg)	52,91	58,18
Number of hatched broilers per mother hen	134,82	153,9
Feed concentrates per day old broiler (kg)	0,392	0,378

3.2.2 Hatching

Table3.4 shows the energy used at the hatchery. The biofuel plant at the hatchery was out of operation in January-March 2020 and therefore the energy consumption for 2019 is used.

Table3.4 Energy use at the hatchery Samvirkekylling.

	2015	2019
Total production of chickens (number)	36 986 533	35 413 678
Electricity (kWh)	3 199 163	2 698 439
Fuel oil (litre)	5 534	13 392
Biofuels, briquettes* (kg)	365 550	493 770

** Energy content 4.7 kWh / kg, (utilization rate 90%)*

3.2.3 Consumption of feed concentrate

Table3.5 shows the weighted average of all broilers for 2020. In 2015 the feed was specified in different levels of energy content. The feed consumption increased after 2015 due to higher slaughter weight and use of feed without narasin. The last two years the feed consumption is reduced again due to progress in breeding.

Table3.5 Amount of feed concentrate (kg) in broiler production.

Feed concentrate	2015	2020
Low energy content	2,18	2,20
Medium energy content	2,08	
High energy content	2,09	

3.2.4 Emissions from enteric fermentation

The emission factor for methane from enteric fermentation (tier 1) is 0.02 kg CH_4 / animal / year (Norwegian Environment Agency, 2019). The slaughter age of broiler is 33.3 days, changed from 31.5 days in 2015 due to higher slaughter weight.

Methane from broiler: 0.02 * (33.3 / 365) = 0.0018 kg CH_4 per broiler

Methane from mother hen: 0.02 * (126+280/365) = 0.0222 kg CH_4 per hen

Mother hen in breeding from 0-18 weeks = 126 days and producing egg from week 18-58 weeks = 280 days.

3.2.5 Methane emissions from manure

Emissions of methane from manure are calculated on the basis of tier 2 (Norwegian Environment Agency, 2019). EF is the emission factor for methane (kg).

EF = VS * 365 days/year * Bo * 0.67 kg/m3 * ∑(MCF * MSij

Table3.6 Factors for calculation of methane emission from manure

Description		Broiler	Mother hen	References
kg dry matter per animal	Manure	0.63	15.72	(Karlengen et al., 2012)
% VS excreted	VS%	0.9	0.9	Norwegian Environment Agency, 2019
Daily VS excreted for an animal within defined population, in kg	VS	0.57	14.15	Ibid.
Maximum CH4 producing capacity for manure produced by an animal within defined population, m3 /kg of VS	Bo	0.36	0.36	Ibid.
CH4 conversion factors for each manure management system by climate region	MCF poultry manure	0.015	0.015	Ibid.
Emissions of methane (kg per animal)	-	0.00205	0.05119	-

The share of manure management system for poultry production is 97% solid storage and 3% for pit storage (Carbon Limits, 2018). The specific farms that deliver to Hærland have according to Nortura 100% solid storage, which is used in this analysis.

3.2.6 Direct nitrous oxide emissions from manure storage

Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the excretion. Table 3.7 shows the nitrogen content of manure and emission factor that are used in the. The N_2O-N emissions are then converted to N_2O.

Table 3.7 Calculation of direct nitrous oxide emission from manure storage

Description	Broiler	Mother hen	References
N in excreta (kg per animal)	0.0297	0.7065	(Karlengen et al., 2012)
Emission factor poultry manure, kg N_2O-N/kg N excreted	0.001	0.001	Norwegian Environment Agency, 2019
kg N_2O-N/animal	2.97E-05	7.07E-04	-
kg N_2O /animal (N_2O = 44/28 of N)	4.67E-05	1.11E-03	-

3.2.7 Indirect nitrous oxide emissions from manure storage

Indirect emissions result from deposition of N from NH_3 and NOx emissions from housing and storage and loss through runoff and leaching the manure system (Norwegian Environment Agency, 2019). Table 3.8 shows the emissions factors used and the content of TAN (total ammonium nitrogen) in the excretion for calculation of the losses of NH_3-N from housing. TAN remaining for storage is the TAN in excretion subtracted the losses. Some of the remaining TAN is immobilised in solid manure due to bedding. Losses of NH_3-N from manure storage is the TAN remaining for storage including immobilization due to bedding material multiplied with the emission factor and a temperature correction factor for storage. Losses of NO-N from manure storage is calculated from the N-content in excretion (table 3.7).

The sum of losses N from deposition is:

Losses of NH_3-N from housing + Losses of NH_3-N from manure storage + Losses of NO-N from manure storage.

Indirect losses of N_2O-N from deposition is multiplied with the emissions factor and the N_2O-N emissions are then converted to N_2O.

Table 3.8 Calculation of indirect N_2O from deposition from NH_3 and NOx emissions from housing and manure storage per animal

Description	Broiler	Mother hen	References and factors
Emission factor, housing	28 %	41 %	Norwegian Environment Agency, 2019
TAN excretion (kg per animal)	0.0112	0.2871	Carbon Limits, 2018
Losses of NH_3-N from housing	*0.0029*	*0.1089*	Temperature correction factor - housing 0,925
TAN remaining for storage	0.0083	0.1782	-
TAN immobilised in solid manure due to bedding	0.0033	0.0713	Immobilisation factor 0,4
TAN remaining for storage including immobilization due to bedding material	0.0050	0.1069	-
Emission factor, storage	17 %	14 %	Norwegian Environment Agency, 2019
Losses of NH_3-N from manure storage	*0.00072*	*0.01272*	Temperature correction factor – storage 0,85
Losses of NO-N from manure storage	*7.20E-06*	*1.27E-04*	Emission factors for losses of NO from manure storage 0,01
Sum of losses N from deposition	3.63E-03	1.22E-01	-
Indirect losses of N_2O-N from deposition	3.63E-05	1.22E-03	N_2O emission factor for deposition 0,01
Indirect losses of N_2O from deposition (N_2O = 44/28 of N) (kg per animal)	5.70E-05	1.91E-03	-

Table 3.9 shows calculation of indirect losses of N_2O-N from leaching and runoff during manure storage. It is assumed that the share of leaching 25% and this share is multiplied with the emissions factor. The N_2O-N emissions are then converted to N_2O.

Table 3.9 Calculation N_2O emission from leaching and runoff during manure storage per animal

Description	Broiler	Mother hen	References and factors
N in excreta (kg per animal)	0.0297	0.7065	(Karlengen et al., 2012)
Indirect losses of N_2O-N from leaching and runoff during manure storage	5.57E-05	1.32E-03	Share of leaching 25%, N_2O emission factor for leaching/runoff 0,0075
Indirect losses of N_2O from leaching and runoff (N_2O = 44/28 of N) (kg per animal)	8.75E-05	2.08E-03	

3.2.8 Nitrous emissions from agricultural soil

Manure is assumed exported from the farm as a product with no economic value. Emissions and benefits as fertiliser from application of manure on land are not included. Directs emissions of nitrous oxide from soil by spreading manure on agricultural soil are therefore not included in the LCA (cut-off), as it is outside the system boundaries.

3.2.9 Heating

Data for energy consumption in broiler houses is based on Nortura's own questionnaires to a representative sample of manufacturers, se Table3.10. The data are from 2015 as there are no figures more recently updated .

Table3.10 Average energy consumption for heating per broiler delivered to slaughterhouse.

Energy heating	Fossil	Biofuel	Electricity	Total
kWh/broiler	1.2	0.3	0.28	1.78

Fossil fuels are mainly propane. Some producers (approx. 5%) of those who burn fossil fuels have heat recovery systems in the house and then the energy used for heating is halved. This is not expected to have a significant impact. Biofuels are mainly wood chip and the heat from here is also used for residential houses etc. on the farm.

3.2.10 Bedding material

Almost all manufacturers use wooden chips for bedding material. According to Carbon Limits (2018), 0.405 kg of bedding material is used per broiler place annually, and it is assumed that new chickens are put into production 7.5 times per year (Paulsen et al., 2019), i.e. 0.05 kg of bedding is used per broiler. Wooden chips are a residual product from the production of sawn timber and Ecoinvent 3 data has been used for this.

3.3 Slaughter and processing

Transport from farm to slaughterhouse is on average 50 km / ton slaughter weight, calculated on the basis of total mileage and quantity per year. A truck with a total weight of up to 32 tonnes is used.

Data for slaughtering and processing were obtained from Nortura Hærland for 2015 and 2020, see Table3.11.

Table3.11 Data for slaughter and processing

Material	Unit	2015	2020
Total production, fresh and frozen	ton	26 439	31 966
By-products	ton	29 341	28 243
Sludge, used for biogas	ton	2 832	3 857
Water consumption	m^3	358 875	354 886
COD (discharge of water)	mg/l	262	-
BOD (water discharge)	mg/l	108	-
tot-P (discharge of water)	mg/l	2.5	-
tot-N (water discharge)	mg/l	56.3	-
Energy production plant:			
Electricity	MWh	33 145	33 149
Oil	MWh	4 979	3 243
Propane	MWh	1 902	491
Chemicals, waste, etc.			
Chemicals	ton	763	1 144
Plastic waste for recycling	ton	190	36
Plastic waste, mixed	ton	19.8	8.7
Cardboard waste	ton	69	65
Wood	ton	25	13.2
Metal	ton	3.6	22.8
Waste for renovation	ton	389	448
Electric waste	ton		4.5
Hazardous waste	ton	2.5	3.1
N_2 , nitrogen gas	ton	33	72
CO_2 gas[2]	ton	4 346	1 919

Wastage of broilers were 2.83% due to disease (deviations occurred on the farm) of 1.78% and wastage in the slaughterhouse of 1.05%.

Conversion from carcass weight to broiler breast meat is based on distribution as shown in Figure 3.1.

[2] The figures for CO2 gas are based on delivery overview / invoiced volumes from gas suppliers over total purchases of CO2 to Hærland (cooling and stunning). Changes in refrigeration systems and the separation between Norfersk and Hærland are the reason for the decline.

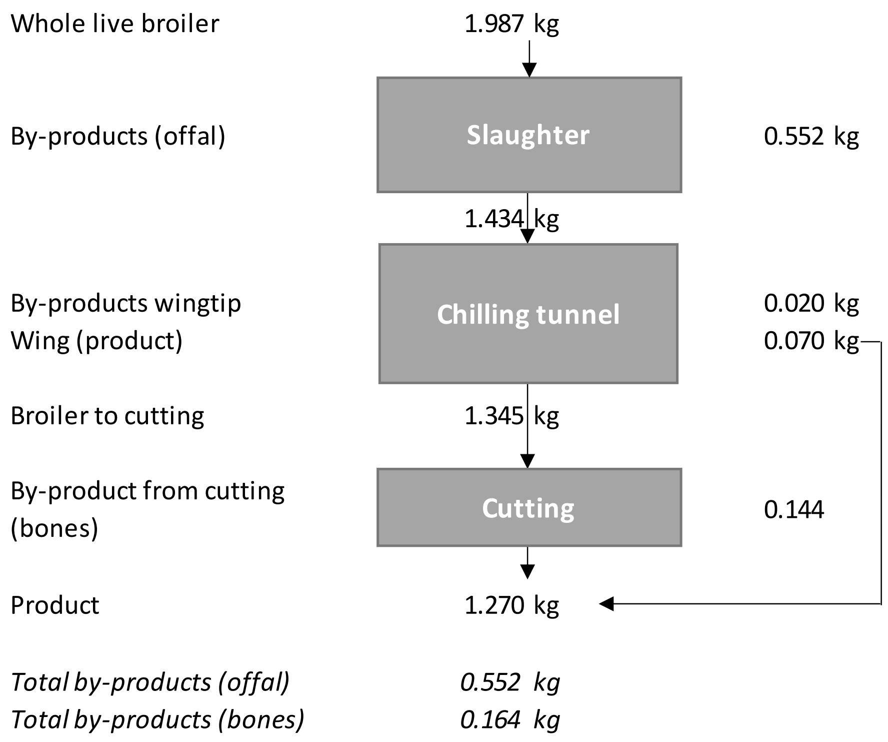

Figure 3.1 Mass balance for slaughter and cutting of broiler.

It is assumed that products sold to consumers correspond to breast meat and therefore the greenhouse gas emission are distributed equally for all consumer products.

3.3.1 By-products

Table3.12 shows the by-products from the production plant at Hærland. Economic allocation is used in this analysis. When calculating the allocation factor, only mass flows that have an economic value are used. This means that only the positive prices are included in the calculation of the allocation factor, se Table 3.13. The streams that have a negative value are thus defined as waste that has a cost for handling.

Table3.12 Amount of by-products

Fraction	Amount 2020 (ton)	Price (NOK/kg)
Category 2	2 016	-2.90
Category 3	1 299	-0.12
Offal	10 843	0.35
Bones, mechanically deboned	5 630	0.65
Bones, mechanically deboned, grinded	1 171	0.50
Bones, mechanically deboned, export	5 892	0.40
Other by-products	3 027	-0.60
Total	29 879	

Table 3.13 By-products and prices for calculation of economic allocation factors

	Products and by-products (kg per broiler)	Value (NOK/kg)	Value (NOK/broiler)	Economic allocation factor
Products	1.270	41.69	52.94	99.5 %
Offal	0.552	0.35	0.19	0.4 %
Bones	0.164	0.52	0.09	0.2 %
	1.987	-	53.22	100.0 %

The calculated allocation factor in Table 3.13 shows that of total greenhouse gas emissions, 99.5% shall be allocated to consumer products, e.g. breast meat.

3.3.2 Packaging

Table shows an overview of the packaging consumption for the broiler breast meat divided into consumer and retail packaging, pallet and type of material. The cup in the consumer packaging is made of 90% recycled plastic. The packaging is unchanged since 2016, however the products weight is increased from 600 g to 650 g per unit.

Table3.14 Packaging for 650 g broiler breast meat (Nortura, 2016)

Packaging	Weight per unit (g)	Number of D-pack	Number of uses
Cup R-PET PE	37.8		1
Over film HB PE A	1.876		1
NLP–box (PP) 400x185x600	1 600	8 consumer packaging i retail packaging	170
NLP-pallet (HDPE)	14 900	24 retail packaging per pallet	65

3.4 Distribution

There are no available specific data of transport from production to average retail and therefore a weighted transport distance was calculated. The calculation was based on the proportion of the population living in the different parts of the country is used. The calculated weighted average distance is 429 km based on the assumptions shown in the table below.

Table 3.15 Distance and proportion of population for calculation of weighted distribution distance. (Source: https://no.wikipedia.org/wiki/Landsdel) and google maps.

	Distance in km	Share of population
From production site to Eastern Norway	100	50 %
From production site to Trøndelag	582	9 %
From production site to Western Norway	555	26 %
From production site to Sørlandet	306	6 %
From production site to Northern Norway	1825	9 %

The following process is used: Transport, freight, lorry 16-32 metric ton, EURO6 [RER] | transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U. The utilization rate is 26.3% including return transport with an average load weight of 5.79 tonnes.

Standard values from PEFCR Dairy Products for electricity for lighting, heating and cooling of product:

- Wholesaler: 1 week storage, calculated volume is 3 times the product volume, electricity 46 kWh / m3 and year.
- Retail: 5 days storage, calculated volume is 3 times the product volume, electricity 1150 kWh / m3 and year. Loss of refrigerant R404A: 0.0145 kg / year pr m^3 occupied.

The following process was used for electricity use in wholesaler and grocery: SimaPro process: Electricity, low voltage [NO] | market for | Cut-off.

3.5 Consumer

The consumption phase includes transport from the store to the household and cooling of the product in the household. Standard values from PEFCR Dairy Products (EDA, 2018) are used:

- 62%, 5 km by passenger car, allocation factor 0.005. SimaPro process: Transport, passenger car, EURO 5 [RER] | market for | Cut-off, U
- 5%, 5 km by van
  SimaPro process: Transport, freight, light commercial vehicle [RER] | market group for transport, freight, light commercial vehicle | Cut-off, U
- 33%, no environmental impact, e.g. transport by bike or by walking

Default values from PEFCR Dairy Products for cooling the product at the consumer's home are 10 days storage time, volume is 3 times the product volume, electricity is 1350 kWh / m3 and year. Electricity for cooling: SimaPro process: Electricity, low voltage [NO] | market for | Cut-off, U

Data for cooking (Environdec, 2012):

- Cooking in the pan on stove: 5.5 kW per hour of operation, 50% of the breast meat for 15 min
- Cooking in the oven (with 15 minutes of pre-heating): 2.2 kW per hour of operation, 50% of the breast meat for 30 min.

Household waste are not included.

3.6 End-of-life packaging

Disposal of C-packaging is based on the average waste system for household waste for 2019 (Grønt punkt Norge, 2020).

- Plastic: 33.5% material recycling, 66.4% incineration.
- Carton: 50.3% material recycling; and 49.6% combustion with energy utilization.

SimaPro processes:

- Plastic waste, delivered for material recycling, [RER] 2018.
  This process includes all processes from waste sorting to the factory gate for recycling. Infrastructure is excluded. Data set from OR.38.18 EPD data to LCA.no verified in December 2018 (Tellnes & Saxegård, 2018).
- Waste plastic, mixture [CH] | treatment of municipal incineration | Cut-off, U
- Scrap aluminum [CH] | treatment of municipal incineration | Cut-off, U

4 Results and interpretation

The results for the carbon footprint are shown in Table 4.1 and

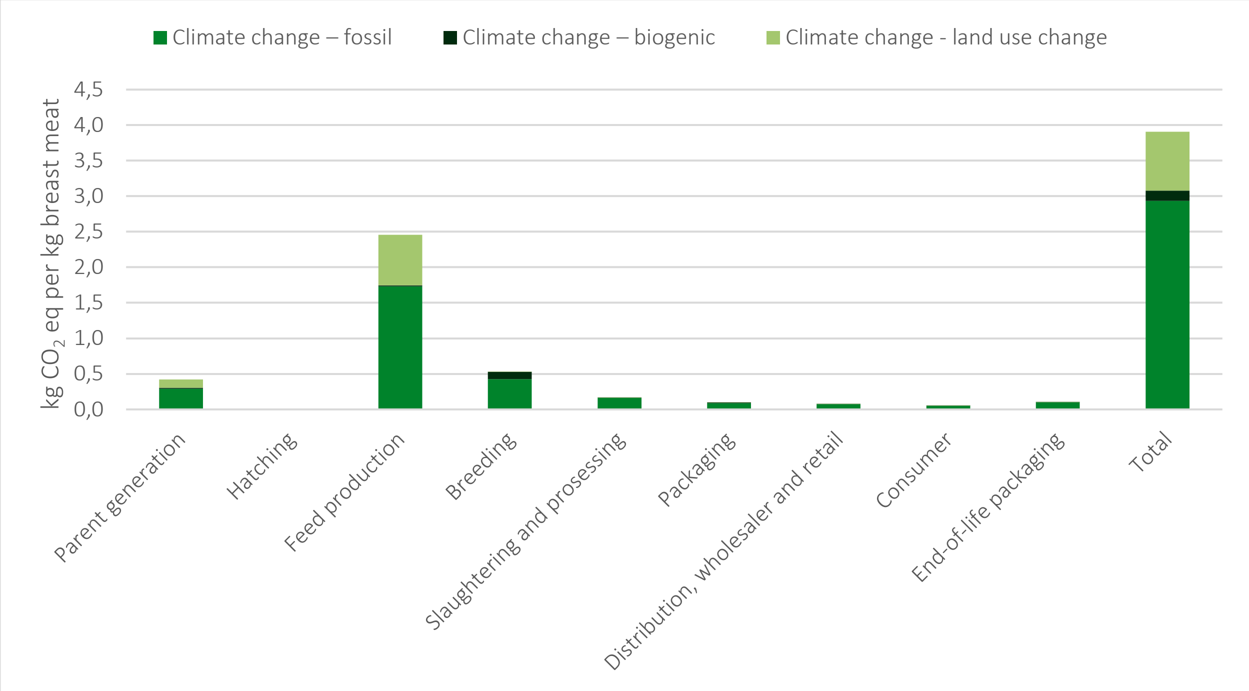

Figure 4.1. The table shows both the results for 2015 and 2020 excluding carbon feedback (IPCC, 2013) and for 2020 including carbon feedback using the characterization method EF 3.0 (Fazio et al., 2018). The results are allocated 99,5% to broiler breast meat and 0,5% to by-products.

Table 4.1 Climate change in kg CO_2 eqv. for 1 kg of broiler breast meat from cradle to grave

	Excluding carbon feedback		Including Carbon feedback
	2015	2020	2020
Parent generation	0,39	0,40	0,42
Hatching	0,01	0,01	0,01
Feed production	2,55	2,35	2,46
Breeding	0,61	0,50	0,53
Slaughter and processing	0,21	0,16	0,17
Packaging	0,08	0,09	0,10
Distribution, wholesaler and retail	0,25	0,07	0,07
Consumer	0,10	0,05	0,05

End-of-life packaging	-	0,10	0,10
Total	4,20	3,74	3,90

The table shows that the results have changed since 2015. The following changes have been made:

- Updated foreground data from Nortura for upstream and manufacturing processes.
- Updated data for downstream based on PEFCR dairy.
- More detailed calculations for methane and nitrous oxide from fermentation and manure.
- Changes in background data, using updated databases.

The climate change is reported as aggregated value and separately for the sub-indicators "Climate change – fossil", "Climate change – biogenic" and "Climate change - land transformation".

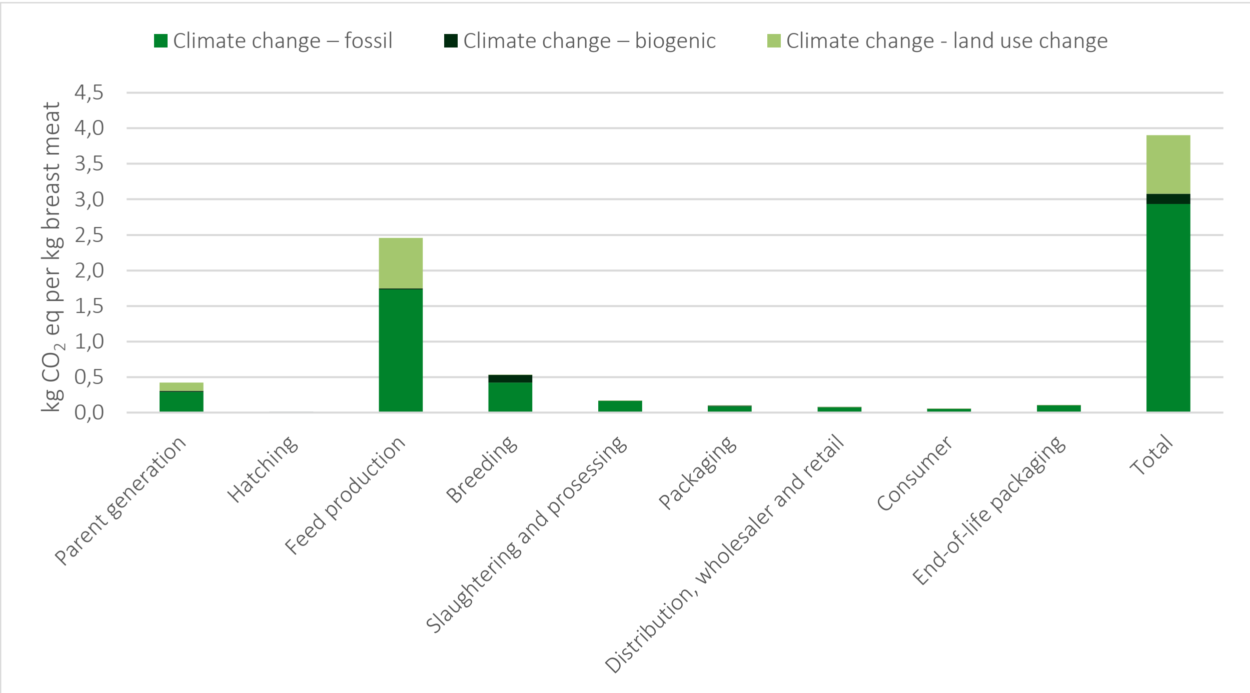

Figure 4.1 Carbon footprint of 1 kg of broiler breast meat from cradle to grave for sub-indicators, including carbon feedback.

Most of the contribution to the climate change impact comes from fossil resources (75%), mainly in production of feed to the parent generation and the broiler, but also in the breeding stage (mostly from heating). The climate impact from land use is 21%, due to production of soybean meal and oil. Biogenic climate change constitutes 4% of the total carbon footprint and is due to fermentation and emissions from manure from both parent generation and broiler in breeding.

4.1 Sensitivity analysis

To investigate how robust the results are, a sensitivity analysis of the most uncertain elements has been carried out. It is especially the principle of allocating between broiler meat and by-products that have economic value, electricity modelling and the carbon footprint associated with soy production.

Market data is used in the modelling of electricity, however according to PEFCR dairy, a residual mix should be used if specific data is not available. Only data for residual mix from 2012 are available and that has been used in a sensitivity analysis. Using the residual mix for electricity gives a 3% higher carbon footprint impact than when using the market process for Norwegian electricity as we have in this study. Thus the choice of electricity mix had little impact on the total results.

Different data sets for soy show that there is great variation in both data and methodological choices. Amaggi, which is a producer of the soy meal used in the feed has commissioned an LCA. The outcome of the study is 0.514 kg CO_2 per kg soybeans including transport to Fredrikstad. This certification is based on land use changes after 2008. According to the requirements of the IPCC and PEF Dairy products, land use changes over the last 20 years must be included. Therefore, the supplier's own calculations cannot be used directly in this study. However, if using these data in this carbon footprint, the result would be 3.1 kg CO_2 eqv. for 1 kg of broiler breast meat i.e. significantly lower. The reduction compared to this study is related to climate change LULUC.

5 Discussion and conclusion

The carbon footprint of the Prior chicken broiler breast product is 3.90 kg CO2-eq/kg product including carbon feedback, 3.74 kg CO2-eq/kg product excluding carbon feedback. Both results are valid. The choice of which result to use depends on the context.

The result (excluding carbon feedback) show that the carbon footprint for broiler breast meat has been reduced by 11 % since 2015. The change is caused by a number of factors, relating to physical differences like change in feed composition, and changes in the way the result is calculated.

The sensitivity analysis shows that the results are robust in terms of residual mix for electricity, but data for soy greatly affect the results. This analysis has been carried out with the best available data that follows methodological guidelines and as such is the result are considered valid.

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