METHODOLOGY

Beef - Sector Decarbonization Pathway

Sustainable Investing Expertise by ROBECOSAM

ROBECO

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Michal Kulak
Senior SI Analyst

Danae Motta
SI Analyst

Introduction

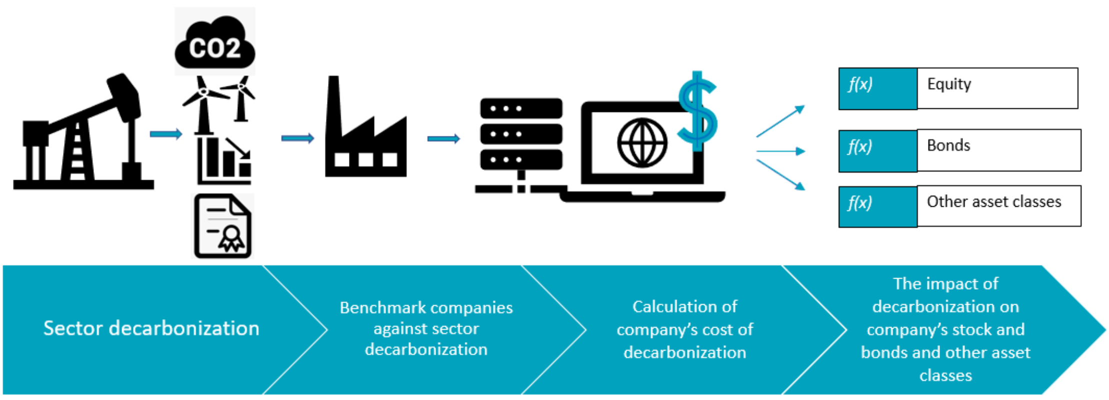
Sectoral Decarbonization Pathways (SDP) are a critical tool to help economic sectors achieve carbon neutrality by 2050. Constructed by climate scientists and industry experts, they provide an objective, scientifically based method for systematically measuring and reducing carbon and other greenhouse gas emissions in business sectors through 2050.

SDPs are based on the goals of the universally ratified UN treaty on climate change (the Paris Agreement of 2015), where countries agreed to reduce carbon emissions in order to keep global temperatures within 1.5 - 2°C of pre-industrial levels.

The carbon budget represents the total amount of carbon and other greenhouse gas emissions that must be reduced in order to achieve the 2°C target. The SDPs allocate the overall 2°C carbon budget across the economy's different economic sectors based on their share of total greenhouse gas (GHG) emissions. High-emitting sectors such as oil and gas, transportation, and materials are allocated higher proportions of the budget, whereas low- emitting sectors such as services and IT are allocated less. The SDP method also takes into account inherent differences among sectors, such as their ability to mitigate emissions as well as their speed of expansion relative to economic and population growth.

The goal of sector decarbonization is not only to anticipate the future impact of climate-related issues on the sector, but also to provide stakeholders, including company executives, investors, regulators and consumers, with consistent and reliable assessments of the performance of constituent companies. Figure 1 presents a schematic view of the sectoral decarbonization.

Figure 1 – Schematic view of sector decarbonization



Source: Robeco, 2023

Why construct an SDP for beef?

At present, more than 77% of agricultural land globally is used for livestock (grazing and feed production). Moreover, beef producer supply chains are directly linked with deforestation, particularly in the Amazon region of Latin America, which is home to some of the globe's largest producers. Meat production has already increased by 30% since the 1990s and is expected to increase a further 30% through 2050.[1] The

[1] H. Ritchie, Our World in Data, Global Meat Consumption estimates based on UN FAO projections through 2050. https://ourworldindata.org/grapher/global-meat-projections-to-2050.

resulting emissions linked to deforestation alone could increase global emissions enough to put the achievement of the 1.5° Paris-Alignment target out of reach.

Food and agricultural emissions

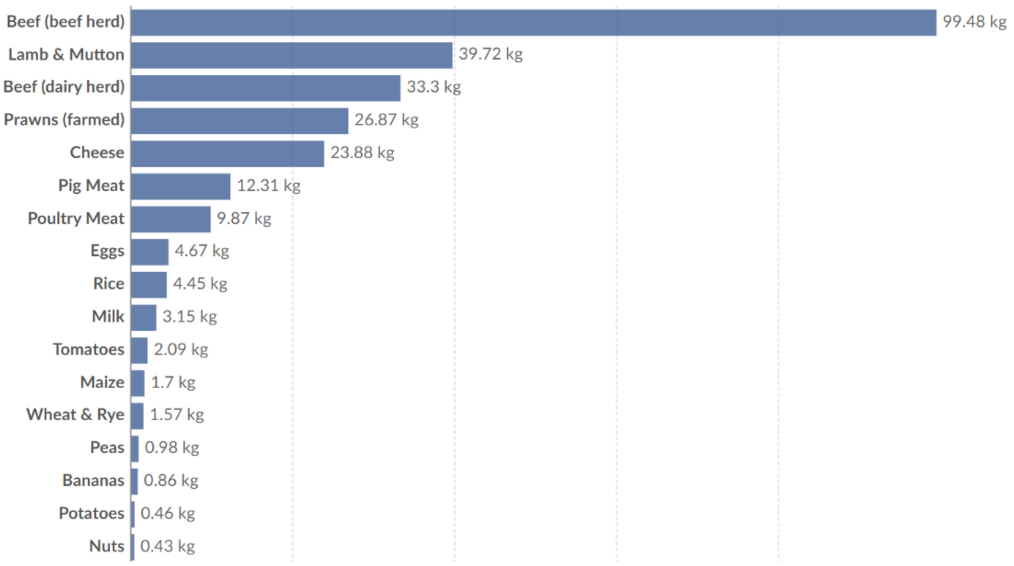
Food and agriculture are responsible for 25-30% of global greenhouse gas emissions.[2] The application of fertilizers to fields releases nitrous oxide – a greenhouse gas that is 273 times more potent in causing climate change than carbon dioxide over a 100-year horizon.[3] In addition, fertilizer production is an energy intensive process that uses vast amounts of natural gas. But natural processes also contribute heavily to emissions. Flooding rice paddies, an essential method of rice cultivation that has been practiced for thousands of years, emits methane, a gas that is 27-30 times more potent than carbon dioxide over a 100-year horizon. And ruminants (cows, goats and sheep) directly emit methane from their digestive systems, a process known as enteric fermentation.

Moreover, the simple process of clearing large areas of forests, peatlands and savannahs is also highly polluting. When vegetation and soils, both rich in carbon, are converted to croplands and pastures, they release their stored carbon into the atmosphere. In later agricultural stages, the farm machinery used to prepare and cultivate fields burn diesel fuel, further adding to atmospheric emissions.

Among the agricultural sector's major business activities, beef production is among the most greenhouse-gas intensive. The livestock industry, which includes all forms of meat and dairy, is estimated to release 7.1 GtCO2e[4] emissions annually (or 14.5% of total man-made emissions). Moreover, cattle production is responsible for over 70% of livestock's global emissions.[5]

Beef generates the largest carbon footprint of any food category (see Figure 2). Cattle emissions are greatest in Latin America (see Figure 3), which is responsible for over a quarter of global beef production.

Figure 2 – Beef, the most carbon intensive food

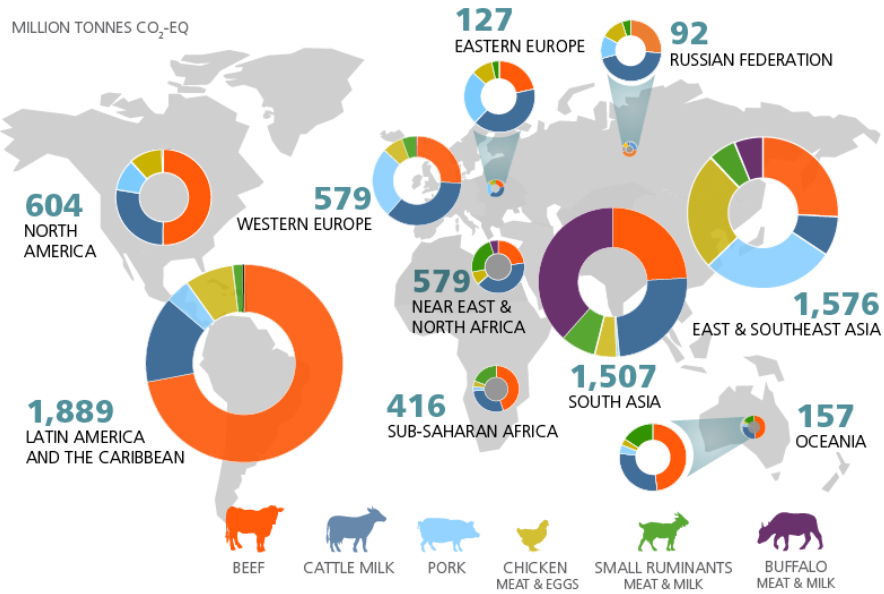


Emissions generated per kilogram of food product. Beef tops the food chain with almost 100 kg of carbon dioxide equivalent gases generated per kilogram of beef produced.

Source: Our World in Data (2020)

[2] https://ourworldindata.org/greenhouse-gas-emissions-food#:~:text=The%20specific%20number%20that%20answers,we%20include%20all%20agricultural%20products.
[3] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials#:~:text=Nitrous%20Oxide%20(N2O,than%20100%20years%2C%20on%20average.
[4] Gigatonnes of carbon dioxide equivalent gas is the standard metric for measuring greenhouse gas quantities.
[5] Source: United Nations Food and Agriculture Organization, 2020.

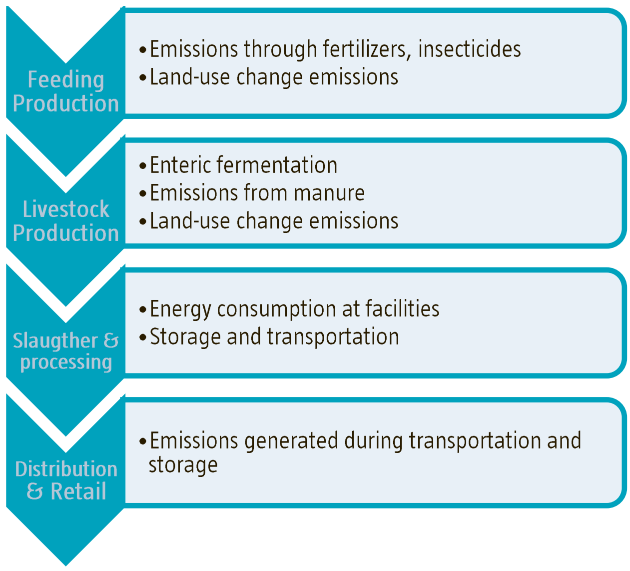
Figure 3 – Latin America leads the world in emissions from cattle and livestock



Source: UN, FAO.org

Beef requires over 20 times more land and emits over 20 times more greenhouse gas emissions per gram of edible protein compared to other types of meat and plant-based foods.[6] Emissions from beef production include carbon dioxide (CO2), methane (CH4) and nitrous oxides (N2O), all generated at different stages of the value chain as a result of enteric fermentation (cattle's digestive gas), ruminant waste (manure) on pastures, production of animal feed and feed concentrates, and land-use change (LUC) which include clearing vegetation for pastureland expansion (see Figure 4).

Figure 4 – Life cycle stages of the meat sector product system

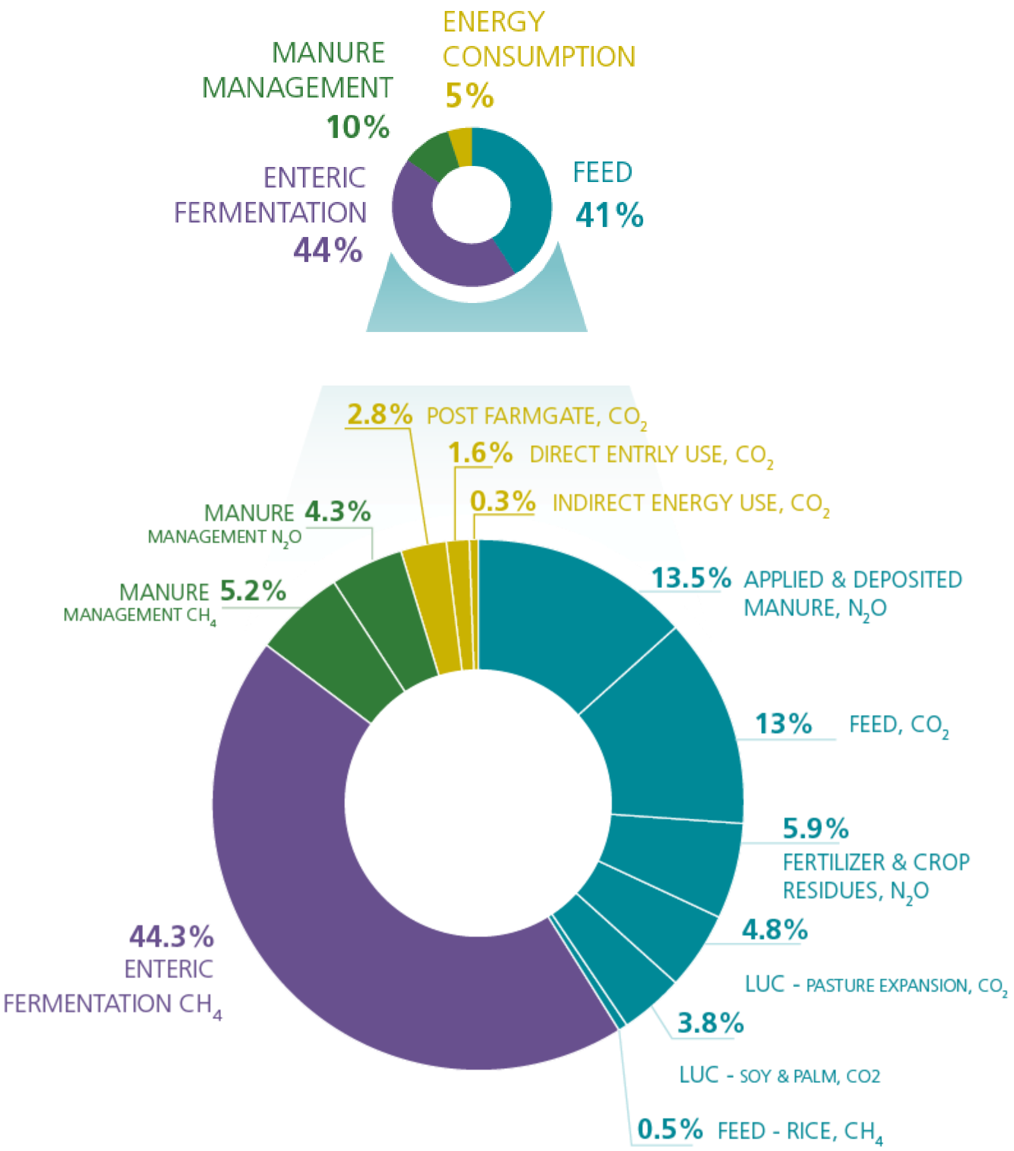


Source: Robeco

As seen in Figure 5, enteric fermentation is the largest contributor to emissions from the beef industry (44%) followed by emissions related to clearing land to be used for livestock grazing (land-use change, LUC) and raising crops for additional feedstock (e.g., fertilizers, feed, manure).

[6] Source: World Resources Institute

Figure 5 – Share of emissions in meat production (including beef, meat types)



Source: UN, FAO.org

Key metrics and methods

Robeco's SDP-beef model is a proprietary tool that systematically evaluates how beef processors are managing the transition to a low-to-zero carbon economy. This section explains our methodology for measuring a company's future carbon emission performance, one of the model's three components.

In 2022, the Science Based Targets Initiative (SBTi), published its final guidance for science-based emission reduction targets for Forest, Land and Agriculture (FLAG).[7] At present, it is the only sector decarbonization framework for the beef processing industry. It focuses on the agricultural industry's land-related emissions, including CO_2 emissions associated with land use change (e.g., biomass and soil carbon losses from deforestation and soil degradation), and emissions from land management (e.g., nitrous oxide (N_2O) and methane (CH_4) emission from enteric fermentation, fertilizer use, manure management, etc.).

The SBTi provides multiple reference approaches (or pathways) for food sector companies based on whether their level of diversification across food categories. The FLAG Sector Approach is the annual emission reductions needed to decrease the entire agricultural sector's carbon budget by 2050, in line with the temperature targets of the Paris Agreement (Table 1). The FLAG Sector Approach should be used by companies whose emissions are dispersed across diverse food categories. The second type of reference pathway breaks down the larger agri-carbon budget into smaller commodity-specific subsets (e.g., chicken, beef). For each pathway type, the SBTi provides a detailed methodology for company target-setting and offers a science-based understanding on how much and how quickly a company needs to cut its land-related emissions.

Table 1 – Overview of SBTi FLAG pathways

Near-Term target pathway name	Pathway type	Units	Absolute % reduction* (%/yr 2020-2030)
FLAG Sector Approach	Absolute	tCO_2e	3.03
FLAG Commodity–Beef	Intensity	tCO_2e/t fresh wt	2.40
FLAG Commodity–Chicken*	Intensity	tCO_2e/t fresh wt	3.90
FLAG Commodity–Dairy	Intensity	tCO_2e/t fresh wt FPCM	3.10
FLAG Commodity–Leather	Intensity	tCO_2e/t fresh wt	2.50
FLAG Commodity–Maize*	Intensity	tCO_2e/t fresh wt	3.50
FLAG Commodity–Palm Oil*	Intensity	tCO_2e/t fresh wt	3.10
FLAG Commodity–Pork*	Intensity	tCO_2e/t fresh wt	3.30
FLAG Commodity–Rice*	Intensity	tCO_2e/t fresh wt	2.90
FLAG Commodity–Soy*	Intensity	tCO_2e/t fresh wt	3.80
FLAG Commodity–Wheat*	Intensity	tCO_2e/t fresh wt	3.60
Mixed Sector Pathway (non-FLAG	Absolute	tCO_2e	4.20**

*Reduction rates listed here for intensity pathways include emissions and removals and assume starting with global average emissions intensity for 100,000 tonnes of production. The percent reduction on both an intensity and an absolute basis is shared. Intensity is calculated as tonnes of CO_2e per tonne of product. Actual company targets depend on starting emissions intensity, projected company growth in production and location of production/sourcing. See FLAG tool for calculations and target-setting.

**AFOLU sector is expected to decarbonize more slowly than energy/industry because continued nitrous oxide and methane emissions are more challenging to reduce in agricultural production.

Source: SBTi, 2022

[7] Source: https://sciencebasedtargets.org/resources/files/SBTiFLAGGuidance.pdf

SBTi's FLAG approach

This approach is used for companies with diversified, land-intensive activities in their supply chain, and/or with limited access to data from suppliers. It also includes companies with land-based emissions which are not covered by the commodity approach. The FLAG Sector approach uses absolute emission reduction targets.[8] To stay Paris-aligned, food companies should reduce absolute emissions (tCO2e) by 3.03% annually from 2020-2030.

FLAG-Commodity approach

FLAG also provides reduction pathways for important food commodities, namely: beef, palm oil, chicken, dairy, corn/maize, pork, rice, soy, wheat, timber and wood fiber. Companies can use this approach when the commodity being measured accounts for 10% or more of their company's total FLAG emissions.

An interesting distinction between the two approaches is their emissions reduction metric. The FLAG Commodity Approach measures reductions in carbon intensity rather than absolute reductions. The targeted reduction in emission intensities is set for 2.4% annually from 2020-2030. Emission intensities are measured by dividing total carbon emissions for the commodity by tons of animal weight (tCO2e / t fresh weight). Fresh weight is defined as the combined weight of meat and bones of an animal carcass (which can be fresh, chilled or frozen).

Robeco's selected approach

Robeco's SDP model employs the FLAG Commodity Approach for beef. We zeroed in on beef as opposed to other food sub-sectors because of its outsized share of emissions compared to other food categories in the food and agriculture sector. According to the FLAG Commodity Approach for beef, the sub-sector as a whole must reduce its emissions intensity by 24% between 2020 and 2030, or 2.4% per year.

As prescribed by the FLAG Commodity approach, we use carbon intensity as our standard metric for measuring the decarbonization efforts of beef producers.

- **Carbon emissions Intensity** = tons of CO2-equivalent emissions[9] generated per ton of fresh weight (tCO2/t fresh wt).

Beef producers vary extensively by size and growth capacity. As a result, comparing companies by absolute emissions would yield a distorted view of performance and progress, with bigger or faster-growing companies being disproportionately penalized (for emissions generated) or rewarded (for emissions reduced). Carbon intensity normalizes the comparison process by considering reductions as a function of size, making it easier to compare companies' performance.

Moreover, only Scope 3 emissions, which result from activities in their supply chains, are considered. These account for over 97% of a beef processor's overall emissions. Therefore, reducing these are mission critical for beef producers to have any chance of successfully hitting FLAG targets.

Data sources

In general, Scope 3 data can be obtained from a variety of sources including Bloomberg, CDP, Trucost, MSCI and other publicly available datasets. Whereas Scope 1 and 2 are widely disclosed by companies, there is far less transparency in Scope 3 emissions reporting. This is due to often diverse and inconsistent accounting methodologies. For many beef processors (discussed later in our illustrative examples),

[8] According to FLAG, absolute contraction is a method used to calculate absolute emission reduction targets that requires organizations to reduce annual emissions by an amount consistent with underlying mitigation pathways.
[9] Based on SBTi FLAG Commodity guidance, only Scope 3 emissions are considered as they account for nearly all beef production emissions.

"Purchased Goods and Services" is the most relevant category for tracking Scope 3 emissions, as beef producers purchase cattle from livestock farm suppliers. These purchases represent over 95% of a company's GHG emissions.

For our analysis, we used total Scope 3 emission estimates from MSCI and Trucost, as company and CDP reports showed too much variance.

Assumptions applied

Base year: We selected 2019 as a base year for our decarbonization pathways. This is standard practice for Paris-aligned strategies which ensures consistency in measuring climate targets across sectors and industries.

Emission intensity calculations: As previously stated, emission intensity is the prescribed metric for measuring decarbonization performance within the beef processing sector. It is calculated using Scope 3 emissions generated in tons of greenhouse gas emission equivalent, per ton of fresh weight, where fresh weight is defined as the weight of the animal's carcass at the time of slaughter.

According to FLAG guidance, fresh weight accounts for 50% of the animal's live weight. To calculate tons of fresh weight processed in a year from each company, we used the average weight of beef carcasses at slaughter in Brazil. Brazil's average cattle weight is a reasonable reference as it is the largest producer and exporter of beef globally and one of the key suppliers of beef for the companies analyzed by our model. To retrieve total fresh weight for each company, we multiplied the fresh weight average by the company's production capacity (number of heads processed in a year).

Table 2 – Summary of Robeco's SDP model for beef

Emission reduction framework	*SBT FLAG Guidance, Commodity Approach Beef*
Emission Reduction Framework	SBT FLAG Guidance
Pathway Type	Commodity Approach – Beef
Scope	Scope 3
Reduction	24% reduction in tCO_2/ t fresh weight (intensity-based)
Timeframe	2020-2030
Baseline	2019

Source: Robeco, 2023

Robeco's SDP Model

Robeco's SDP model evaluates the current and future capacity of beef producers to reduce emissions, mitigate climate risks and successfully transition to Paris-aligned goals. The model analyzes three major factors – company decarbonization performance, its capital expenditures towards decarbonization solutions as well as its exposure to financially material regulation.

Measuring company performance

The FLAG Guidance for commodities refers to specific company emission reduction pathways and not to an overall industry target. The distinction is important, as companies are not expected to converge to the same emission intensity by 2030, which is the case in other high-emitting sectors. Rather, beef producers are expected to follow a linear year-on-year percent reduction in emissions intensity based on their individual starting and ending points. This is because natural endowments such as high-quality soils, access to water, and higher elevations can make cattle production more efficient in some regions, creating stark regional differences in emission-reduction capacities. As a result, the model takes into account these regional characteristics and may grant additional emission intensity allowances to companies accordingly.

Company decarbonization performance is measured based on the extent of the gap between companies' public emission reduction commitments and the FLAG reduction pathway of 2.4 % year-on-year emission intensity reductions by 2030.

To illustrate how the model works, we screened two beef processors: Marfrig Global Foods – a leader in sustainability practices and a best-in-class holding – and JBS SA, a competitor with less exemplary sustainability credentials.

Marfrig, a sustainability leader

Marfrig Global Foods is a Brazilian processor of beef, pork, lamb and poultry. It also produces frozen vegetables, canned meats, fish, and ready meals. It operates in South America, the United States, Europe and Asia.

As reported in Table 3, Marfrig has set Scope 3 emission reduction targets which have been approved by SBTi and are consistent with 1.5°C Paris Agreement. Its decarbonization strategy for Scope 1 and 2 focuses on increasing efficiency of effluent treatments, switching to biomass rather than fossil fuels, and scaling up renewable energy sources (80% by 2025). For Scope 3, Marfrig plans to increase its low greenhouse gas emission processes using methods such as Crop-Livestock Integration (ILP), Crop-Livestock-Forest Integration (ILPF), and organic production systems.

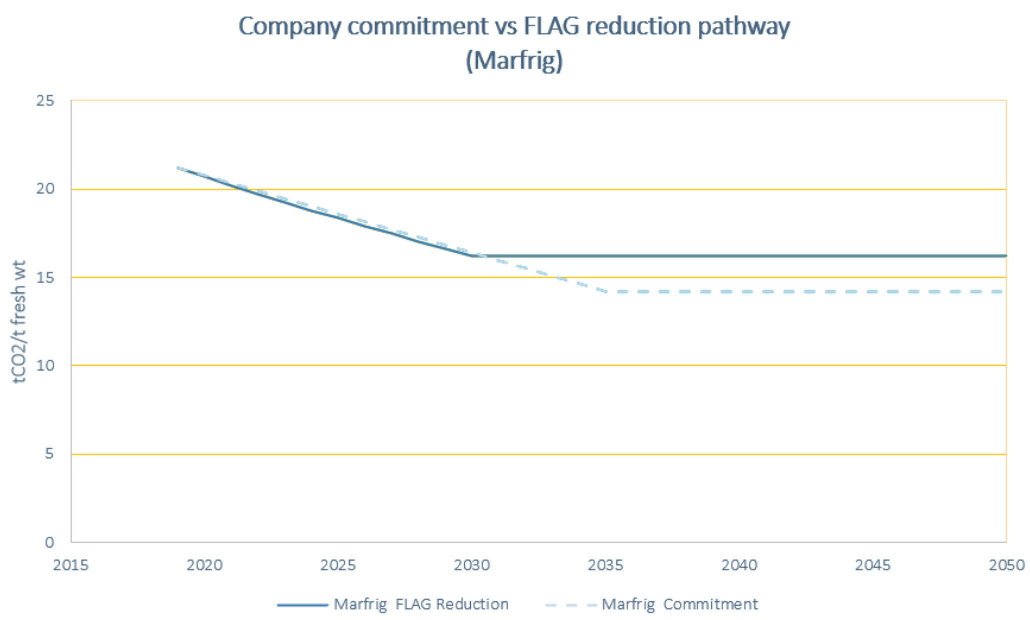
Table 3 – Marfrig's emission reduction targets

Marfrig's emission reduction strategy	*Target 1 (Scope 1 + 2 emissions)*	*Target 2 (Scope 3 emissions)*
Target	68% reduction	33% reduction
Target Scope	Scope 1 + 2 (absolute reductions)	Scope 3 (intensity ratio reductions)
Target Unit	Absolute (tCO_2)	Intensity (tCO_2 / fresh weight)
Target Year	2035	2035
Base Year	2019	2019

Source: Robeco, Marfrig, 2022

When plotted against FLAG's emission reduction pathway (Figure 6), we can see that the company is broadly aligned with a 24% reduction in emission intensity by 2030. It shows only a small gap between what it has committed to reach by 2030 (16.4 tCO2/t fresh wt) and the target recommended by FLAG's emission reduction pathway (16.3 tCO2/t fresh wt). We also note that according to a study of Cederberg et. al[10], average emissions intensities for beef (excluding land-use change emissions) range between 16-27 tCO2e/t fresh wt in Europe, and 28 tCO2e/t fresh wt in Brazil, meaning Marfrig is already signaling its status as a best-in-class beef processors among peers.

Figure 6 – Marfrig's decarbonization commitment vs FLAG reduction pathway



Source: Robeco, 2022

It is, however, important to note that Marfrig has not accounted for emissions linked to land-use change from pasture expansion (as required in FLAG Guidance). This topic will be discussed later in the Limitations section.

Illustrative example of JBS SA, room for sustainable improvement

JBS SA is a Brazilian meat processor, the world's second-largest food company and the largest animal protein producer. It focuses on processing beef, pork, lamb and chicken.

Table 4 – JBS' emission reduction strategy

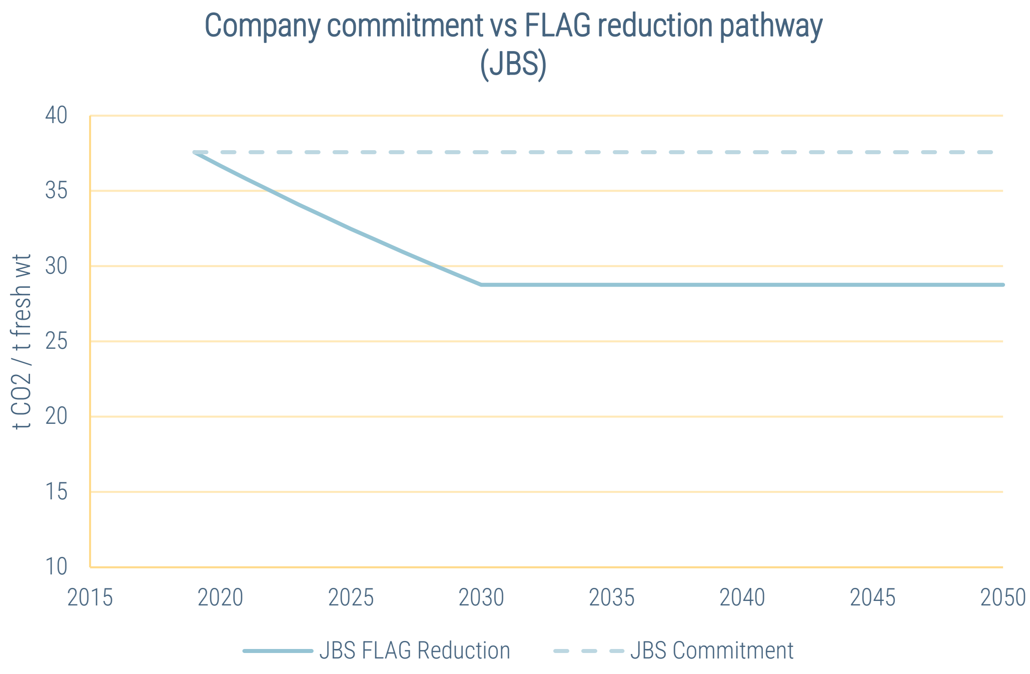
JBS's emission reduction strategy	*Target 1 (Scope 1 + 2 emissions)*	*Target 2 (Scope 3 emissions)*
Target	30% reduction	Net Zero
Target Scope	Scope 1 + 2 (absolute emission reductions)	-
Target unit	Intensity (n.a.)	-
Target Year	2030	2040
Base Year	2019	-

Source: Robeco, JBS 2022

[10] Source : https://pubs.acs.org/doi/10.1021/es103240z

As shown in Table 4 and Figure 7, the company has not set a Scope 3 target. We therefore considered emission reduction by 2030 to be 0%. Its strategy to reduce Scope 1 and 2 emissions focuses broadly on improving energy efficiency, logistics and waste management as well as adopting renewable energy in its operations. Its Scope 3 emissions reduction strategy is lacking, focusing loosely on monitoring and tracking its suppliers to ensure that the supply chain is free of illegal deforestation.

Figure 7 – JBS' decarbonization commitment vs FLAG reduction pathway



Source: Robeco, 2022

When plotted against FLAG's recommended emission reduction pathway of 2.4% intensity reduction per year (Figure 7), JBS's lack of commitment and thus of emission reduction potential is apparent. In addition, the company – even when not accounting for land-use change emissions, shows a carbon footprint well above the average 28 tCO_2 /t fresh wt in Brazil. Although the company has committed to zero illegal deforestation in the Amazon, according to a study from Bloomberg, JBS has doubled its suppliers' base in the area since 2010. We can conclude that the company is far from aligned to SBTi FLAG Guidance and isn't likely to be within the next three years.

Discussion and limitations

We identified several limitations to our analysis, including data availability and company transparency, especially on accounting for deforestation, which complicates efforts to measure company performance. The following are a list of the most salient issues impacting emission pathway forecasting.

Zero-deforestation commitments

Deforestation-related emissions represent 12% of global emissions and 50% of AFOLU emissions.[11] Organizations setting FLAG targets will therefore also be required to publicly submit a "zero deforestation" commitment, with a target to have deforestation-free supply chains by 2025. Since both Marfrig and JBS have a target, they theoretically comply.

However, a major gap is the lack of transparency, particularly over Tier 2 (livestock farms for raising and breeding, and slaughterhouses), which can account for up to 11% of deforestation associated with livestock.[12] Marfrig is better positioned, having tracked and included in its deforestation commitment almost 70% of its Tier 2 supplier base. So far, JBS plans to only cover Tier 1 and direct suppliers, leaving out Tier 2 altogether.

Accounting for land-use change (LUC) emissions

In addition, to comply with FLAG's emission reduction targets and benchmark, companies will be required to account for land-use change emissions, which measures the carbon-stock loss due to land conversion (e.g., biomass and soil carbon losses from deforestation, conversion of coastal wetlands and natural grasslands, burning of peatlands).

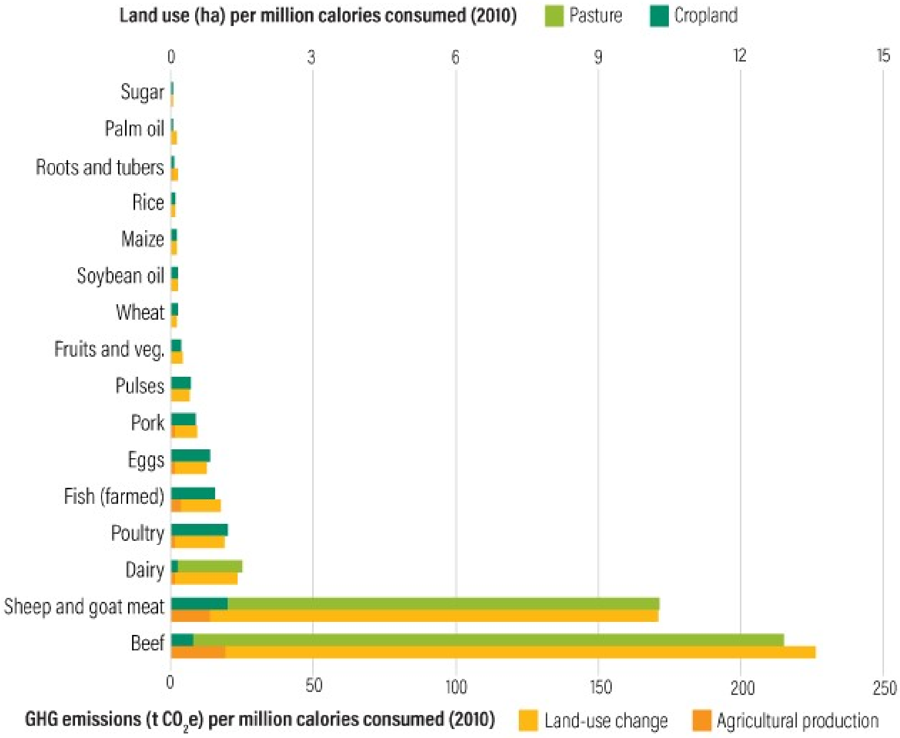
According to the GHG Protocol's Land Sector and Removal Guidance[13], emissions should be measured over a period of 20 years following the land-use change event, using linear discounting. For our SDP model, the main limitation has been the lack of transparency over companies' supply chains, particularly over hectares of land converted across their global operations. Accounting methodologies are currently being developed by consultancy firms such as Quantis and South Pole, so we expect companies to start reporting in the upcoming years.

Despite gaps, we can provide rough estimates for LUC emissions using other data sources. According to the World Resources Institute, LUC emissions can account for over ten times the amount of CO_2 emissions per tonne of protein consumed (see Figure 8). So, we know that deforestation can increase emissions by several orders of magnitude.

FLAG Guidance requires us to convert LUC-emissions based on its carbon intensity metric (tonnes of CO_2-equivalent per ton of fresh weight, tCO2/t fresh wt). A study of Cederberg et. al. estimated the LUC-related carbon footprint of Brazilian beef at 726 ± 252 t CO2e per t of carcass weight, (435 t CO2e per t of fresh weight ± 151) which is 26 times more than the national average carbon footprint without land use change.[14]

[11] AFOLU, Agriculture, Forestry and Other Land Use, Source: https://www.nature.com/articles/s41558-019-0591-9
[12] Tier 2 level refers to indirect suppliers to beef processing companies. Tier 1 refers to direct suppliers. Source: https://www.visipec.com/wp-content/uploads/2020/02/Sumario_Executivo.pdf#page=2
[13] Greenhouse Gas Protocal, https://ghgprotocol.org/land-sector-and-removals-guidance
[14] Source: https://pubs.acs.org/doi/10.1021/es103240z

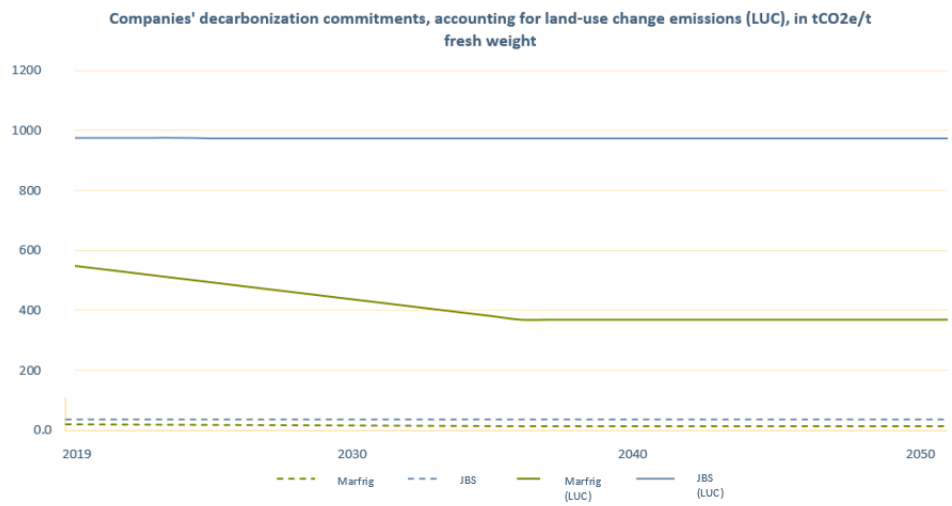
Figure 8 – Land use (ha) per tonne of protein consumed



Source: World Resources Institute, GlobAgri-WRR model

We thus applied the 26 times emission intensity factor to reported company data and targets (Figure 9), as sourced cattle from Marfrig and JBS were mostly in Brazil and Latin America. Although we acknowledge that both companies have global production facilities and that using this order of magnitude (26x) may somewhat overestimate total emission intensity globally, it is still clear that the industry's real emissions are much higher than what is currently being reported.

Figure 9 – Deforestation accounting makes hitting climate targets a lot harder



Solid lines show what Marfrig and JBS' carbon emission intensity pathways (tCO2e/t) would look like if emissions from land use changes (LUC) were included. Though FLAG pathways require the inclusion of LUC emissions, most beef companies are struggling to collect and report data from direct and indirect suppliers, limiting the accuracy of current beef-sector emission pathways.
Source: Robeco, 2023

Missing Scope 3 data and targets

Another challenge to applying this model is that beef processors (including companies screened for this report, but not analyzed) often do not provide Scope 3 emission reduction targets or pathways (e.g., JBS). Moreover, if targets are set, our beef-sector SDP model also considers how companies plan to achieve them. For example, JBS expects to reach its net-zero targets by 2040 largely through carbon offsetting.

The purchase of offsets is, however, not allowed under FLAG Guidance, which stipulates that FLAG targets can only include carbon emission reductions that are carried out on land that is owned or operated by the company. That excludes carbon credits gained from emission reductions in other parts of the world. Our model will downgrade companies that integrate carbon-offsets compared to FLAG-compliant companies that rely on actual reductions in their operations and supply chains.

Increase in beef production

Despite the commitments of the industry, company analysis has shown that production of beef products has significantly increased over the past few years. Marfrig, for example, has seen its production capacity increase by 117% between 2015 and 2020. In order to be able to decarbonize, companies will need to rely on technology levers (discussed in Chapter 4) and increased productivity. This is particularly the case in South America, where cattle ranching is notoriously unproductive – the average stocking density (a measure of productivity based on cattle and resource use) is only one head per hectare when its actual sustainable capacity is three heads per hectare.[15]

In summary

Neither of the two beef processors analyzed in this report are aligned with SBTi FLAG Guidance. This is largely due to lack of data availability and transparency in companies' supply chains, the nascency of carbon measurement in the industry, as well as the continuous increase in production capacities to meet worldwide demand. While we expect companies to update data collection, reporting and decarbonization plans for the coming years, our preliminary assessment of the industry's decarbonization efforts based on companies' target settings, shows that the industry is highly unlikely to reach the SBTi-FLAG targets of a 24% reduction in tCO_2/t fresh wt by 2030.

[15] Source : https://iopscience.iop.org/article/10.1088/1748-9326/ac6f70#erlac6f70bib28

Technology levers

So far we have discussed company decarbonization committments (or the lack thereof) as well as data deficiencies that potentially reduce the credibility of achieving those committments. In this section we discuss the diverse tools companies can use to decarbonize – from both the field (better agricultural methods), the lab (synthetic meats) and even the boardroom (mergers and acquisitions).

Methodology

Beef companies have the following options to decarbonize:

- Increase efficiency – Improved feeding practices or raising more productive cattle can reduce methane and overall greenhouse gas emissions per unit of beef produced.
- Increase soil-carbon sequestration – Permanent grasslands (grass-fed beef) store more carbon overall than croplands (used in feedstock). Proponents advocate that switching from feed-stock concentrate to grass-fed beef systems can help store more carbon.[16]
- Diversify revenues – Transition away from traditional beef production towards lower carbon or no-carbon protein sources. This can mean investments in chicken and other types of meat, "imitation meat" made entirely from plant ingredients or into creating foods that cater to vegetarian tastes including tofu, quinoa and legumes. This can also mean more R&D into lab-grown meat from animal cell cultures.
- Complete re-engineering – This would entail overhauling the business model to focus on other food categories.

Technologies used to implement the above options can be separated into two categories:

- Technologies for efficiency – These technologies are specifically focused on making farming and livestock more efficient and productive. As demand for beef increases, absolute emissions will only rise. To reduce their carbon intensity measures, beef producers must find ways to use less resources and get more fresh weight out of every unit of carbon emitted.

  They can be animal- or land-based. Animal-based measures include precision feeding optimized by weight, age, sex and growth stage or mixing additives, such as algal compounds or tannins, to feed to inhibit methane production in digestive tracts. Land-based include replacing diesel-powered farming machinery with electric-powered ones as well as using precision farming equipment to reduce inputs (e.g., water, fertilizers, electricity) as well as the use of regenerative agriculture techniques.

- Technologies for transition – These technologies are focused on finding other ways of decarbonizing operations outside of farming. They include diversification into lower-carbon protein sources such as beans, legumes, chicken, pork or seafood. It also includes lab-based technologies such as imitation meat made using plant-based ingredients processed to look and taste like real meat. Cultivating real meat using cell cultures instead of cows in pastures, though costly at present, is also a promising strain of research and investments for companies looking to lower emissions in the field.

[16] Critics to this option assert that grasslands don't provide as much nutrition as concentrated feed stocks and therefore reduce productivity ratios per head of cattle and hectare. They also assert that it would take more land to grass feed cattle, leading to additional deforestation. In addition, grass-fed cattle may produce more methane gas, which would offset gains from reductions in carbon gas.

Table 5 – Overview of metrics used to evaluate the impact of technology levers on companies

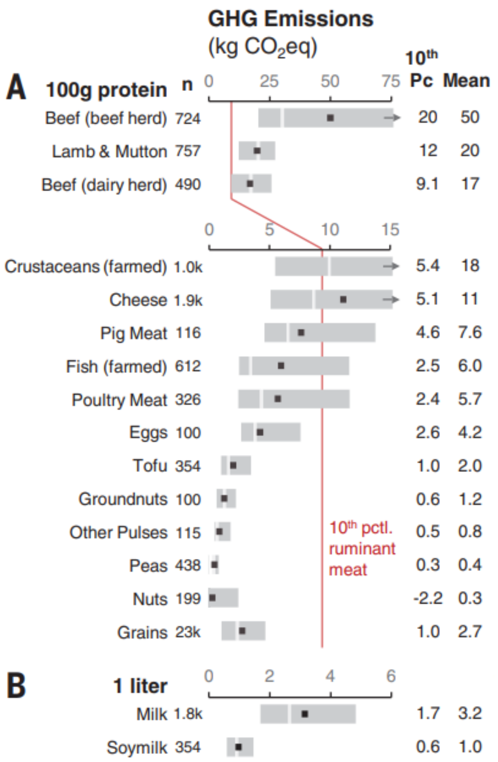
🔵 Selected quantitative metrics 🟠 Tentative, assessed if data is available ⚪ Selected qualitative metrics

Metric		*Description/ rationale*	*Data source*	*Data availability*	*Scoring approach/comments*	*Efficiency technology*	*Transition technology*
Financial metrics							
Overall % of EBITDA from plant-based protein	🔵	Captures business model transition	Company reports	Very low	Measure of business model transition.		x
% revenue from plant-based protein		Top-line contribution from clean businesses	Company reports, FAIRR	Low	Metric provides some insight into clean business exposure		x
Capital expenditures: % low-carbon investment	🔵	Ratio green/brown investments	Company reports	Low	Measure of how companies are investing to improve efficiency. Studies suggest that up to 50% emissions in the beef sector can be reduced by efficiency improvements alone Also a measure of transition if investments are directed at alternative products e.g., plant-based protein, cell-based meat	x	x
Capital expenditures: % low-carbon investment target 2025	🟠	Ratio green/brown investments	Company reports	Low	Measure of how companies are investing to improve efficiency	x	x
% of R&D on low carbon and efficiency improvements		Captures R&D focus on clean energy businesses compared to conventional businesses	Company reports	Very low	R&D investments in efficiency improvements or transition technologies	x	x
Breakeven price USD/tonne of meat		Captures price needed for cash neutrality	Company reports	Very low	Measure to assess profitability; can be used for current or newly invested projects	x	
Technology							
Alternative protein projects	⚪	List of technologies and project stage: R&D, pilot demonstration, small scale commercial, large scale commercial	Company reports	Good		x	x
Patent analysis		Captures company technology R&D and know-how	MSCI CVaR	Good		x	x
Acquisitions and divestments		Changes in stakes in different projects	Company reports	Good	Shows company expansion or exit plans from technologies/resources (both green and brown)		x

Efficiency technologies

Greenhouse gas emissions of beef production are highly variable (Figure 10). There can be more than ten-fold differences in carbon footprint, dependent on the farm – from less than 15 kg per 100 g protein for beef from mixed beef/dairy productions systems to significantly over 100 kg per 100 g protein for less efficient beef production systems.

Figure 10 - The range of greenhouse gas (GHG) emissions of various food sources

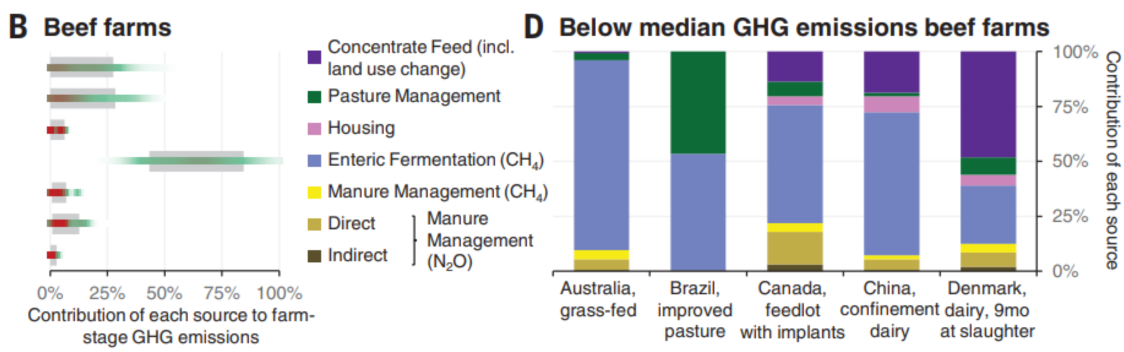


Source: Poore and Nemecek, Nature, 2019

A study based on a sample of over 700 farms from different world regions identified enteric fermentation as the main source responsible for the variation, followed by feeding practices and pasture management.

Figure 11 shows examples of farming systems around the globe that produced less greenhouse gas emissions than the median. They employed various practices to improve efficiency including grass-fed beef, improved pasture or shorter time to slaughter periods.

Figure 11 – Enteric fermentation the major source of GHG emissions in beef farming



Contribution of each source of emissions to the greenhouse gas footprints of beef farms. Regional examples of below median GHG emission farm types.

Source: Poore and Nemecek, Science, 2019

Feeding practices

As seen in Figure 11, the great majority of both greenhouse gas emissions and their variability comes from enteric fermentation. This can be reduced through the optimization of animal feeding practices. In low- and middle-income countries where agriculture tends to be the most inefficient, there is considerable potential to optimize the cow yield using feed conservation. Feed conservation practices include the addition of high-quality forages to diets and concentrate feeding combined with crop yield improvements. Combining these methods can reduce greenhouse gas footprints by 50% in traditional systems and more than 30% in modern ones.[17]

Moreover, the success of feed additives in reducing methane production from ruminant digestive systems has made it an area of intensive research. One such strain of additive showing promising results is macroalgae (seaweed). Recent studies suggest that natural compounds found in certain seaweed species (e.g., halogenated compounds, phlorotannins) have the potential to mitigate methane emissions in vitro by as much as 90% depending on the animal species.[18] Table 6 presents an overview of available techniques and practices to reduce methane emissions from cattle.

Table 6 –Improving efficiency and reducing methane emissions through feed management

Practice/technology	Potential CH_4 mitigating effect[1]	Long-term effect established	Environmentally safe or safe to the animal
Feed additives			
Nitrate	High	No?	NK
Ionophores	Low	No?	Yes?
Plant bioactive compounds			
Tannins (condensed)	Low	No?	Yes
Dietary lipids	Medium	No?	Yes
Manipulation of rumen	Low	No	Yes?
Concentrate inclusion in ration	Low to Medium	Yes	Yes
Forage quality and management	Low to Medium	Yes	Yes
Grazing management	Low	Yes	Yes
Feed processing	Low	Yes	Yes
Macro-supplementation (when deficient)	Medium	Yes	Yes
Micro-supplementation (when deficient)	NA	No	Yes
Breeding for straw quality	Low	Yes	Yes
Precision-feeding and feed analyses	Low to Medium	Ye	Yes

[1] High = ≥ 30 percent mitigating effect; Medium = 10 to 30 percent mitigating effect; Low = ≤ 10 percent mitigating effect. Mitigating effects refer to percentage change over a "standard practice", i.e. study control that was used for comparison and based on a combination of study data and judgement by the authors of this document.
NK = Unknown.
NA = Not applicable.
? = Uncertainty due to limited research, variable results or lack of/insufficient data on persistence of the effect.

Source: FAO, 2013[19]

[17] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7893068/
[18] https://www.sciencedirect.com/science/article/pii/S2405654521001815#fig2

[19] FAO. 2013. "Tackling climate change through livestock: A Global Assessment of Emissions and Mitigation Opportunities."

Manure management

Following feed optimization, manure management presents the second biggest carbon mitigation tool for beef producers. Manure generates methane as well as nitrous oxide (N_2O) emissions. Methane emissions from manure can be controlled by shortening storage duration, ensuring aerobic conditions or capturing the biogas emitted in anaerobic conditions. However, direct and indirect N_2O emissions are much more difficult to prevent once nitrogen (the "N" in N_2O) is excreted. Techniques that prevent emissions during initial stages of management preserve nitrogen in manure that is often emitted at later stages (e.g., following application of manure of biogas digestate to the fields). Thus, effective mitigation of nitrogen losses in one form (e.g., ammonia, NH_3) is often offset by N losses in other forms (e.g., nitrous oxide, N_2O or nitrate, NO_3). Table 7 presents an overview of various manure handling strategies and their potential in mitigating greenhouse gas emissions.

Table 7 – An evaluation of options to reduce greenhouse gas emissions of manure storage

Practice/technology	Species[1]	Potential CH_4 mitigating effect[2]	Potential N_2O mitigating effect[2]	Potential NH_3 mitigating effect[2]
Dietary manipulation and nutrient balance				
Reduced dietary protein	AS	?	Medium	High
High fibre diets	SW	Low	High	NK
Grazing management	AR	NK	High?	NK
Housing				
Biofiltration	AS	Low?	NK	High
Manure system	DC, BC, SW	High	NK	High
Manure treatment				
Anaerobic digestion	DC, BC, SW	High	High	Increase?
Solids separation	DC, BC	High	Low	NK
Aeration	DC, BC	High	Increase?	NK
Manure acidification	DC, BC, SW	High	?	High
Manure storage				
Decreased storage time	DC, BC, SW	High	High	High
Storage cover with straw	DC, BC, SW	High	Increase?	High
Natural or induced crust	DC, BC	High	Increase?	High
Aeration during liquid manure storage	DC, BC, SW	Medium to High	Increase?	NK
Composting	DC, BC, SW	High	NK	Increase
Litter stacking	PO	Medium	NA	NK
Storage temperature	DC, BC	High	NK	High
Sealed storage with flare	DC, BC, SW	High	High	NK
Manure application				
Manure injection vs surface application	DC, BC, SW	No Effect to Increase?	No Effect to Increase	High
Timing of application	AS	Low	High	High
Soil cover, cover cropping	AS	NK	No Effect to High	Increase?
Soil nutrient balance	AS	NA	High	High
Nitrification inhibitor applied to manure or after urine deposition in pastures	DC, BC, SH	NA	High	NA
Urease inhibitor applied with or before urine	DC,BC, SH	NA	Medium?	High

[1] DC = dairy cattle; BC = beef cattle (cattle include *Bos taurus* and *Bos indicus*); SH = sheep; GO = goats; AR = all ruminants; SW = swine; PO = poultry; AS = all species.

[2] High = ≥ 30 percent mitigating effect; Medium = 10 to 30 percent mitigating effect; Low = ≤ 10 percent mitigating effect. Mitigating effects refer to percentage change over a "standard practice", i.e. study control that was used for comparison and based on combination of study data and judgement by the authors of this document.

NK = Unknown.

NA = Not applicable.

? = Uncertainty due to limited research, variable results or lack of/insufficient data on persistency of the effect.

Source: FAO, 2014

Animal husbandry

Improving productivity throughout the animal lifetime also leads to reduced greenhouse gas emissions per mass of beef produced. This can be achieved through breeding more productive animal varieties or overall improvements to animal health and reduced mortality. Table 8 presents an overview of options.

Table 8 – Techniques and practices for mitigating greenhouse gas emissions of beef through animal husbandry

Practice/technology	Species[1]	Effect on productivity	Potential CH_4 mitigating effect[2]	Potential N_2O mitigating effect[2]
Animal management				
Genetic selection (Residual feed intake)	DC, BC, SW?	None	Low?	NK
Animal health	AS	Increase	Low?	Low?
Reduced animal mortality	AS	Increase	Low?	Low?
Optimization of age at slaughter	AS	None	Medium	Medium
Reproductive management				
Mating strategies	AR, SW	High to medium	High to medium	
Improved productive life	AR, SW	Medium	Medium	
Enhanced fecundity	SW, SH, GO	High to medium	High to medium	
Periparturient care/health	DC AR, SW	Medium	Medium	
Reduction of stress	AR, SW	High to medium	High to medium	
Assisted reproductive technologies	AR, SW	High to medium	High to medium	

[1] DC = dairy cattle; BC = beef cattle (cattle include *Bos taurus* and *Bos indicus*); SH = sheep; GO = goats; AR = all ruminants; SW = swine; PO = poultry; AS = all species.
[2] High = ≥ 30 percent mitigating effect; Medium = 10 to 30 percent mitigating effect; Low = ≤ 10 percent mitigating effect. Mitigating effects refer to percentage change over a "standard practice", i.e. study control that was used for comparison and based on combinations of study data and judgement by the authors of this document.
NK = Unknown.
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Source: FAO, 2014

Carbon sequestration

The potential for agriculture to sequester carbon in the soil and therefore contribute to mitigating climate change is frequently discussed. Adding organic matter to the soil (e.g., manure) increases its organic carbon content, therefore sequestering carbon from the air in the soil. These types of practices that restore carbon and other aspects of soil health are grouped under the umbrella term "regenerative agriculture". However, it is debated within the scientific community whether the soil carbon sequestration is as effective as advocates assert.

To truly reduce carbon levels in the atmosphere, carbon needs to be sequestered from the air and retained in the soil for at least 100 years – the common horizon for assessing Global Warming Potential (GWP). There are some field experiments that demonstrated increased soil carbon content in fields with increased application of organic matter (generally organic farming) versus control fields where less organic matter is applied, but the validity of these studies has been questioned.[20]

A number of studies have shown that topsoil that is left undisturbed, such as in untilled permanent grasslands and croplands, sequesters more carbon. But these studies were short-term. Long-term studies showed no difference when the entire soil profile is taken into account. Opponents of soil sequestration techniques argue that over the longer soil cycle, carbon simply travels from lower to upper levels of the soil. This means there is no sequestration from the air, which is where it counts for solving the climate challenge.[21] Going further, even under the best-case scenario – that of a permanent meadow – carbon capture is small and this is largely offset by enteric methane emissions of cows grazing on it.

20 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3357676/
21 https://www.sciencedirect.com/science/article/abs/pii/S0167880906001617

Moreover, even if grasslands were found to be effective at sequestering carbon, reductions would be further neutralized by productivity losses as well as emission increases later in the production chain. Life Cycle Assessment (LCA) studies comparing grass vs concentrate-fed beef usually show higher greenhouse gas footprints of grass-fed beef, even including carbon sequestration benefits.[22]

Grassfed cows develop at slower rates compared to cows that are fed nutrient-packed concentrates. That means more resources invested and more emissions via gas per head over the herd's lifetime.

Transition technologies

External research studies looking at the greenhouse gas impacts of diets conclude that a combination of production as well as consumption changes will be necessary to address the food system's negative impact on the environment. Some companies have started to invest in R&D and roll out alternative products that will help them to diversify business activities away from beef. Research from Bloomberg Intelligence suggests the plant-based market could reach a value of USD 162 billion by 2030 – a 451% increase from its 2020 valuation of USD 29.4 billion.

Plant-based proteins

Protein-rich meat alternatives produced from plants are one potential solution for reducing the negative impacts of human diets on the climate. They are typically made of legumes such as soy, pea, chickpea or lentils that are blended with oils and additives and then subjected to heat and pressure (a process known as extrusion) to replicate the taste and texture of meat. There are also companies that use industrial biotechnology to synthetically produce the molecule's that govern meat's characteristics. Examples are Beyond Meat (private) which

Efficiency Technologies – carbon-neutral beef

The Brazilian government's agricultural research organization (EMBRAPA) has developed a new system of beef production referred to as "Carbon Neutral Brazilian Beef".[1]

In this system, fast-growing Australian eucalyptus trees are planted in pastures, producing wood and providing shade for the cattle. When wood is used as a construction material, this locks up the carbon that the tree has taken up from the air during its growth, thus providing carbon sequestration benefits. As the grass competes with eucalyptus for light, it allegedly intensifies photosynthesis and provides grasses that are richer in nitrogen, which then enhances protein production in cows.

EMBRAPA researchers claim that this shortens the beef production cycle, reducing methane emissions over the animal's lifetime, therefore reducing carbon footprint per kg of meat. The EMBRAPA report was published in 2017 but has not been audited or approved according to ISO 14040 standards for conducting LCA studies.

Even without the ISO label, several independent studies appear to confirm the eucalyptus system results. A study from 2020 estimates the carbon sequestration potential of eucalyptus plantations at 9.62 to 11.4 t C ha^{-1} y-r,[1] in line with EMBRAPA's carbon absorption figures (35-42 t CO_2). In a more recent study, researchers found that Brazilian cows raised on pastures release methane that is equivalent to 7 to 29.25 t CO_2-eq.[1] The density of eucalyptus trees in agroforestry systems with cows will be lower than in plantations, but these numbers mean that there is potential for these systems to be at last partially effective.

The effectiveness of the system relies on the assumption that wood is used as construction material and that it locks up carbon for sufficiently long periods (at least 100 years). If the wood is burned or cut and composted before that, the carbon would be released and all climate mitigation benefits would be lost. Methane, on the other hand, is a short-lived greenhouse gas whose heating effect only lasts around 10 years. Most construction projects survive much longer than that, which mean they should offset beef emissions.

Methane's Global Warming Potential (GWP) is most intense over a 20-year period, rather than the 100-year interval used for assessing the effectiveness of carbon reduction technologies. But methane's GWP is also 20-30 times higher than that of CO2, such that its impact could be nearly equivalent if normalized over a 100-year period.

The viability of carbon neutral beef as an effective carbon combatting application still needs to be confirmed, but the evidence so far shows it's got potential.

[22] https://www.oxfordmartin.ox.ac.uk/downloads/reports/fcrn_gnc_report.pdf

produces HEME – a precursor of hemoglobin in blood that lends meat its distinct taste. Perfect Dairy (private) uses synthetic biology to produce dairy proteins such as casein and whey.

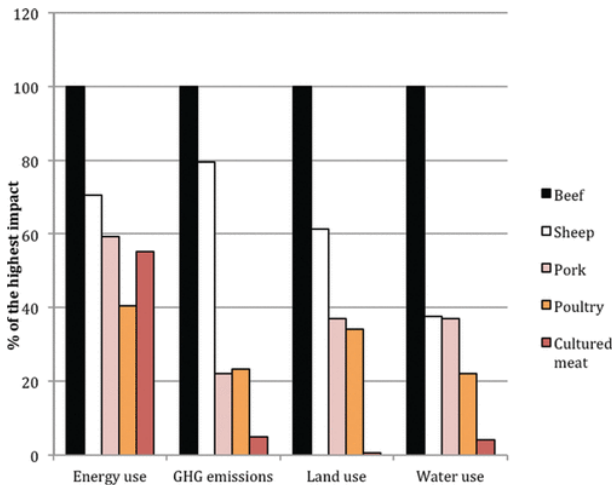
Plant-based protein products typically contain flavors and colorants to improve product appeal. It is highly competitive with numerous startups entering the space. They join Big Food's already formidable incumbents which are racing to expand offerings and meat companies that wish to transition away from meat and dairy.

Cell-based meat

Muscle tissues can be grown in a controlled environment from stem cells similar to the way replacement organs are produced for transplantation. This approach delivers the same physical properties of meat products without harming animals. An LCA study from 2011 demonstrated that cell-based meat can have significantly lower greenhouse gas footprints compared to traditional meat (Figure 12). Though production costs are still high, they have dropped significantly in the past decade. In 2020, Singapore approved the world's first cultured meat products for human consumption. One year later, a restaurant made headlines offering cultured chicken meat for USD 15.

Despite the optimism found in some sell-side research reports and the media, cultured meat's progress has been slow. Significant bottlenecks still need to be solved. For one, critical serums needed for cultivation are harvested from dead animals – making it unacceptable for vegetarians. Two, "in vitro" cell cultures grown in the lab require the same biological hormones and growth factors that govern "in vivo" cell growth inside the body. At present, these cannot be cost-efficiently manufactured at industrial scale. Moreover, most industrial biotechnology processes consume significant amounts of energy to maintain optimal temperatures for organism growth over extended periods of time.

Figure 12 – Life Cycle Assessment of cultured meat compared to traditional meat



Source: Tuomisto et. Al, 2011

Investments from companies

An analysis of a company's capital expenditures provides a unique lens into its future growth and development strategy. We would therefore expect that companies that have pledged to reduce future emissions and set reduction targets to have capex investments in carbon-reducing technologies as well as R&D to help discover new solutions. In the absence of capex, pledges lose their credibility and cast doubt on companies' commitment and ability to reach carbon targets and successfully transition according to the timeline in the Paris Agreement. Below, we summarize our initial findings into Marfrig and JBS's capex and R&D outlays into both efficiency and transition technologies. It is clear that both companies recognize the need to use resources more efficiently as well as to diversify away from high-carbon, cattle-bred beef products. Still, both companies lack a well-coordinated, well-financed and well-disclosed strategy that directly links carbon reduction targets with technology investments.

Marfrig's investments towards decarbonization technologies

Despite ambitious targets, Marfrig has not disclosed quantified estimates of capex or R&D investments to decarbonize. We do however have evidence that Marfrig has commercialized the Carbon Neutral Brazilian Beef system (see insert box, "Efficiency technology – carbon neutral beef"). It is selling products from these systems under the Viva! Brand. This is a promising development that most likely reduces emissions, but there is no disclosure at the moment over sales volumes, costs of production, or expansion plans. Moreover, the actual carbon footprint of the system is also unclear.

In general, greater resource efficiency is a priority for Marfrig. According to its 2021 report, Marfrig invested BRL 23 million[23] in water efficiency projects in slaughterhouses (although the greenhouse gas impact of this investment is expected to be minor).

Diversifying into alternative meat products is also a tool used by Marfrig. In 2020, the company entered into the alternative-protein space with the launch of the "Revolution Burger" – a new brand for burgers made from plant-based ingredients. Also in 2020, Marfrig partnered with US-food behemoth, Archer Daniels Midland (ADM) to create the joint venture PlantPlus Foods which will co-produce and market foodstuffs based on vegetable protein. Again, it is difficult to make a prognosis of the potential of these new business activities, given there are no disclosures over the share of revenues coming from plant-based ingredients.

Decarbonizing through acquisitions

In addition to investments to organically grow new business lines, Marfrig has also begun to diversify its protein sources through acquisitions. In June 2021, Marfrig completed its gradual build-up of a 32% stake (at an estimated cost of approximately USD 1 billion) in the Brazilian chicken and pork producer BRF SA.

In January 2022, PlantPlus Foods LLC bought Sol Cuisine – a Canadian processor of tofu as well as fresh and frozen plant-based meat alternatives – and DEW Drink Eat Well – a US-based manufacturer of meat-free burger and sausage substitutes which it markets under the "Hilary's" brand. The acquisitions cost around USD 125 million, of which USD 88 million can be attributed to Marfrig given its 70% ownership share in PlantPlus Foods.

JBS's investments towards decarbonization

In its 2021 sustainability report, JBS disclosed that it will invest USD 1 billion through 2030 to decarbonize operations and that it will allocate USD 100 million specifically focused on decarbonization research and development projects. It also committed to submit a detailed SBTi roadmap by the end of 2023. In terms of actual decarbonization efforts, the 2021 report mentions that they invest in feed additives and feed efficiency and carbon fixation in the soil, however, cost figures are not disclosed.

JBS reported investing BLR 110 million in water efficiency and wastewater treatment projects. While important for lowering their environmental footprint and increasing resource efficiency, they are not material for assessing its decarbonization strategy. There are currently no disclosures of investments in efficiency technologies to reduce cattle emissions.

[23] The Brazilian real (s.), reais (pl.)

Decarbonizing through acquisitions

2021 was also the year JBS went on a shopping spree buying up sources of alternative plant and animal protein. On June 17, 2021, JBS completed its acquisition of Vivera, the third largest plant-based food producer in Europe, at a cost of USD 406 million. On November 17, 2021, it acquired HUON, an Australian salmon aquaculture company at a cost of USD 302 million and on the same day entered into an agreement to acquire BioTech Foods, a major player in the development of biotechnology to cultivate protein. JBS will invest approximately USD 100 million in the construction of a new plant in Spain (BioTech's headquarters) to increase production and in the implementation of an R&D center in Brazil focused on biotechnology and cultivated protein.

Table 9 – Financial commitments to decarbonize and acquisitions

USD	*MARFRIG*	*JBS*
R&D commitment for decarbonization	No disclosures	100 million by 2030
CAPEX commitment	No disclosures	1 billion by 2030
REVENUE (for comparison)	19.33 billion	70.22 billion
2021 ACQUISITIONS (costs):		
- Protein diversification (chicken, pork, fish)	1 billion	302 million
- Alternative protein	88 million	500 million
MARKET CAP (for comparison)	1.24 billion	10.57 billion

Source: Robeco, 2022

Policies

In this section we give an overview of current and planned emissions regulations in major markets worldwide and their likely impact on agriculture and food industries.

Regulators are using carbon pricing schemes as a stick to curb emissions in other high-emission industries, and of all carbon credit markets globally, the EU is one of the most stringent. But according to many experts, even Europe's carbon price averages are still below what's needed to incentivize companies to accelerate their net-zero trajectories.[24]

Thus far, food producers have been given an easy ride by regulators. European Union and United States are the most advanced economies when it comes to carbon pricing but even here, the food sector has largely managed to escape inclusion in current and planned emission cap-and-trade schemes as well as the stringent regulations on methane and carbon dioxide. This is unlikely to change in the near term as food prices are often used as a political tool, especially in emerging markets where consumers spend a considerable amount of their income on food.

High food prices have been linked to a number of turbulent conflicts throughout history, from the French revolution to the Arab Spring. Most governments wish to avoid the fallout that would inevitably arise from tax hikes on food products. On the contrary, policymakers typically use various protectionist mechanisms to keep them under control, including state subsidies, value-added tax waivers or stocking reserves when prices are low.

New Zealand

The one exception is New Zealand which has adopted a harder line than most despite local opposition. It was the first country in the world to announce direct taxation of agricultural emissions. The system, which proposes a tax on methane emissions is expected to take effect by 2025.[25] The revenues will be reinvested into the agricultural sector through payments to farmers as well as in investments into new technology and research. The proposal is currently under consultation and has met with significant backlash by the nation's farmers.

European Union

European authorities recognize that agriculture's current and planned emission reduction measures are insufficient for aligning the EU's agriculture sector with the 1.5-degree scenario.[26] Currently, agricultural emissions are loosely monitored by two organizations.

Non-CO_2 greenhouse gas emissions (e.g., methane and nitrous oxide) from agriculture are covered by the European Effort Sharing Regulation (ESR), which provides national annual emissions targets for buildings, agriculture, waste, small industry, and transportation members.

Moreover, management of agricultural emissions is only partially included in the Common Agricultural Policy and Nitrates Directive through requirements over the handling of fertilizers and manure. More importantly, agriculture is not including in the EU's ETS, its flagship cap-and-trade scheme for reducing the bloc's greenhouse gas emissions.

24 IMF, Finance and Development, A ath to net zero, September 2021.
25 For comparison the US levy for methane leaks targeting the energy sector will rise to USD 1500 per metric ton of methane.
26 https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-agriculture

Based on recent national projections, only a modest EU-level decline of 2% is expected by 2030 compared with 2005 levels. Additional measures are planned but would only result in a 6% reduction, highlighting the need for further action.

Europe's agricultural policy over the last decade has focused on improving efficiency and reducing the resource intensity of farming (lowering inputs and production volumes), causing it to favor low-input farming systems, organic farming and local production.

We believe, the EU regulator's focus on these carbon-reduction measures is overly optimistic and will be ineffective at bringing down the sector's emissions at the speeds needed. Given the deficiency gap, we expect discussions and possibly stricter policy measures targeting greenhouse gas in food and agriculture to follow. However, we think it unlikely that Europe will go as far as New Zealand and enact a carbon tax on farming in the next three to five years.

Conclusion

We anticipate that as net zero targets grow closer and the political climate changes, regulatory action on the food and agri-related sectors will grow more stringent. Moreover, as temperature and extreme weather intensify, agriculture will be among the sectors most acutely impacted, prompting companies themselves to take action. As a result, we will continue to monitor the regulatory outlook and incorporate the monetary impact of stricter policies into the Beef's SDP assessment model.

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