TECHNICAL NOTE

CRITICAL EVALUATION OF THE METHODOLOGY ADOPTED IN THE IATP (*Institute for Agriculture and Trade Policy*) STUDY TO ESTIMATE JBS' GHG EMISSIONS

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1 BACKGROUND

On April 21, 2022, the organizations *Institute for Agriculture and Trade Policy* (IATP)[1], DeSmog[2] and Feedback[3] published a media briefing[4] entitled: "*World's largest meat company, JBS, increases emissions by 51% in five years despite 2040 net zero climate target, continues to greenwash its huge climate footprint*" saying that JBS increased its annual greenhouse gas (GHG) emissions by 51% between 2016 and 2021. The disclosure was based on emissions estimates calculated from the *Global Livestock Environmental Assessment Model* (GLEAM)[5] methodology that were provided in the 2018[6] and 2021[7] *Emissions Impossible* reports.

For these reasons, WayCarbon was hired to investigate and critically evaluate the methodological approach and assumptions adopted by IATP in the calculations made for the estimate of JBS' GHG emissions. Therefore, this document aims to provide the results of this critical evaluation, thereby setting up a technical note that shows the quality IATP's methodology and assumptions. The main conclusions of this report are presented below, and later the issues analyzed will be detailed by section.

2 SUMMARY OF RESULTS

This section presents the main results of the IATP study evaluation subdivided into the most relevant themes, including: **i.** Generalist approach; **ii.** Estimation of the number of animals slaughtered; **iii.** Emissions from enteric fermentation; **iv.** Emissions from Land Use Change (LUC); and **v.** Analytical boundaries.

1. **Generalist approach**: To calculate the intensity of emissions in the production of 1 kilogram of animal carcass, an approach based on the GLEAM methodology was adopted, based on assumptions estimated at global and macro-regional levels according to FAOSTAT database[8] dated 2010. These assumptions, such as the average weight of animals, age at slaughter, carcass yield rate, dry matter in animal feed, land use changes, among others, were used to characterize the herd and production systems, and make up the calculation of factors used in estimating JBS operation's emissions. In this sense, we can see that specific data and own to the JBS operation were not used. For example, the data for the average weight of cattle at the age of slaughter for the operation in Brazil is 6% lower in the IATP analysis, considering a less efficient production system compared to the JBS' reality.

[1] https://www.iatp.org/
[2] https://www.desmog.com/
[3] https://feedbackglobal.org/
[4] https://www.iatp.org/media-brief-jbs-increases-emissions-51-percent
[5] https://www.fao.org/gleam/model-description/en/
[6] https://www.iatp.org/emissions-impossible
[7] https://www.iatp.org/emissions-impossible-series
[8] https://www.fao.org/faostat/en/

2. **Estimation of the number of animals slaughtered**: Given the unavailability of primary data from the JBS operation, IATP adopted assumptions to estimate the production volume, based on JBS' installed capacity utilization rates found in public documents. In the study, the utilization rates adopted varied between the years under analysis, from 62% in 2016 to 97% in 2021, resulting in an increase in production volume for cattle estimated at 54%. The difference in the adopted assumptions is directly associated with the increase in animal production and consequently influence the 51% increase in GHG emissions referred in the study. We can see that if the actual number of animals slaughtered were used, by applying the IATP study methodology, the result of JBS's emissions would show a reduction of 3%, comparing the year 2016 with 2021.

3. **Emissions from enteric fermentation**: Emissions of similar categories were compared and it was found that the calculation of GHG emissions performed by JBS Brazil, using the IPCC methodology and the emission factors of the fourth national notice generate a result, per head of cattle, 25% lower than the results taken in the IATP study, considering the GLEAM methodology.

4. **Emissions from land use change (LUC)**: JBS' emissions associated with the climate impact of land use change in its value chain have not yet been published and such emissions provided for in the IATP study represent, approximately, 30% of emissions in the animal production stage. When comparing the IATP data with average data of emissions by LUC in the expansion of grazing land in Brazil, calculated according to the BRLUC tool[9], made available by the Brazilian Agricultural Research Corporation (Embrapa) and based on the same assumptions adopted by the IATP for the carrying capacity of grazing land of 3.88 animal-unit.ha^{-1}, we see that the study emissions are approximately 7 times higher than those found with the simulation made in the BRLUC tool.

5. **Boundary of analysis**: The boundary of the IATP study is different when compared to the boundary of the JBS inventory. In 2016, the company's inventory did not yet consider the main emission sources of its value chain. In 2021, JBS's inventory was updated to partially include these emission sources. Emissions from the management of waste from livestock raised on third-party farms account for less than 5% of total emissions and by the cut-off criterion were not included in the JBS inventory. Additionally, the impact on emissions was considered only from animal husbandry inputs that comprise more than 95% of the volume, such as soybeans. As mentioned above, emissions by LUC are not yet included in the inventory and, differently from the IATP study, the climate impact associated with the production of capital goods, estimated from the use of indirect energy in the manufacture and maintenance of machinery, tools, equipment, and buildings, were also not considered in the JBS inventory.

6. **GWP_{100} Factors**: The values of the 100-year Global Warming Potential (GWP_{100}) factors were also different between the IATP study and the JBS emissions inventory. The IATP adopts GWP_{100} factors reported in the AR5 (*Fifth Assessment Report*)[10] within an approach that

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[9] https://www.cnpma.embrapa.br/forms/BRLUC.php
[10] https://www.ipcc.ch/report/ar5/syr/

includes carbon feedback, while in the JBS GHG emissions inventory the GWP_{100} reported in the AR5 without carbon feedback were considered. From the different methodological choices, a difference of 22% was found for GWP_{100} for methane (CH_4) and 9% for nitrous oxide (N_2O).

3 TECHNICAL ANALYSIS

In this section the quality of the methodology adopted in the study will be evaluated and compared with the JBS emissions calculation approach, to highlight the main differences and discuss the ability to support the arguments presented in the briefing. The section includes a discussion of the assumptions and methods.

3.1 GENERALIST APPROACH

The emissions presented by the IATP were calculated from the model developed by the *Food and Agriculture Organization of the United Nations* (FAO) called the *Global Livestock Environmental Assessment Model* (GLEAM)[11], with a robust theoretical framework, based on processes and structured within the logic of Life Cycle Assessment (LCA). LCA is a method defined in the ISO 14040[12] and 14044[13][14] standards and is widely accepted to assess the environmental impact of products, considering a holistic assessment of production processes regarding the use of resources.

When evaluating the input information used in the study, it appears that these were based on broad assumptions and generalist data, and no specific data were used for the reality of the JBS operation. To characterize the animal production systems, the IATP was based on assumptions estimated at global and macro-regional levels, according to the FAOSTAT[15] database, dated 2010. Consequently, results were generated that reflect the order of magnitude of emissions associated with the average regional characteristics of agricultural and livestock production in 2010 that may be different from the specific situation of JBS in the years 2016 and 2021

The annual production volume was the only data used by IATP related to information found in public documents of JBS. The estimate of the number of animals slaughtered was based on the maximum installed capacity of the JBS operation, adjusted by a utilization rate and proportionally divided among the three production regions: Latin America, North America and Oceania. The other factors used were obtained from the GLEAM database, such as the data for the characterization of the slaughter herd in terms of structure, age, weight and carcass conversion rate, information related to the production and type of feed, and the production system models.

[11] https://www.fao.org/gleam/en/

[12] ISO (2006a). Environmental management—life cycle assessment: principles and framework. ISO14040, Geneva.

[13] ISO (2006b). Environmental management—life cycle assessment: requirements and guidelines. ISO14044, Geneva.

[14] https://www.iso.org

[15] https://www.fao.org/faostat/en/#home

For example, the average weight of cattle at slaughter age in the JBS operation in Brazil in 2021 was approximately 6% higher than the weight adopted in the study' calculations, according to information reported by JBS. This difference in weight in the calculations contributes to the overestimation of emissions per animal. By using the same emission factors for a smaller mass of meat produced, a less efficient production system is simulated compared to the real one. This same logic can be extrapolated to the carcass yield rate and age at slaughter of the animal.

The IATP study also did not consider changes in production conditions between 2016 and 2021. The emission estimates were based on the assumption that JBS operates exactly like the average of all producers in Latin America, North America, and Oceania in 2010. However, given the unavailability of public information and inaccessibility to primary data on JBS operation, the IATP used the standard GLEAM model database based on regional averages in its calculations. Here, there is an opportunity to increase the accuracy of the input data used in the study. The average data for Latin America can be replaced by updated information, considering the Brazilian reality, based on public documents from nationally recognized research institutions, to adapt the country's animal production conditions differently from the rest of the continent.

The intensity of GHG emissions, obtained in the study, to produce 1 kg of beef carcass will be compared with the emission factor available in a recognized database, to show the impact of using data characteristic of Brazilian livestock. Ecoinvent[16] is internationally recognized as an important database for life cycle assessment and includes specific data for livestock production in Brazil, updated in 2020 by the Brazilian Agricultural Research Corporation (EMBRAPA)[17]. The emission factor generated from GLEAM for Brazil was 67.65 kg CO_2eq/kg carcass, a value 37% higher than that obtained using the Ecoinvent database and performing the analysis in *OpenLCA*[18] software *(the Open Source Life Cycle and Sustainability Assessment software)* which resulted in a carbon footprint of 49.35 kg CO_2eq/kg carcass. The Ecoinvent 3.8 process used was *market for cattle for slaughtering, live weight | cattle for slaughtering, live weight | Cutoff, U - BR*, adapted for a carcass yield of 51.67%, as proposed by IATP, considers enteric fermentation, manure management, feed production, production and use of inputs and fertilizers, field operations, energy in animal production, transportation and land use change, and like the GLEAM model, within an LCA approach.

3.2 ESTIMATION OF THE NUMBER OF ANIMALS SLAUGHTERED

IATP reports in its publication that "*...the number of animals in the JBS supply chain over the past five years substantially increased: cattle numbers increased by 54%, pigs by 67%, and chickens by 40%, resulting in a huge increase in emissions.*" This section aims to discuss the method to calculate the percentages given in this statement.

In view of the unavailability of data on the annual production volume of JBS, IATP adopted assumptions of utilization rates of the installed slaughtering capacity reported by the company in public documents.

[16]https://ecoinvent.org/
[17]https://www.embrapa.br/en/busca-de-projetos/-/projeto/214336/inventarios-de-ciclo-de-vida-de-produtos-agricolas-brasileiros-uma-contribuicao-ao-banco-de-dados-ecoinvent
[18]https://www.openlca.org

In 2016, the production volume used for the emissions estimates presented in the *Emissions Impossible* report (Grain & IATP, 2018)[19] was adapted, considering the utilization rate of 62% of the installed capacity for cattle slaughter of 76,950 head per day, reported in the public document "*JBS DAY New York 4Q13 and 2013 Results*[20]". For 2021, the estimate of the number of cattle slaughtered considered 97% of the installed slaughter capacity of 76,150 cattle per day, published in the document *JBS (2022) Institutional Presentation including 4Q21 and 2021 Results*[21].

As reported in the study, the 97% utilization rate refers to a conservative approach in which the number of days of the year referring to national holidays in 2021 was excluded, considering all other days as productive days. The 62% rate for the year 2016 was not made explicit in the study. Therefore, these 62% were calculated for this evaluation by relating the installed capacity of 76,950 animals per day, assumed from the numbers shown in the JBS documents consulted by IATP, with the production volume of 47,672[22] animals per day that was used for the calculation of emissions shown in the *briefing*.

When comparing the installed capacities, we observe that they varied little between the years, resulting in a reduction in the order of 1% from 2016 to 2021. However, the study suggests a growth in the volume of cattle slaughtered in the order of 54%. The assumed increase in the number of animals slaughtered from 2016 to 2021 is directly related to the 51% increase in emissions mentioned in the *briefing*.

Even in the absence of primary data from JBS, is recommended the use of specific data on the rate of utilization of installed capacity for animal production in Brazil that can be found in the Quarterly Animal Slaughter Survey available on the website of the Brazilian Institute of Geography and Statistics (IBGE)[23], enabling the definition of precise average assumptions for the Brazilian reality.

When comparing the input data used by IATP and the actual data from the JBS operation we can see that for the year 2016 there was assertiveness in the production estimates with variations in production volume in the order of 1% for cattle, 3% for pigs and -8% for poultry, between the actual data and those used in the study. However, when comparing the data for 2021, for all categories the amount of animals slaughtered used by the IATP were overestimated regarding the real data from JBS, by 30% on average, consequently resulting in higher emissions than the real one. Once the same assumption is maintained for the utilization rate between the years, a variation in emissions directly associated with differences between the volume of animals slaughtered would not be verified. To show the impact caused by using different assumptions between the years, in a percentage variation evaluation, a data sensitivity analysis was performed. In this analysis, the same utilization rate of 62%

[19] IATP & GRAIN (2018). How big meat and dairy are heating up the planet. Kansas, July, 2018, 28 p. Available: www.iatp.org/emissions-impossible-series.

[20] JBS (2014). Day New York, 4Q13 and 2013 Results Presentation. 25 March 2014. Available: http://jbss.infoinvest.com.br/enu/2892/JBSDayNY_4Q13_eng.pdf.

[21] https://api.mziq.com/mzfilemanager/v2/d/043a77e1-0127-4502-bc5b-21427b991b22/89617df2-cf31-77d8-d102-c2dee83873fb?origin=1

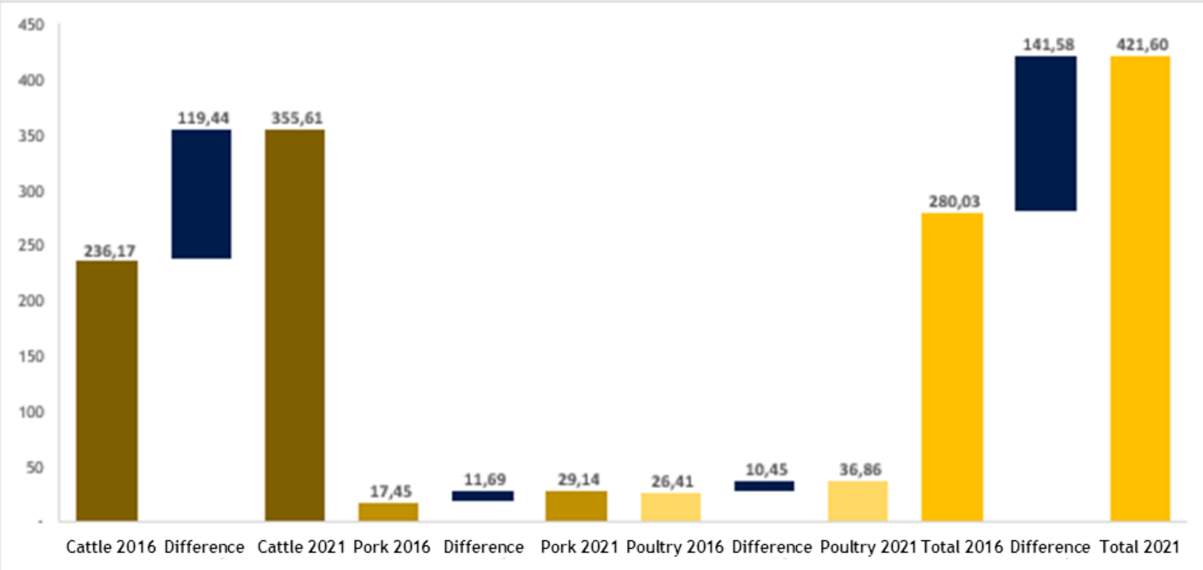
[22] https://docs.google.com/spreadsheets/d/13G4bWV7kL3hiSjkWA5q1_qWCiRJKCuxb/edit#gid=1089782244

[23] https://sidra.ibge.gov.br/home/abate/brasil

of the installed capacity of JBS, used in 2016, was adopted for 2021, fixing all other data of the emissions estimate.

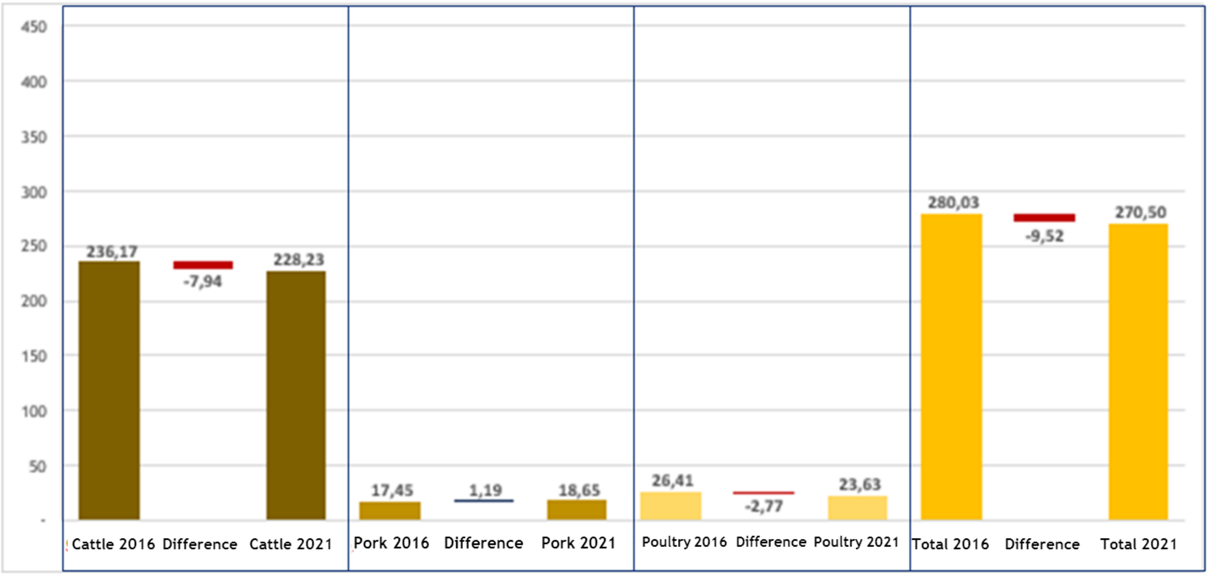
The Chart 1 stands for the percentage variations between 2016 and 2021 in the original form submitted by the IATP, in which the increase of 51% in emissions between the years can be observed, directly proportional to the increase data in the volume of animals slaughtered of 53%. The Chart 2 stands for the results of the sensitivity analysis in which the utilization rates were equalized for both years, and a reduction of 3.4% in emissions from 2016 to 2021 is observed. This means that, by adopting the same assumption for both years, a reduction in emissions is observed between 2016 and 2021 and not an increase, as stated in the article.

Chart 1. GHG emissions in t CO_2eq per year considering 62% of capacity utilization rate in 2016 and 97% in 2021, according to the IATP publication.



Source: Prepared by WayCarbon from information published by IATP (IATP, 2022).

Chart 2. GHG emissions in t CO_2eq per year considering 62% of capacity utilization rate in 2016 and 62% in 2021.



Source: Prepared by WayCarbon from information published by IATP (IATP, 2022)[24][25].

It is worth mentioning that this analysis is a hypothesis and due to the non-specificity of the input data found, we cannot affirm that the reduction seen in the paired methodologies scenario is real. Due to the use of non-specific data and assumptions the emission results may show variations higher or lower than the real ones, depending on the assumption adopted.

3.3 EMISSIONS FROM ENTERIC FERMENTATION

Emissions from enteric fermentation are directly related to the animal's type of feed and life cycle. In this sense, the quality of the feed has a major impact on enteric emissions of ruminants and can therefore vary between different production systems. This fact is related to methane production being directly proportional to dry matter intake, regardless of the amount of energy that the animal can extract from food. Given the great variability of production systems and consequently of animal nutrition, the methodological approach adopted by IATP uses global values for energy and nitrogen content and grass digestibility, thus, these are not very specific data considering JBS' reality.

JBS' emissions are calculated based on particular characteristics of the production system and the herd that supplies its operation. This primary data is related to the emission factors defined in the Fourth National Inventory of Emissions and Anthropic Removals of Greenhouse Gases (MCTI, 2020)[26] that includes the factors segmented according to sex, age, and specific factors of the macro-region where

[24] IATP (2022a). World's largest meat company, JBS, increases emissions by 51% in five years despite 2040 net zero climate target, continues to greenwash its huge climate footprint. Media briefing, 21 april 2022. 12 p. Available: https://www.iatp.org/media-brief-jbs-increases-emissions-51-percent.
[25] IATP (2022b) Datasheet: JBS Calculation based on EI 2018 methodology 7 April 2022, 2022.
[26] MCTI (2020a) Fourth national inventory of anthropogenic greenhouse gas emissions and removals, Reference Report - Agricultural Sector/Enteric Fermentation subsector.

the animals are raised. Additionally, the average weight of the animals was estimated based on the carcass production in each state of the country and applied a carcass yield of 52% to 48% for pasture-raised steers and cows and 54 to 50% for confined cattle (SCOT, 2022)[27]. The digestibility rate used in the calculation of GHG emissions of JBS in Brazil was based on 200 studies in national literature, which consider the year and the amount of dry matter in the feed. Thus, we can see that the company used specific data from the production systems and the herd that supplies its production for the calculation of emissions by enteric fermentation.

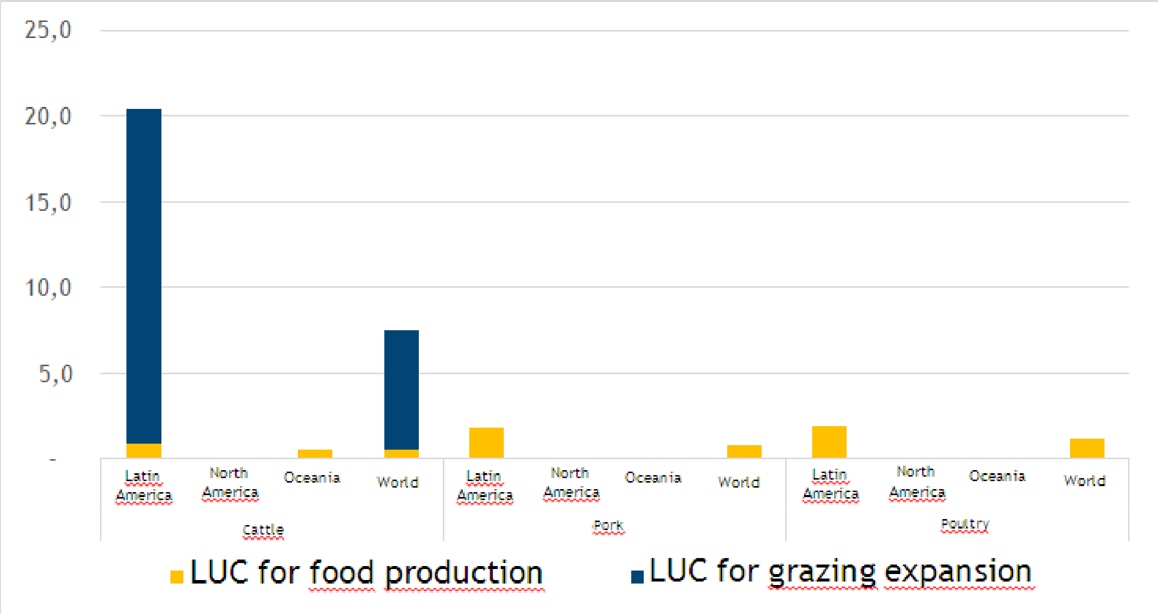
In a conservative approach, considering the highest annual enteric emission factor defined in the Brazilian national inventory (MCTI, 2020) for adult cattle grazing, 1,600 kgCO_2eq/animal, and the average life to slaughter of 3.56 years (JBS, 2022)[28], we have an emission of 5,698 kgCO_2eq/animal, which corresponds to approximately 25% of the emissions of the animal production stage of JBS in Brazil. In contrast, the emissions adopted by IATP for enteric fermentation of cattle production in Latin America result in 7,603.00 kgCO_2eq/animal, when multiplying the intensity of enteric emissions for the production of 1 kg of carcass, obtained from GLEAM, by the average weight of the animal at the age of slaughter and the percentage of carcass yield, adopted in the study. This value amounts to more than 45% of the emission factor for the production of one kilogram of carcass. Therefore, a 25% lower value is observed for enteric fermentation emissions calculated by JBS based on specific data, when compared to emissions estimated by IATP based on generalist data.

3.4 EMISSIONS FROM LAND USE CHANGE

In GLEAM two land use change (LUC) scenarios are considered, the first refers to the conversion of forested areas to arable land for crops and the second is represented by the transition from forested areas to pasture. The emissions used in the model were based on the standard values for LUC available in the PAS 2050 standard, quantified according to the IPCC Tier I guidelines, referring to transitions that occurred between 1990 and 2010 (FAO, 2018)[29]. Food crop expansion is limited to soybean and palm oil production. This cut-off results from the observation of trends in land use transitions and crop expansions in the period 1990-2010, used as the reference period in GLEAM for the analysis of land use change. In a breakdown of the LUC emission factor calculated by GLEAM we have the following profile, according to Chart 3 below.

[27] SCOT (2014). Carcass yield in slaughterhouses in Brazil. Available at: www.scotconsultoria.com.br/noticias/artigos/37616/rendimento-de-carcaca-emfrigorificos-do-brasil-.htm. Accessed on: May 17, 2022.
[28] JBS, 2022. GHG emissions inventory base year 2021.
[29] FAO (2018). Global Livestock Environmental Assessment Model: Version 2.0, Model Description - Revision 5, data reference year: 2010. Food and Agriculture Organization, Rome, July, 2018, 109 p. Available: http://www.fao.org/fileadmin/user_upload/gleam/docs/GLEAM_2.0_Model_description.pdf.

Chart 3. GHG emissions by LUC in kgCO_2eq/kg carcass with reference to land use conversions that occurred between 1990 and 2010 according to GLEAM and the IATP study.



Source: Prepared by us from information published by IATP (IATP, 2022).

To exemplify the impact of the use of regionalized assumptions in the estimation of emissions by LUC, we will discuss below part of the numbers in a cutout for the expansion of pasture in Brazil, according to the IATP study. This approach was structured by considering the activity and the region where the impact by LUC was the most relevant in the estimates made, thus, the expansion of pastures for cattle raising in Brazil.

The land use change (LUC) emissions by pasture expansion in Brazil calculated from GLEAM, result in 6,684.44 kg of CO_2eq per animal, considering the average live weight of 466.24 kg (IATP, 2021) for cattle, which represents approximately 30% of emissions per animal unit produced. According to the data found in the PAS 2050 standard the emissions of LUC in Brazil by pasture expansion were 26 tCO_2eq.ha^{-1}.year^{-1} between 1990 and 2010, indicating that a stocking rate of 3.88 animal units per hectare was adopted when dividing 26,000 kgCO_2eq/ha by 6,684.44 kgCO_2eq/animal.

In the absence of public primary data on LUC emissions by the JBS operation, average data for Brazil available from Embrapa were used to suggest LUC emissions closer to the JBS reality. The BRLUC (Novaes et al., 2017)[30] is a tool developed at Embrapa and currently considered the most updated and accurate public database for estimating emissions by LUC per Brazilian Federative Unit.

In a simulation using the BRLUC tool[31], it was found an average emission of 3.36 tCO_2eq.ha^{-1}.year^{-1} for the expansion of pasture areas throughout the Brazilian territory, an annual emission rate by LUC due to pasture expansion 7.73 times lower than that indicated in GLEAM's description of 26 tCO_2eq.ha^{-1}.year^{-1}. Considering the same stocking rate of 3.88 animal-units per hectare, apparently adopted by

[30] Novaes RML, et al (2017) Estimating 20-year land use change and derived CO2 emissions associated to crops, pasture, and forestry in Brazil and each of its 27 states. Global Change Biology, 23(9), 3716-3728, doi.org/10.1111/gcb.13708
[31] https://www.cnpma.embrapa.br/forms/BRLUC.php

GLEAM, with a cycle of 3.56 years, according to JBS information, emissions by LUC would account for 14% of animal production emissions, and no longer 30%, resulting in emissions by LUC on the order of 3,082.89 kgCO_2eq/animal, thus proving the influence of the assumptions adopted in the analysis result.

3.5 BOUNDARIES OF ANALYSIS:

The estimates made by IATP followed the logic of Life Cycle Analysis, while the GHG emissions reported by JBS are calculated based on the methodology of corporate emissions inventory according to the GHG Protocol[32]. Such methodological differences demand specific delineations of analysis boundaries to achieve similar results.

LCA is suitable for accounting for GHG emissions from the entire life cycle of a product, good or service, from the extraction of raw materials and manufacturing to its use and final disposal, resulting in emissions per functional unit (e.g.: kg of product). The GLEAM model covers the entire livestock production chain, from feed production to the arrival of the product at the point of sale. The product system boundary is defined as "from cradle to market of processed animal products" and only emissions that occur in the consumption of the product are excluded from the analysis. Thus, life cycle GHG emissions associated with the functional unit 1 kg of processed beef, pork or poultry carcass were estimated to represent the JBS operation worldwide within a year. The emissions disclosed by IATP were calculated from the company's annual production estimate.

The organizational GHG emissions inventory is indicated to account for the GHG emissions of all the activities of an organization within a given period for the evaluation, and therefore with boundaries that are subdivided into scopes 1, which refers to direct emissions, 2 related to indirect emissions from energy consumption, and 3 that encompasses the indirect emissions of the value chain. Usually, the inventories are prepared on an annual basis, considering the emissions generated by the company from January 1 to December 31. In the case of JBS, the emissions from the life cycle of the animals (enteric fermentation, waste management, food production, animal and food transportation, etc.) are allocated to the year of slaughter, resembling the life cycle approach used by the GLEAM methodology. The boundaries of the systems responsible for generating GHG emissions are quite similar, with some differences between the emission sources as found and presented in the Table 1 below.

[32] https://ghgprotocol.org/

Table 1. Emission sources inserted in the boundary of analysis of the GHG emissions calculation performed by IATP and for the JBS inventory.

Key: X emission source considered; **–** emission source disregarded; **Scope 1** direct emissions considered; **Scope 2** indirect emissions from electricity consumption considered; and **Scope 3** indirect emissions from the value chain considered.

Emission sources (according to the GLEAM methodology)EMISSION FACTORS	IATP		JBS	
	2016	2021	2016	2021
Enteric fermentation.	X	X	Scope 1	Scope 1 Scope 3
Field operations: fuel consumption in machinery and equipment for livestock, planting and harvesting.	X	X	Scope 1	Scope 1 Scope 3
Animal feed: production and use of fertilizers and pesticides, grain and palm oil production, and feed production.	X	X	–	Scope 3
Land Use Change for pasture and cropland expansion for animal feed.	X	X	–	–
Manure management.	X	X	Scope 1	Scope 1 Scope 3
Direct energy use in livestock production.	X	X	Scope 2	Scope 2 Scope 3
Indirect energy use* in livestock production: emissions associated with energy demand in the manufacture and maintenance of capital goods including machinery, tools, equipment and buildings.	X	X	–	–
Transport in animal production.	X	X	–	Scope 3
Post-farming processes: Processing of livestock products and coproducts, including emissions from slaughter, coproduct processing, and packaging.	X	X	Scope 1 Scope 2	Scope 1 Scope 2 Scope 3
Post-farming processes: Transportation of products to the point of sale.	X	X	Scope 1	Scope 1 Scope 3

Source: Prepared by WayCarbon from internal JBS data and information published by IATP (IATP, 2022).

**Indirect energy use refers to emissions associated with the manufacture and maintenance of capital goods including machinery, tools, equipment and buildings.*

From the information shown in the table above, we can see that from 2016 to 2021, JBS began to account for indirect emissions from enteric fermentation, livestock inputs, direct energy use in livestock raising, processing of co-products, and transportation of livestock production and products. We can also see that the analysis boundary of the IATP study includes emission sources not yet published by JBS, such as indirect energy use in livestock raising, which refers to the climate impact for the production of capital goods, and land use change.

Notably, according to the *datasheet*[33] made available by IATP, the LUC emissions in Latin America account for, 30% of emissions for cattle production or 57,894.70 tCO_2eq in 2021, mainly related to the expansion of pastures, 26% for pork or 1,452.09 tCO_2eq in 2021 and 41% for poultry or 5,584.42 tCO_2eq in 2021, related to the conversion of native vegetation for the production of animal feed.

In the Table 2 the emissions calculated by IATP in 2016 and 2021 are presented and the emissions reported by JBS in these same years to support the discussion related to the impact of the analysis boundary in the calculation of emissions. Noteworthy is the geographical boundary that limits the data source that will be shown below: the total emissions calculated by JBS for 2016 comprises scopes 1 and 2 for the global operation of JBS and for 2021, includes scopes 1 and 2 for the global operation of JBS and scope 3 for the units in Brazil, since the data for the rest of the world are not yet available for all categories. IATP data considers the "cradle to point of sale" boundary, which is equivalent to the reporting of scopes 1, 2 and 3 for the JBS Global operation.

Table 2. Annual GHG emissions calculated for the company's operation in tCO_2eq.

Year	IATP	JBS	Variation (%) JBS x IATP
2016	280,025,751	8.527.288[1]	-97%
2021	421,602,035	64.142.312[2]	-85%

[1] Within scope 3, Category 1 (purchase of goods and services) and Land Use Change (LUC) were not considered.
[2] Within Scope 3, emissions from Category 1 (purchase of goods and services) were considered for Brazil and Land Use Change (LUC) was not considered.

The increase in emissions reported by JBS between 2016 and 2021 is related to the boundary of the inventory analysis and is due to the fact that emissions from animal production were only accounted for in 2021. Of the 64,142,311.87 tCO_2eq emitted by the company's operation in 2021, 53,725,897 tCO_2eq refer to emissions from livestock production for the operation in Brazil, i.e., 83% of the total. When comparing the IATP emissions with those reported by JBS, we can see that the main differences are related to the considered production volume, the assumptions, the methodological approach and the analysis boundary.

In both studies, some similar emission categories were also considered, allowing the comparison between the results of the climate impact of animal production that supplies JBS in Brazil. The percentage results were calculated by comparing the emissions data consolidated by IATP and available in the published *datasheet*, with internal data from JBS. From the analysis of these variations, we can see that the emission sources from livestock farming were overestimated by the study, reaching values up to 8 times higher compared to the JBS data, e.g. for nitrous oxide emissions in the management of pork manure.

[33] https://docs.google.com/spreadsheets/d/13G4bWV7kL3hiSjkWA5q1_qWCiRJKCuxb/edit#gid=1089782244

Table 3. Variation of emissions estimated by the IATP study compared to the JBS calculation for Brazil, by type of emission source and animal category.

Emission source	Animal category	Variation of emissions (IATP x JBS)
Enteric fermentation	Cattle	53%
	Pork	49%
Manure management CH_4	Pork	16%
	Poultry	58%
Manure management N_2O	Pork	84%
	Poultry	41%

Source: Prepared by WayCarbon based on information published by IATP (IATP, 2022) and data from the JBS GHG emissions inventory 2021.

It is worth mentioning that emissions from the management of manure from Brazilian livestock raised on third-party farms were not considered in the JBS inventory, since they account for less than 5% of total emissions. Additionally, the impact on emissions was considered only from animal husbandry inputs that comprise more than 95% of the volume. The emissions associated with indirect energy use, which were calculated by the IATP and are not considered by JBS, are not separated in the results of the study. However, if all emissions by direct and indirect energy demand are considered, they account for 0.6% of the emissions in cattle raising, 4% in pork raising and 10% in poultry raising.

3.6 GLOBAL WARMING POTENTIAL FACTORS

The 100-year Global Warming Potential (GWP_{100}) equivalence factors adopted in the IATP study were higher when compared to those used by JBS inventories and those more recently published by the IPCC (*Intergovernmental Panel on Climate Change*) in Chapter 7 of the AR-6 (*Chapter 7, Sixth Assessment Report*) (IPCC, 2021)[34] as can be seen in Table 4.

[34] IPCC (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, 2021, 204 p. Available: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07_Supplementary_Material.pdf.

Table 4. Global Warming Potential 100-year factors (GWP_{100}) adopted in each approach.

GHG	JBS AR5 IPCC (2014) without carbon feedback	IATP AR5 IPCC (2014) with carbon feedback	AR6 IPCC (2021)	Variation (%)	
				JBS X IATP	AR6 X IATP
CO_2	1	1	1	0%	0%
CH_4	28	34	27.9	21%	22%
N_2O	265	298	273	12%	9%

The GWP_{100} factors used in the study, of 34 for methane (CH_4) and 298 for nitrous oxide (N_2O), were respectively 21% and 12% higher than the values used in the GHG emissions inventories calculated by JBS. The use of higher GWP_{100} values generates high emission factors that consequently result in overestimated absolute emissions. The GWP_{100} factors with climate-carbon feedback, adopted in the IATP study, consider the indirect effects of changes in carbon storage due to climate change. Despite being a more conservative approach that results in higher factors, according to IPCC (2013)[35] these factors have a higher level of uncertainty and are therefore used with low frequency in GHG emission studies and inventories. However, in the study the same GWP_{100} was used for 2016 and 2021, so there was no influence of this factor for the increase in emissions reported between the years evaluated by the IATP.

IATP states in its media briefing that JBS' emissions in 2021 are larger than Italy's climate footprint in the same year. The country's emissions data was extracted from the *United Nations Framework Convention on Climate Change* (UNFCCC) Transparency Panel[36] and corresponds to robust information. Given the understanding that the choice of the Global Warming Potential in the calculation of GHG emissions is extremely relevant for the results, it was found that Italy's emission inventory adopted a GWP_{100} of 25[37] for CH_4, a value 26% lower than the one used in the IATP study. In any case, methane (CH_4) emissions account for just over 10%[38] of the total inventoried for Italy in 2021.

4 FINAL CONSIDERATIONS

Throughout the critical evaluation of the IATP study it was found that generalist assumptions and data were adopted in view of the unavailability of public primary data from the JBS operation. Emission

[35] IPCC (2013). Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 8: Anthropogenic and Natural Radiative Forcing.
[36]https://di.unfccc.int/time_series
[37]https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/frequently-asked-questions/global-warming-potentials-ipcc-fourth-assessment-report
[38]https://www.isprambiente.gov.it/files2021/pubblicazioni/rapporti/nir2021_italy_14apr_completo.pdf.

factors were calculated according to the IPCC (2006)[39] recommendations and based on characterization data of the herd, production system and land use, according to 2010 FAOSTAT[40] database. At the same time, JBS emissions are calculated based on representative primary data for the corresponding analysis years 2016 and 2021. When comparing this generalist data with the specific data, specific to JBS's reality, it is observed differences that contribute to different GHG emissions results.

Differences were checked in the assumptions adopted by the IATP for the JBS capacity utilization rate used to estimate the amount of animals slaughtered between 2016 and 2021. It was observed that the boundary of analysis of the IATP study differs from the approach adopted for the calculation of emissions performed by JBS. The 100-year Global Warming Potential factors were also distinct between the emissions studies.

The Table 5 was elaborated to conclude the evaluation with a consolidation of the main elements that may contribute to the different results of absolute emissions, and can be checked below.

Table 5. Summary of the main differences in factors and assumptions adopted in the IATP study and in the JBS inventory that influence the GHG emissions results achieved.

Factor	IATP	JBS	Variation
Reference year	Emission factors calculated according to IPCC, 2006 and based on characterization data of the herd and production system according to FAOSTAT database of 2010.	Year of inventory 2016 and 2021.	N/A
Average weight of cattle	466 kg	500 kg	6%
Average age of cattle slaughter	Information unavailable in the study methodology.	3.56 years	N/A
Boundary of analysis	a. Includes emissions from animal production for both years analyzed; b. Includes manure management in livestock production; c. Includes LUC (30% of emissions); d. Includes indirect energy use for production of inputs and capital goods; e. Generalist data.	a. Did not consider Category 1 of Scope 3 in 2016; b. Considers manure management only for animals confined by JBS; c. Does not include LUC; d. Does not include indirect energy use for the production of inputs and capital goods; e. Specific data.	N/A

[39] IPCC (2006), 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, V.4, Chapter 10 – Emissions from livestock and Manure Management.
[40] https://www.fao.org/faostat/en/

Factor	IATP	JBS	Variation
Emissions from enteric fermentation	7,603 kgCO_2eq/animal	5,698 kgCO_2eq/animal	25%
Global Warming Potential 100-year factors (GWP_{100})	CO_2 = 1 CH_4 = 34 N_2O = 298	CO_2 = 1 CH_4 = 28 N_2O = 265	0% 21% 12%

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