Credit: *shutterstock*

5. Annex 1: Detailed methodology

This report presents calculated estimates of the emissions associated with the meat and milk processed and supplied by some of the largest meat and dairy companies in the world. In the absence of transparency about supply chain emissions in the food industry or consistent reporting by food companies, the calculations are made by cross-referencing publicly available data about the number of animals and quantity of milk processed by individual companies with emission factors from the most recent update of the UN Food and Agriculture Organization (FAO) Global Livestock Environmental Assessment Model (GLEAM,[103] most up-to-date version from 2018). This allows us to present estimates of the supply chain GHG emissions, including methane, that can be expected if the animals milked and slaughtered for these companies are raised in line with typical practices in their regions of origin.

The data gathering and calculation process for this report is similar to that documented for earlier reports in IATP's *Emissions Impossible* series, and consists of the following steps:

1. Determining the annual number of animals slaughtered and quantity of milk processed for each company considered, and the region(s)[N] in which animals were raised.

2. Using standard carcass weight data by animal and region from GLEAM[O] to convert from the number of animals slaughtered for each meat company to the estimated carcass weight produced. Typical carcass weights are provided for animals in specified production systems. We have treated the slaughter weights and dressing percentages of 'mixed or grassland' cattle,[P] 'industrial' pigs and 'broiler' chickens as representative.

3. Using regional average data on emissions of methane, nitrous oxide and carbon dioxide per kilogram of carcass weight/milk produced to estimate the climate impact associated with livestock reared for each company. The GLEAM-based regional-average emission factor data was provided by UN FAO in 2017 and reflects a reference year of 2010 – although the FAO started to publish a GLEAM update, the full update with regional estimates was not yet available at the time of the writing of this report.

4. Multiplying the production quantity by the emissions factors to get the totals for each company.

N The GLEAM emissions factors are specified at the level of continental or sub-continental regions, e.g. 'Latin America', 'East and Southeast Asia', 'Western Europe'.

O This data is contained in the GLEAM 2.0 Supplementary data spreadsheet http://www.fao.org/fileadmin/user_upload/gleam/docs/GLEAM_2.0_Supplement_S1.xlsx

P Cattle production systems are not distinguished for dressing percentage.

Our emissions estimations based on this methodology can be found in our dataset: http://changingmarkets.org/wp-content/uploads/2022/11/Emissions-Impossible_Methane-Edition-_Public-Dataset_FINAL.xlsx

The use of regional average data means that our analysis is necessarily limited in the accuracy that can be achieved. Using regional typical emission factors allows us to highlight the order of magnitude of the emissions that are associated with these businesses, but we are not able to model in detail the characteristics of the herds of animals used, such as the fraction of animals supplied to a given company that are grass-fed versus feedlot-fed or the differences in enteric fermentation emissions that may be associated with different animal diets. Data at that resolution can only be provided with cooperation from the companies themselves or through mandatory reporting and verification requirements by national regulators.

There are uncertainties associated with the emissions estimated on this basis. The livestock practices associated with any individual company's supply chain may be more or less damaging to the climate than the average for each region. A company may use livestock reared in a country where the typical livestock emissions are lower or higher than the regional average. A company may source meat and milk from farms that follow best practices in manure management or from farms that are more polluting. The companies are in the best position to give truly detailed insights into the impact of their supply chains.

The emission factors provided by GLEAM by the FAO are stated in terms of carbon dioxide equivalent emissions based on global warming potentials from the IPCC fifth assessment report (AR5). In order to reflect the most up-to-date science we have adjusted the emission factors for methane and nitrous oxide to reflect the global warming potentials from the IPCC's more recent sixth assessment report (AR6).[104] This is done by multiplying each emission factor by the ratio between the AR6 global warming potentials for the relevant greenhouse gas and accounting period and the corresponding AR5 global warming potentials used in GLEAM. The results of the analysis are presented in terms of carbon dioxide equivalent emissions based on both the 100-year and 20-year global warming potentials. The 100-year global warming potentials are 27.0 for non-fossil methane and 273 for nitrous oxide. The 20-year global warming potentials are 79.7 for non-fossil methane and 273 for nitrous oxide.[Q]

TABLE 5: **THE CHANGES OF GLOBAL WARMING POTENTIALS (GWP) OF DIFFERENT GREENHOUSE GASES IN THE LAST TWO IPCC REPORTS – THE NUMBERS HIGHLIGHTED IN BLUE ARE THE ONES USED IN GLEAM**

	IPCC AR5		IPCC AR6	
	GWP_{100}	GWP_{20}	GWP_{100}	GWP_{20}
CH_4 (non-fossil)	28/34*	84/86*	27.0	79.7
CH_4 (fossil)	29/35*	86/88*	29.8	82.5
N_2O	264/268	265/298	273	273
CO_2	1	1	1	1

* The higher number in AR5 includes climate-carbon feedbacks in response to emissions of the indicated non-CO_2 gases. AR6 factors include the carbon cycle response for non-CO_2 gases. These (highlighted) factors were used in GLEAM.

Reference: Based on Table 8.7 p.714, IPPC AR5 report: https://archive.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf and Table 7.15 p. 1017, AR6 report: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07.pdf

Q Nitrous oxide has a similar atmospheric residence time to carbon dioxide and there is no difference between the 20 and 100 year GWPs given by IPCC AR6.

Production data

Data on the number of animals slaughtered for each meat company and quantity of milk processed for each dairy company were solicited directly from the companies by email. The final data used in the emissions estimation reflects a combination of data from sources provided by the companies and data from other publicly available sources. Note: Publicly available data on these figures is not always consistent from one site to the next; often it is not consistent in different publications of the same company. We have made a good faith effort at arriving at these figures based on the dysfunctional state of publicly available data.

Meat companies – Data was primarily sourced from public company reports (e.g. company annual reports and sustainability reports), complemented where necessary by data from other sources. For two meat companies (Danish Crown, WH Group), annual slaughter numbers could be directly obtained from publicly available sources. For three companies (Tyson, JBS and Marfrig), annual slaughter numbers were estimated on the basis of animal processing capacity. Where data was available, we disaggregated the quantity of production by GLEAM's geographic regions. The sources used for the five meat companies assessed are detailed below.

In this analysis, all poultry reported in company slaughter data are treated as chickens in the emissions estimation. It is often not possible to distinguish which type of birds publicly available data relates to (e.g. chickens, ducks, geese or turkeys). Turkeys and geese have more meat per carcass than chickens and therefore are expected to have higher emissions per bird, while ducks have less meat per carcass and are therefore generally expected to have lower emissions per bird. GLEAM only provides emission factors for chickens, but it is understood that ducks and chickens have similar emissions footprints per kilogram of meat produced, while geese and turkeys may have higher emissions.[105] FAOSTAT data on annual meat production and the number of birds slaughtered suggests that globally the average poultry animal is slightly heavier than the average chicken. Given that this treatment of all poultry as chickens is likely to slightly underestimate both meat production and average emissions intensity per kilogram of meat production, we consider our estimate to be conservative.

Dairy companies – For the dairy companies, additional data on the total quantity of milk processed by the companies in 2020 is taken from IFCN[R] Dairy Research Network Dairy Processor Report: Top 20 Dairy Processor List 2021.[106] Where no region-specific data was provided by the companies the calculations are done on the basis that all milk is sourced from the region in which the company is headquartered. Company-specific information was provided to us by Saputo, Danone and Arla and used as detailed below.

Data source: *2021 Annual Report on Form 10-K, Item 2 (https://s22.q4cdn.com/104708849/files/doc_financials/2021/q4/TSN-2021-10K-DRAFT-11.12.21.pdf).*

No aggregate production figures were reported by the company. Annual production figures were calculated based on weekly production capacity and capacity utilisation reported by the company. We have assumed that weekend and holiday closures are included in the calculation of the published weekly capacities and therefore production is estimated as 52 times the stated weekly capacity multiplied by the stated capacity utilisation.

R Formerly known as the International Farm Comparison Network.

- **Beef production facilities** were reported to have a weekly slaughter capacity of 155,000 with average utilisation 78%, which implies 6.3 million cattle are slaughtered annually. One of the 14 beef production facilities is located in Australia and the rest in the US. Assuming facilities are comparably sized gives an estimate of 5.8 million (93%) cattle slaughtered annually in North America and 0.4 million (7%) in Oceania.

- **Pork production facilities** were reported to have a weekly slaughter capacity of 469,000 with average utilisation 88%, which implies 21.5 million pigs slaughtered annually. All pork facilities are understood to be in the US.

- **Chicken production facilities** were reported to have a weekly slaughter capacity of 47.0 million with average utilisation 79%, which implies 1.9 billion chickens slaughtered annually. Twenty of the 186 chicken production facilities are located in East Asia and the rest are in the US. Assuming facilities are comparably sized gives 1.7 billion (89%) chickens slaughtered annually in North America and 0.2 billion (11%) in East Asia.

Danish Crown

Data sources: Danish Crown Annual Report 2020/21 and Danish Crown Annual Report 2019/20 (https://www.danishcrown.com/en-gb/about-us/our-results/annual-reports).

For 2021, the Annual Report 2020/21 identified 18.9 million slaughtered pigs and sows and 0.8 million slaughtered cattle but does not indicate a regional breakdown. The regional breakdown is therefore based on data in the Annual Report 2019/20, which gives a breakdown of pig and sow slaughter of 69% in Denmark, 17% in Germany, 8% in Poland, 6% in Sweden, i.e. 8% Eastern Europe and 92% Western Europe. All cattle are understood to be slaughtered in Denmark and Germany, i.e. Western Europe.

萬洲國際 WH GROUP

Data sources: WH Group 2021 Annual Report (http://www.wh-group.com/html/ir_report.php), Smithfield 2021 Sustainability Impact Report (https://www.smithfieldfoods.com/sustainability-reports).

Pork – According to company reports, 50.7 million pigs were slaughtered in 2021. Based on data for capacity and capacity utilisation the following regional breakdown was estimated: 11.3 million in China, 32.2 million in the US and 7.2 million in Europe.

Poultry – In 2021 184.0 million poultry (chickens, turkeys and geese) were slaughtered. Poultry operations are identified in China and Eastern Europe (Poland and Romania). We were not able to directly identify the number of chickens slaughtered in the respective regions but based on the comparison of the Smithfield 2021 Sustainability Impact Report and the WH Group 2021 Annual Report it appears that Europe represents approximately a third of poultry sales revenue. In 2021, the reported average price for EU chicken was around €2/kg (https://circabc.europa.eu/sd/a/7984db58-8eaa-492a-8074-a7a75cf0641d/Poultry%20price_Europa_41.pdf) while the price in China was slightly higher at around €2.2/kg (https://www.oigcn.com/en/news/industry/4322, given an exchange rate of 7.7 Yuan to the Euro). However (based on GLEAM data) the average broiler chicken in Eastern Europe is slightly larger than in China (2.2kg to 1.9kg). We therefore assume that the difference in bird sizes approximately cancels out the difference in price per kilo, and treat poultry sales revenue as an acceptable proxy for the distribution of poultry production. We consequently assume that one-third of WH Group poultry is produced in Eastern Europe and two-thirds in China. Note that this is a source of uncertainty in the analysis as the GLEAM emission intensity for poultry rearing in Southeast Asia is more than double that for Eastern Europe.

JBS

Data sources: JBS Institutional Presentation including 4Q21 and 2021 Results (https://api.mziq.com/mz-filemanager/v2/d/043a77e1-0127-4502-bc5b-21427b991b22/89617df2-cf31-77d8-d102-c2dee83873fb), Pilgrim's Pride Form 10-K for fiscal year 2021 (https://sec.report/Document/0000802481-22-000012/#i365101cbe4f04749b160988d470f6822_25) and the JBS USA and Pilgrim's Pride websites (https://sustainability2019.jbssa.com/chapters/who-we-are/about-our-company, https://sustainability.pilgrims.com/chapters/who-we-are/facilities-and-locations).

In its Institutional Presentation to investors, JBS gives daily numbers of animals associated with its processing facilities, stating 'beef production', 'pork and value added production', 'production of prepared foods and fresh poultry and pork products' without specifying whether these terms refer to the company's actual production or its total slaughter capacity.[107] Based on recent JBS documentation[108], we conclude JBS is presenting processing capacity rather than average daily production. No total annual slaughter figures for 2021 have been reported by the company that we are aware of. We have estimated processing capacities and processing utilisation rates as follows:

Daily processing capacities:

- **For beef,** the Institutional Presentation lists 42,700 head per day for JBS USA (including the USA, Canada, Australia and Europe) and 33,450 head per day for JBS Brazil.[109]

- **For pigs,** the Institutional Presentation lists 92,600 head per day for JBS USA Pork related to US operations only, 25,300 head per day for Seara in Brazil and 10,100 head per day for Pilgrim's Pride in Western Europe. The Pilgrim's Pride Form 10-K identifies processing capacity as slightly higher, 11,133 per day, and we use this second number in the analysis. In addition, the JBS USA website identifies a further 4,000 head per day of pig processing capacity in Australia. We assume that this capacity is additional to the capacity reported elsewhere.

- **For chickens,** the Institutional Presentation lists 5.1 million birds per day for Seara and 8.7 million birds per day for Pilgrim's Pride. The Pilgrim's Pride 10-K Form identifies daily chicken processing capacity as 8.8 million, and we use this second value. Note: Wattagnet, a poultry industry news outlet, has published JBS's total slaughter figures for 2021 as 4.4 billion animals which is far higher than our estimate (3.6 billion animals) based on what JBS has published.[110] We have chosen to use our estimate based on the JBS figures which are more conservative.

Capacity utilisation:

- **For cattle,** we are not aware of a document in which JBS reports its capacity utilisation rates. We have thus based utilisation assumptions on estimates given for the US in 2020 by John Nalivka (https://www.porkbusiness.com/news/industry/nalivka-economics-capacity-and-utilization-0). This is likely to be slightly conservative due to the influence of COVID. Nalivka's work was identified as a source in recent JBS documentation for estimated utilisation rates. For our estimations, we decided to use Nalivka's estimated capacity utilisation rate of 91% for fed cattle. These assumptions are used for all regions.

- **For pork,** Nalivka estimates a capacity utilisation rate of 96%. Pilgrim's Pride 10-K Form reports a utilisation rate of 82.6%. We used Nalivka's estimate for capacity utilisation in the regions North

America, Latin America and the Caribbean, and Oceania. We applied the rate reported by Pilgrim's Pride to its production in Western Europe.

- **For chicken,** Pilgrim's Pride 10-K Form reports a utilisation rate of 86.6%. For Seara's chickens, we assume the capacity utilisation rate is comparable to Pilgrim's Pride. Thus, the same rate is assumed for all regions.

For all animals and regions, we assume a six-day operational week and eleven days of holiday closures per annum (i.e. plants operational on 83% of days). No definitive information is available on the number of days JBS facilities are open per year, and conversations with trade unions and industry experts suggest a large amount of variation between countries and factories (with factories operational between five and seven days a week and holiday closures between six and eleven days a year). Based on the additional research conducted for this study we have based the current estimate on a conservative assumption that the company's facilities operate six days a week with eleven holiday days per year.

Regional distribution:

- **Cattle:** The regional distribution of cattle processing by JBS USA is further disaggregated based on data on daily capacities and numbers of facilities by region on the JBS USA website. The JBS USA website identifies 28,000 head per day of capacity in the US, 4,200 in Canada and 10,000 in Australia. On this basis we assume that JBS USA cattle production is split 76:24 between North America and Oceania.
- **Pork:** Pilgrim's pig production is identified as entirely within Western Europe.
- **Chicken:** The regional distribution of chicken processing by Pilgrim's Pride is further disaggregated based on data on daily capacities and numbers of facilities by region on the Pilgrim's Pride website. It reports 40 fresh chicken processing plants, eight of them in Western Europe and the rest in North America. On this basis, we assume that Pilgrim's Pride's poultry production is split 80:20 between North America and Western Europe.

Marfrig

Data source: *Marfrig Sustainability Report 2021 (https://www.marfrig.com.br/en/Lists/CentralConteudo/Attachments/3/Sustainability%20Report%202021.pdf).*

The report states that Marfrig has the capacity to slaughter 29,100 cattle daily, with 13,100 of this capacity in North America and the rest in South America. Following the same approach as explained above for JBS, we assume a cattle slaughter capacity utilisation rate of 91% combined with an assumed six-day operational week and eleven days of holiday closures per annum (i.e. plants operational on 83% of days).

Saputo

Data source: *2021 investor factsheet, provided to us by Saputo (https://www.saputo.com/-/media/ecosystem/divisions/corporate-services/sites/saputo-com/saputo-com-documents/investors/fy2023/saputo_factsheet2021_eng.ashx).*

The factsheet states that Saputo processes about 11 billion litres (approximately 11.4 million tonnes)[S] of milk annually.

DANONE

Data source: *Exhaustive 2021 Extra Financial Data, provided to us by Danone (https://www.danone.com/content/dam/danone-corp/danone-com/investors/en-sustainability/reports-and-data/cross-topic/danoneexhaustive2021extrafinancialdatav2.pdf).*

This document states that in 2021 Danone sourced 5.6 million tonnes of milk. Algeria, Argentina, Belgium, Brazil, Egypt, France, Germany, Mexico, Poland, Romania, Russia, South Africa, Spain and the US are identified as collectively accounting for over 80% of Danone's milk intake. The milk intake is regionally divided: 26% from Europe (we believe this is primarily Western Europe and therefore treat this as 16% Western Europe and 10% Eastern Europe in our calculations); 23% from CIS (Commonwealth of Independent States; we assume this is primarily Russia); 29% from North America; 10% from Latin America; 11% from other regions (as Algeria, Egypt and South Africa are the other significant sourcing countries identified, we treat this as being sourced two-thirds from the Near East and North Africa and one-third from Sub-Saharan Africa).

Arla

Data source: *2021 Annual Report, provided to us by Arla (https://www.arla.com/493351/globalassets/pdf-files/annual-report-2021/arla_consolidated_annual_report_2021_en.pdf).*

The report states that in 2021 Arla had a milk intake of 13.6 million tonnes.

S A density conversion factor of 1.032kg per litre was applied, e.g. Parmar et al. (2020) The effect of compositional changes due to seasonal variation on milk density and the determination of season-based density conversion factors for use in the dairy industry. *Foods* 9(8): 1004. [ONLINE] Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7466286/#:~:text=The%20density%20of%20milk%20fluctuates,lower%20in%20winter%20%5B24%5D

6. Annex 2: Main emissions results

TABLE 6: **OVERALL GHG IN METHANE EMISSION OF 15 MEAT AND DAIRY COMPANIES**

Company	GHG emissions (GWP100 basis)	GHG emissions (GWP20 basis)	CH_4 emissions (GWP100 basis)	CH_4 emissions (GWP20 basis)	Fraction of GHG emissions as methane (GWP100)	Fraction of GHG emissions as methane (GWP20)	Methane/CH4 emissions
	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	%	%	kg CH_4
Tyson	83,784,741,795	166,667,351,111	42,463,575,930	125,346,185,246	**51%**	**75%**	1,572,725,034
Danish Crown	14,434,620,804	22,200,486,990	3,978,717,021	11,744,583,206	**28%**	**53%**	147,359,890
萬洲國際 WH GROUP	23,933,616,549	37,707,923,013	7,057,045,058	20,831,351,522	**29%**	**55%**	261,372,039
JBS	287,928,882,902	540,564,236,134	129,433,672,434	382,069,025,665	**45%**	**71%**	4,793,839,720
Marfrig	102,617,247,172	201,792,968,636	50,811,090,693	149,986,812,156	**50%**	**74%**	1,881,892,248
Fonterra	30,922,750,517	56,990,438,174	13,355,361,798	39,423,049,456	**43%**	**69%**	494,643,030
DFA Dairy Farmers of America	45,644,653,013	97,821,797,403	26,732,123,312	78,909,267,703	**59%**	**81%**	990,078,641
Groupe Lactalis	29,997,842,295	57,238,009,801	13,956,063,048	41,196,230,554	**47%**	**72%**	516,891,224
Nestlé	18,800,491,024	35,872,669,737	8,746,657,026	25,818,835,739	**47%**	**72%**	323,950,260
Arla	18,938,729,928	36,136,439,367	8,810,970,680	26,008,680,119	**47%**	**72%**	326,332,247
FrieslandCampina	16,312,190,741	31,124,816,389	7,589,011,243	22,401,636,891	**47%**	**72%**	281,074,490
DANONE	11,190,512,922	23,441,872,905	6,276,787,847	18,528,147,831	**56%**	**79%**	232,473,624
dmk Group	9,123,767,703	17,408,795,608	4,244,701,204	12,529,729,109	**47%**	**72%**	157,211,156
Saputo	18,117,416,119	38,827,728,815	10,610,596,638	31,320,909,334	**59%**	**81%**	392,985,061
Yili	22,228,357,608	44,205,467,881	11,259,620,064	33,236,730,338	**51%**	**75%**	417,022,965
Total	733,975,821,092	1,408,001,001,966	345,325,993,996	1,019,351,174,870	**702%**	**1073%**	12,789,851,629

TABLE 7: **SHARE OF (METHANE) EMISSION COMING FROM MANURE MANAGEMENT OR FROM ENTERIC FERMENTATION**

Company	Fraction of GHG emissions from enteric fermentation (GWP100basis)	Fraction of GHG emissions from manure management (GWP100basis)	Fraction of GHG emissions from enteric fermentation (GWP20basis)	Fraction of GHG emissions from manure management (GWP20basis)
	%	%	%	%
Tyson	43.74%	6.93%	64.91%	10.28%
Danish Crown	14.56%	13.00%	27.94%	24.95%
萬洲國際 WH GROUP	3.22%	24.46%	6.04%	45.83%
JBS	41.15%	3.78%	64.70%	5.95%
Marfrig	47.22%	2.29%	70.89%	3.44%
Fonterra	38.98%	4.21%	62.43%	6.74%
DFA Dairy Farmers of America	36.12%	22.45%	49.75%	30.92%
Groupe Lactalis	39.10%	7.43%	60.48%	11.49%
Nestlé	39.10%	7.43%	60.48%	11.49%
Arla	39.10%	7.43%	60.48%	11.49%
FrieslandCampina	39.10%	7.43%	60.48%	11.49%
DANONE	48.62%	7.47%	68.51%	10.52%
dmk Group	39.10%	7.43%	60.48%	11.49%
Saputo	36.12%	22.45%	49.75%	30.92%
Yili	48.89%	1.77%	72.56%	2.63%
Total	40.09%	6.89%	61.70%	10.60%

For detailed calculations see: http://changingmarkets.org/wp-content/uploads/2022/11/Emissions-Impossible_Methane-Edition-_Public-Dataset_FINAL.xlsx