Strategies for a sustainable future in the footwear industry in the face of greenhouse gas emissions (GHG)

Estratégias para um futuro sustentável na indústria calçadista diante das emissões de gases de efeito estufa (GEE)

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doi:10.18472/SustDeb.v15n1.2024.52330

Received: 20/01/2024
Accepted: 11/04/2024

ARTICLE – VARIA

ABSTRACT

In spite of the efforts of the footwear and textile industries to understand their greenhouse gas (GHG) emissions and develop reduction strategies, knowledge on the subject is still incipient. Given this scenario, this paper aims to identify, quantify, and present the main sources of GHG in this economic sector, followed by proposing solutions aimed at more efficient management. A qualitative and quantitative study was conducted with four companies in southern Brazil to achieve this purpose. Among the main sources of emissions are fuel and energy consumption. The main reduction alternatives include searching for alternative fuels and considering energy generation through clean sources. It is clear that implementing initiatives aimed at reducing emissions is not a simple task. However, the research highlighted the technical feasibility of new forms of production with a reduced environmental impact.

Keywords: Footwear Industry. Greenhouse Gases. Brazil GHG Protocol Program. Strategy. Sustainable Future.

RESUMO

Apesar dos esforços das indústrias de calçados e têxtil para compreenderem suas emissões de gases de efeito estufa (GEE) e desenvolverem estratégias de redução, o conhecimento sobre o tema ainda é incipiente. Diante desse cenário, o objetivo deste artigo é mapear, quantificar e apresentar as principais fontes de GEE desse setor econômico, seguido pela proposição de soluções visando uma gestão mais eficiente. Para alcançar esse propósito, realizou-se um estudo qualitativo e quantitativo com quatro empresas situadas no Sul do Brasil. Entre as principais fontes de emissões destacam-se o consumo de combustível e energia. As principais alternativas de redução incluem a busca por

combustíveis alternativos e a consideração da geração de energia através de fontes limpas. Percebe-se que a implementação de iniciativas voltadas para a redução de emissões não é uma tarefa simples. No entanto, a pesquisa evidenciou a viabilidade técnica de novas formas de produção com um impacto ambiental reduzido.

Palavras-chave: *Indústria Calçadista. Gases de Efeito Estufa. Programa Brasileiro GHG Protocol. Estratégia. Futuro Sustentável.*

1 INTRODUCTION

Climate change has emerged as one of the greatest challenges faced by humanity in the 21st century. The increase in greenhouse gas (GHG) emissions resulting from human activities contributes significantly to changes in the global climate. The Earth is witnessing unprecedented climate change, evidenced by extreme events such as more intense hurricanes, prolonged droughts, and rising sea levels. These phenomena threaten biodiversity and ecosystems and directly affect global economic and social stability (IPCC, 2023; Lima *et al.*, 2020).

In the period from 2011 to 2020, the global temperature recorded an average increase of 1.1ºC compared to the period from 1850 to 1900, with this increase attributed to GHG emissions. Each year, there is a progressive increase in the emission of these gases (Adedeji *et al.*, 219). In 2018, emissions reached the mark of 48.9 gigatons of carbon dioxide equivalent ($CO_{2\text{-eq}}$), and in 2022, this number reached 50 $GtCO_{2\text{-eq}}$ (Ghimouz *et al.*, 2023; IPCC, 2023).

This outcome is intrinsically linked to the significant growth in energy generation from fossil sources, changes in land use, and the uncontrolled deforestation that occurs in several parts of the world, especially in Brazil. These intensive human activities have played a crucial role in the escalation of climate change, highlighting the pressing need to transition to more sustainable practices and reduce GHG emissions (IPCC, 2023). In response to the urgency of climate change, organisations are increasingly pressured to adopt more sustainable practices and minimise their GHG emissions. Notably, the consumer goods and fashion goods industries, such as the footwear and textile industries, present a linear production mode, representing this sector's dominant paradigm (Ghimouz *et al.*, 2023). In this context, the search for innovative and responsible strategies becomes an environmental necessity and an opportunity for companies to lead the way towards a low-carbon future (Gallego-Alvarez *et al.*, 2015).

In this context, this paper aims to map and quantify GHG emissions from footwear industries located in the southern region of Brazil and then identify possibilities for reducing emissions. Accurate measurement of GHG emissions is essential for understanding and controlling the environmental impact of industrial operations. To achieve the established objective, a multiple case study was conducted involving quantitative and qualitative approaches in four footwear industries located in the mentioned region during the period from August to December 2023. In the qualitative phase, the premise of data triangulation was employed through semi-structured interviews, documentary research and non-participant observation, following the guidelines proposed by Yin (2015).

For the quantitative stage of the research, the methodology of the Brazil GHG Protocol Program (BGHGPP) was used for the meticulous quantification of GHG emissions associated with the operations of the companies involved for subsequent identification of reduction opportunities. According to Caldeira *et al.* (2022), this is Brazil's most widely used methodology, developed by the Getulio Vargas Foundation.

Efforts to curb greenhouse gas (GHG) emissions necessitate an accurate and consistent compilation of GHG emissions inventories across various economic sectors. These inventories serve as crucial

documentation of GHG emissions stemming from diverse economic activities over specific timeframes (Aguiar *et al.*, 2016; Chandrakumar *et al.*, 2019; Ding *et al.*, 2019). The findings derived from these inventories play a pivotal role in informing national policies and strategies related to climate action, underpinned by established methodologies (Abreu *et al.*, 2014; Singh et al., 2014).

It is worth mentioning that, from the total greenhouse gas emissions in 2022 (50 $GtCO_{2-eq}$), approximately 1.7 $GtCO_{2-eq}$ correspond to the contribution of the textile and footwear industry on a global scale, representing 8.5% of the total. Furthermore, it is estimated that this specific industry will emit 2.7 $GtCO_{2-eq}$ in 2030, reflecting a significant increase of 63% from previous levels (Ghimouz *et al.*, 2023).

In this regard, this research seeks to foster the creation of more sustainable and efficient strategies, in line with the dedication to reduce environmental footprints and encourage more responsible practices within the footwear market in the area. The growing desire from consumers for sustainable products is increasingly apparent (Kumar; Carolin, 2020; Pimenta *et al.*, 2023). Furthermore, the numbers presented by Abicalçados (2023) and Pimenta *et al.* (2023) highlight that, in 2022, Brazil produced 840 million pairs of shoes, exporting 143 million to 170 different destinations, responsible for 266,000 formal jobs generated in 5.4 thousand companies all over the country. This significant volume resulting in revenues exceeding R$ 25.2 billion, consolidating the country as the 5th largest footwear producer in the world. This data highlights the importance of the sector for the Brazilian economy, while this study aims to guide the industry to adopt more sustainable practices, contributing to a more responsible and balanced future. For this reason, this paper aims to identify, quantify and present the main sources of GHG in this economic sector, followed by proposing solutions aimed at more efficient management.

2 THEORETICAL FOUNDATION

2.1 CLIMATE CHANGE

Climate change represents one of the greatest contemporary threats to the stability of our planet. Caused primarily by excessive greenhouse gas emissions resulting from human activities such as burning fossil fuels and deforestation, these emissions significantly impact ecosystems, climate, and communities worldwide (IPCC, 2023).

Greenhouse gases are substances present in the atmosphere that have the ability to absorb and re-emit thermal radiation originating from the Earth's surface. This capacity creates an effect similar to what occurs in a greenhouse, allowing part of the solar heat to be retained in the atmosphere and contributing to the planet's warming (IPCC, 2023). Although this natural phenomenon is essential to keep the Earth's temperature at levels suitable for life, human activities have intensified the concentration of some of these gases, worsening the greenhouse effect and causing significant climate change.

The main greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), tropospheric ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) (Serweta *et al.*, 2019). In order to make the impact of these gases on climate change more understandable, the amount emitted by them is quantified by the equivalent of carbon dioxide (CO_{2e}), measured in tons (tCO_{2e}) or kilograms ($kgCO_{2e}$) (BGHGPP, 2023; IPCC, 2023; Serweta *et al.*, 2019). This equivalence makes it possible to compare GHG emissions using a common rating scale. However, it is important to note that different gases contribute to global warming to different degrees, measured through an indicator called "global warming potential", or better known by the acronym GWP (BGHGPP, 2023; IPCC, 2023; Serweta *et al.*, 2019).

According to the IPCC (2023), the value of GHG emissions reached 50 $GtCO_{e-eq}$ in 2022. Within this panorama, the energy sector is linked to 34% of emissions (20 $GtCO_{2-eq}$), followed by industry with 24%

(14 $GtCO_{2-eq}$), Afolu (Agriculture, Forestry and Land Use) with 22% (13 $GtCO_{2-eq}$), transport with 15% (8.7 $GtCO_{2-eq}$) and civil construction with 6% (3. 3 $GtCO_{2-eq}$) (IPCC, 2023). In this context, it is crucial to highlight that the United States and China jointly represent around 40% of total emissions, with energy generation being the main source of GHG emissions in both countries. Both have intensive production and consumption of goods, including manufacturing and industrial processing, directly contributing to GHG emissions (IPCC, 2023).

When specifically analysing data from Brazil, it is observed that the changes in land use and forestry are responsible for 1.1 $GtCO_{2-eq}$, followed by agriculture with 617 megatons of carbon dioxide equivalent ($MtCO_{2-eq}$), energy with 412 megatons of carbon dioxide equivalent ($MtCO_{2-eq}$), waste with 91 $MtCO_{2-eq}$ and industrial processes with 65 $MtCO_{2-eq}$ (Seeg, 2023).

Regardless of the country or sector of activity, the high level of greenhouse gas emissions increases global average temperatures. According to the IPCC (2023) report, the global average surface temperature was approximately 1.1°C higher than the period 1850 to 1900 during the years 2011 to 2020. Furthermore, it is noteworthy that the global average surface temperature has increased more rapidly since 1970 than in any other period in the last 2000 years, at least (IPCC, 2023).

The average increase in temperature results in several global risks for humanity, covering crucial areas such as health, livelihoods, food security, water supply, human security and economic growth. These risks highlight the urgency of effective actions to mitigate climate change and preserve the sustainability of our planet (Adger, 2014; Diffenbaugh; Field, 2013; IPCC, 2023; Rosenzweig; Neofotis, 2013).

2.2 GREENHOUSE GAS EMISSIONS IN BRAZILIAN COMPANIES

Finding studies related to climate change is a simple task to do. In a quick search on Science Direct in December 2023, when entering the keyword “climate change”, more than 850 thousand results are obtained. However, when combining this search with the keyword “footwear industry”, the results decrease to just over one thousand (Science Direct, 2023).

Going deeper into the investigations, it is noted that most studies are focused on quantifying GHG emissions related to specific products throughout their life cycle. For example, a specific footwear category is analysed to evaluate its carbon footprint, from the extraction of raw materials to disposal by the end consumer. This covers the phases of transporting raw materials to the factory, the production process, and the delivery of finished products to consumers.

In two studies conducted in China, Cheah *et al.* (2013) and De Ponte *et al.* (2023) found that most emissions in Chinese industries are concentrated in the footwear production phase, covering energy consumption, the use of fossil fuels and the generation of waste. In a total emission of 14 $kgCO_{2-eq}$ to produce a pair of shoes, 9 $kgCO_{2-eq}$ are associated with the manufacturing stage (Cheah *et al.*, 2013; De Ponte *et al.*, 2023). It is important to note that China predominantly depends on coal as its main energy source, which directly influences this result. The other 5 $kgCO_{2-eq}$ are distributed in raw materials for manufacturing the product, transporting it to the customer, final disposal, and usability. In another study conducted in Europe, similar results were also found by Gajewski *et al.* (2014).

Unlike carbon footprint studies, there are GHG inventories, in which the analysis covers not just one line of products but all those produced by a given company (PBGHG, 2023). In Brazil, it is common to observe companies allocating resources to projects aimed at the comprehensive assessment of their emissions, not limited to a specific product. According to BGHGPP (2023), in 2008, less than 100 companies carried out and made public their GHG inventories, while in 2022, this number reached 434 in Brazil alone.

Still in Brazil, among these companies that release their inventories, 55% are distributed across different sectors, 28% in the manufacturing industry, 10% in the transport, storage and mail sector, 9% in the electricity and gas segments, and 8% in financial activities, insurance and related services. The remaining 45% cover sectors such as professional, scientific, and technical activities; extractive industries; trade and repair of motor vehicles and motorcycles; agriculture, livestock, forestry production, fishing, and aquaculture, among others (BGHGPP, 2023). It is worth mentioning that the BGHGPP (2023) does not provide specific data for the footwear industry.

Regarding the GHG emissions profile of Brazilian organisations, the highlights are emissions from energy consumption, stationary combustion (emissions from burning fuel to produce energy) and industrial processes (emissions from the chemical or physical transformation of any material), as well as fugitive emissions (unintentional release during the production, processing, transmission, storage, or use of the gas). These categories are considered sources owned or controlled directly by the organisation (BGHGPP, 2023).

It is worth mentioning that compared to other electric power systems, the GHG emission factor of the Brazilian electrical grid is notably low. This can be attributed to the composition of the grid, where a significant portion (67.6%) of the energy is generated from hydroelectric sources. Additionally, wind power (8.9%), biomass (8.3%), and other renewable sources contribute to the grid, further reducing its carbon footprint. Non-renewable sources such as oil (2.9%) and gas (7.9%) play a smaller role, with minimal contributions from solar (1.1%) and nuclear (1.2%) energy. This data underscores the relatively clean nature of the Brazilian electrical grid (Caldeira *et al.*, 2022).

Conversely, that is, indirect emissions that occur along the organisation's value chain, categories considered "administrative", such as business travel, waste generated in the organisation's operations, upstream transport, and distribution (emissions from transport and distribution of products purchased) and employee transportation are highlights (BGHGPP, 2023; Caldeira *et al.*, 2022). Measuring emissions without direct control by the organisation presents a more significant challenge. The complexity in measurement arises from the fact that many data are subject to the control of the supply chain and/or intermediate or final consumers of products or services.

On the other hand, Brazilian companies, although they report on a smaller scale, also present records of emissions originating from mobile combustion (resulting from the burning of fuels to generate movement), categories associated with agricultural activities, changes in land use, waste, effluents, and downstream transport (emissions related to the transport and distribution of commercialised products) (BGHGPP, 2023).

3 METHODOLOGY

As mentioned in the introduction of this study, qualitative and quantitative research was conducted to carry out a survey and quantification of greenhouse gas emissions from footwear industries in the southern region of Brazil. A detailed description of each of these steps is presented below.

3.1 QUALITATIVE AND QUANTITATIVE STAGE

In the qualitative stage of this study, which is characterised by the opportunity to carry out interpretations and attributions of meanings, a multiple case study was conducted according to Yin's (2015) guidelines. This method involves data triangulation through semi-structured interviews, non-participant observation and documentary research. This step proved crucial for researchers to obtain in-depth knowledge of the companies involved in the research and to consolidate the process of mapping the sources of greenhouse gas emissions for later requesting data to be used to quantify

emissions. Furthermore, through the semi-structured interview, it was also possible to understand the maturity of the companies in terms of their emissions and what strategies they had already adopted or planned to adopt in the coming years to reduce them.

The four organisations selected to take part in the study were designated as Alpha, Beta, Gamma and Delta companies. The companies agreed to this nomenclature to preserve their identity and guarantee confidentiality. The decision to maintain confidentiality in disclosing the names of the organisations played a fundamental role in obtaining more concrete and truthful answers, following the guidelines of Yin (2015). Both the sector and the footwear industries chosen to be part of the study were chosen non-probabilistically, intentionally and for convenience. Even so, there was concern that they all had similar characteristics that would allow comparison of the data obtained, such as: located in the south of Brazil; large companies; operations in the footwear sector, both nationally and internationally; and having annual revenues exceeding R$ 300 million.

The choice to limit the sample to 4 companies was based on the theoretical saturation criterion, as described by Fontanella *et al.* (2008). The authors considered the information already obtained to date sufficient for the proposed analysis, understanding that including new participants would contribute minimally to the material already collected. All empirical data were subjected to content analysis following the recommendations of Bardin (2011). This entire process lasted 4 months (August-November/ 2023).

In the GHG emissions quantification phase, the emission factors previously established by BGHGPP (2023) were used based on previously specified sources of emissions. From this enumeration, requesting consumption data from organisations was feasible, multiplying the values by the respective emission factors. The calculation process lasted one month, during December 2023.

4 RESULTS

In order to ensure the efficient structuring of the results and discussion phase, it was decided to start the process by providing a succinct characterisation of the companies studied. Subsequently, the sources of emissions associated with these organisations are addressed. Finally, quantitative results are presented, thus outlining possible alternatives for reducing emissions for the companies analysed.

This sequential approach aims to provide a clear and comprehensive understanding of information related to companies' environmental impact, facilitating analysis and discussion.

4.1 CHARACTERISTICS OF COMPANIES

The four companies involved in the research are established in the southern region of Brazil, serving both the national and international markets. The southern region of Brazil is recognised as the birthplace of the footwear industry in the country, standing out for its significant contribution to the development and consolidation of this industrial sector over time.

Alfa operates with two units, Beta operates in three units, while Gama and Delta maintain four units each. These companies are key players in the industry, each contributing uniquely to the sector's dynamics and overall performance. In Table 1, it is possible to check the characteristics of each company.

Table 1 – Characteristics of companies

Categories/Companies	*Number of operation units*	*Employees*	*Millions of pairs/ Year*	*Target audience*
Alfa	2	1.035	2	Infant
Beta	3	2.500	8,5	Women
Gama	4	6.000	18	Women
Delta	4	3.000	9,1	Women

Source: Authors (2023).

All of these companies play a fundamental role in developing the region where they are located, providing a significant economic, social and environmental impact. Not only do they generate more than 10,000 direct jobs, but they also manufacture more than 30 million pairs annually. This large-scale production not only enhances the economic strength of local communities but also indirectly impacts an entire value chain, encompassing manufacturers of raw materials and component manufacturers that are interconnected with it.

Each of the companies was asked about carrying out a similar study, that is, whether they had already mapped and quantified their emissions. Two of them stated it was the first time, while two others mentioned it was the second time. When asked why the process is not yet fully developed within the organisations, they all mentioned the complexity of the supply chain, which often involves multiple suppliers and subcontractors, making it difficult to track and quantify emissions throughout the production process. Additionally, the lack of consistent standards and methodologies for measuring sector-specific emissions hinders comparison and monitoring over time. Another challenge is the limited availability of data and information on production practices and energy consumption at different stages of the footwear manufacturing process. Although they acknowledge the difficulty of quantifying their greenhouse gas emissions, all of them have shown interest in improving their understanding of the subject.

4.2 GHG SOURCES

Although they belong to the same sector of activity, each of the companies has distinct characteristics that directly influence the results of their GHG emissions. An in-depth understanding of these nuances is essential for a precise and personalised analysis of emissions mitigation strategies, allowing for more effective approaches adapted to the uniqueness of each company, as well as the data presented by the IPCC (2023) and Seeg (2023), in which highlights the particularities of each country in the emissions scenario, with one strategy not always applicable to another.

In Table 2, it is feasible to observe the sources of emissions directly controlled by the company and the electricity consumption identified in all organisations. This table provides a comprehensive view of the sources of emissions directly managed by companies.

Table 2 – Sources of GHGs controlled by companies

Categories/Companies	*Alfa*	*Beta*	*Gama*	*Delta*
Stationary Combustion	Generator, Welder, Kitchen Stove, Brushcutter.	Generator and Kitchen Stove.	Boiler, Generator, Kitchen Stove and Brushcutter.	Generator and Kitchen Stove.
Mobile Combustion	Forklifts	Own Vehicle Fleet	Rented Fleet of Vehicles and Forklifts	Rented Fleet of Vehicles and Forklifts
Fugitive Emissions	CO_2 Fire Extinguishers, Air Conditioning, Refrigerators, Shaping Machines, Chiller.	CO_2 Fire Extinguisher, Air Conditioning, Refrigerator, Drinking Fountain and Shaping Machines	Shaping Machines, Air Conditioners, Drinking Fountains, CO_2 Fire Extinguishers, Refrigerators, Air Dryers and Cold Stabilizers.	CO_2 Fire Extinguisher, Air Conditioning, Drinking Fountain, Refrigerators and Shaping Machines.

Source: Authors (2023).

As seen in Table 2, in the stationary combustion category, all companies have generators and kitchen stoves. Specifically, Alfa also uses welders, characterising particularities in its operations. When we asked about the use of this equipment, all companies indicated the use of generators only in situations of lack of electricity, and kitchen stoves are intended for the culinary environment, an installation present in all companies.

As for the brushcutters, present in the companies Alfa and Gama, due to their location in open spaces with abundant vegetation, these companies have them to maintain the area, ensuring the cleanliness and organisation of the space. This care demonstrates companies' attention to issues related to emissions and the physical environment around them.

In relation to the mobile combustion category, which involves the burning of fuels in equipment to generate movement (BGHGPP, 2023), unlike stationary combustion, some particularities are observed. Two companies, Gama and Delta, maintain a rented fleet of vehicles, while Beta has its own fleet. On the other hand, the company Alfa does not have a fleet of vehicles, whether rented or owned. When asking the managers of the companies Beta, Gama and Delta about the use of their vehicle fleets, information was obtained that travel occurs primarily between the company's various units and during visits to customers. It is worth mentioning that although the manufacturing units are in the south of Brazil, these companies provide services to customers throughout the national territory.

In a complementary way, Gama and Delta were asked why the fleet was rented and not owned. In this case, the manager explained that this practice provides the advantage of constantly updating the fleet, eliminating the need to make significant investments in vehicles. permanent property, but not mentioning anything regarding GHG emissions.

On the other hand, when we questioned the company Alfa about the lack of its own fleet, the manager clarified that the necessary investment was not considered advantageous. In situations requiring travel, employees are encouraged to use their own vehicles, with the possibility of later reimbursement of fuel costs or travel through transport apps.

Regarding fugitive emissions, all companies present unintentional emissions from fire extinguishers, air conditioning systems, refrigerators, pre-shaping and shaping machines. In particular, the Alfa company has a chiller. When questioning the manager about the function of this device, he clarified that it was a machine used for cooling, operating as an air conditioning system with cooling based on water and refrigerant. In other words, it is a large piece of equipment. It is relevant to highlight that all companies were surprised to realise that equipment like these emitted greenhouse gases, initially perceiving that only burning fossil fuels was the main source of these emissions.

The company's indirect emissions, that is, those under the control of its value chain, are presented in detail in Table 3. The same surprise occurred when the scope 3 categories were listed for the companies. At that moment, the organisations were unaware they were co-responsible for so many aspects.

Table 3 – Sources of GHGs not controlled by the company

Categories/Companies	*Alfa*	*Beta*	*Gama*	*Delta*
Purchased Assets and Services	x	x	x	x
Capital goods	x	x	x	x
Activities related to fuel and energy not included in Scopes 1 and 2	-	-	-	-
Upstream Transport and Distribution	x	x	x	x
Downstream Transport and Distribution	x	x	x	x
Waste	x	x	x	x
Business Travel	x	x	x	x
Home-Work Commuting	x	x	x	x
Leased assets (the organisation as lessee)	-	-	-	-
Leased assets (the organisation as lessor)	-	-	-	-
Processing of sold products	x	x	x	x
Use of goods and services sold	x	x	x	x
End-of-life treatment of products sold	x	x	x	x
Franchises	x	x	-	X
Investments	x	x	x	x

Source: Authors (2023).

As shown in Table 3, several categories in which companies do not have direct control over emissions were identified. Only three categories were not identified in all companies, namely "Leased Assets" and "Activities related to fuels and energy not included in Scopes 1 and 2". Furthermore, only one company does not have franchises, with this category being present only in the other companies participating in the study. Even so, categories such as business travel, waste generated in the organisation's operations, upstream transport and distribution (emissions from transport and distribution of purchased products) and employee commuting are highlights.

4.3 GHGS EMISSIONS

After thoroughly identifying the sources of emissions in companies, we moved on to the phase of quantifying these emissions. Table 4 provides a clear view of the quantified categories, presenting the corresponding values in tons of carbon dioxide equivalent in each company.

Table 4 – GHG emissions (tCO2-eq)

Categories/Companies	*Alfa*	*Beta*	*Gama*	*Delta*	*Total*
Stationary Combustion	14,93	19,77	48,8	44,78	125,28
Mobile Combustion	0,05	440,24	164,2	132,99	737,48
Fugitive Emissions	126,47	6,91	77,21	87,27	297,86
Energy	195,01	474,15	1.047,57	378,36	2.095,09
Home-Work Commuting	121,47	190,87	589,55	552,4	1.454,29
Upstream Transport and Distribution	1.070,35	-	-	-	1.070,35
Downstream Transport and Distribution	-	166,28	-	328,65	494,93
Business Travel	107,81	11,88	177,66	65,25	362,60
Total	**1.636,09**	**1.310,1**	**2.104,99**	**1.589,7**	**6.640,88**

Source: Authors (2023).

When examining Table 4, it is possible to see that not all categories were quantified, especially those not under the organisations' direct control. Each of the companies analysed faced challenges in presenting related data. When asked about the reason for this difficulty, all managers pointed to their recent concern with monitoring their own emissions, indicating that they have not yet asked their business partners to provide the same data. Furthermore, they explained that in some categories, there is a lack of knowledge about the specific type of data that should be monitored, contributing to the complexity of disclosing this information. To overcome the difficulties, all companies emphasised the need to train their employees regarding this subject. However, they also consider the possibility of hiring external consultancy to deal with this difficulty initially.

Among the mapped categories, Table 4 shows a significant prevalence in emissions associated with energy consumption, employees' commuting and upstream transport and distribution. Regarding energy consumption, all companies are dependent on this essential resource for the proper functioning of their machines and operational processes, justifying its predominance. When there is a power outage, that is, in situations of supply interruption, the generators are activated, resulting in the use of fossil fuel, as mentioned earlier.

However, it is worth highlighting that all managers commented that companies consume energy from the Free Contracting Environment (ACL), better known as the Free Energy Market. When questioning companies about why they opt for this type of consumption, they all highlighted the economic advantages associated with long-term contracts. Furthermore, they reinforced that consumption through this environment makes purchasing energy generated through clean and renewable sources such as wind and solar power possible. Although managers highlight the economic gains as a differentiator for being in this market, the companies also mentioned issues associated with environmental impacts, meeting the demand of some customers concerned about these issues.

Although all the companies analysed acquired 100% of their energy from this market, managers' concern with reducing energy consumption became evident throughout the interviews. With this understanding, all companies have set goals to reduce consumption by 2030. When asked about how they plan to achieve these goals, several actions were mentioned, such as raising employee awareness, replacing equipment to increase efficiency in energy consumption, exchanging common light bulbs for new and more efficient ones, installing solar panels, implementing presence sensors, among other measures.

For organisational activities to occur, all companies rely on a robust team of employees. As a result, emissions associated with employees commuting from their homes to the workplace came in second place. When asking managers about employee travel, they all stated that control is carried out using buses chartered by the companies, only accounting for production/operational personnel, which represents approximately 80% of the workforce. Employees from other sectors, such as administrative sectors, generally travel in private vehicles, which makes access to relevant data even more difficult. However, the companies mentioned the need to also understand the impact of employees who travel in their own vehicles, suggesting the possibility of implementing a questionnaire to gather data from this group.

The upstream transportation and distribution category concerns the movement category of all raw materials and inputs acquired by the company. This is different from the downstream category, which involves the distribution of the final product to the consumer. Both categories had low adherence by organisations. When questioning managers about this difficulty, he mentioned that transport companies still do not record the information necessary to quantify emissions, which makes access to this data challenging. However, two companies (Beta and Delta) complemented the information, highlighting that, in the last two years, they have conducted outreach workshops with carriers, aiming to make them aware of the importance of starting the process of controlling this information.

Finally, the category of business trips is considered by managers as easy to measure since only listing the number of flights to and from the destination is necessary, as well as listing trips made by car or bus by employees. Generally, this data is held by the administrative department responsible for controlling ticket acquisition. The category of upstream transport and distribution, as well as employees' home-to-work journeys and business trips, are widely highlighted in reports, as indicated by BGHGPP (2023), despite the data not being under the direct control of organisations.

All managers signalled the resumption of business travel after the end of the Covid-19 pandemic. This perspective reflects the global nature of these companies' operations and the trend towards normalisation of corporate travel in the post-pandemic scenario. However, this raises a warning about a possible increase in emissions associated with this category.

5 RESULTS DISCUSSION

Often, strategies to reduce GHG emissions are implemented on a global scale. However, when analysing data from Brazil, the United States and China, there is a disparity in the emissions profiles of each country. For example, the approaches applied in Brazil may not be the most appropriate for implementation in China and the United States. This same consideration must be applied at the organisational level, recognising the diversity of contexts and adopting strategies adapted to each specific reality (IPCC, 2023; Seeg, 2023).

The data provided from the analysis of greenhouse gas (GHG) emissions in various companies within the same sector reveals distinct characteristics influencing their emissions profiles. Comprehending these nuances is essential for mitigation strategies, especially in the quest for innovative processes to lead the way towards a low-carbon future (Abreu *et al.*, 2014; Gallego-Alvarez *et al.*, 201; Singh *et al.*, 2014).

In stationary combustion, for instance, as emphasised by BGHGPP (2023), the category of stationary combustion stands out as one of the most frequently reported categories by Brazilian companies. While all companies possess generators and kitchen stoves, Alfa stands out due to the presence of welders, reflecting its unique operational requirements.

Regarding mobile combustion, which involves burning fuels in equipment to generate movement (BGHGPP, 2023), unlike stationary combustion, some particularities are observed. Gama and Delta opt for rented fleets, while Beta maintains its own. In other words, they are responsible for the fuel their fleet burns. In this case, replacing the fuel with a biofuel or even planning the route to avoid unnecessary travel can be reconsidered. Notably, Alfa lacks a fleet, encouraging employee-owned vehicle use. It is worth mentioning that this type of emission becomes indirect for the organisation, no longer under its direct control (BGHGPP, 2023).

Fugitive emissions are present in all companies, with Alfa having additional equipment like a chiller. This variance highlights the diverse approaches to fleet management among the companies. Concerning the GHG emissions profile of Brazilian organisations, particularly those regarded as sources directly owned or controlled by the organisation, the key emissions highlights include those from energy consumption, stationary combustion, industrial processes, and fugitive emissions (BGHGPP, 2023).

In GHG emissions quantification, energy consumption dominates across all companies, reflecting dependency on this resource for operations as well as Cheah *et al.* (2013), De Ponte *et al.* (2023) and Gajewski *et al.* (2014) results. Since Brazil already has an advanced energy matrix, characterised by renewable and clean sources, which differentiates it from many other countries, reducing emissions requires a specific focus on other areas, making the challenge even more complex. This emphasis on renewable energy procurement demonstrates a commitment to reducing carbon footprints and transitioning towards sustainable practices in response to customer demand for environmentally friendly companies. This finding corroborates with Kumar and Carolin (2020) and Pimenta *et al.* (2023).

Companies face challenges quantifying indirect emissions, highlighting the complexity of data collection and partnerships with third parties. Challenges arise in quantifying emissions associated with upstream transportation and distribution, indicating gaps in data collection from transport partners. These results are also evidenced by BGHGPP (2023) and Caldeira *et al.* (2022). Efforts to engage carriers in emission tracking are underway.

Nevertheless, to reduce these emissions, it is imperative to implement measures in logistics planning, considering sustainable fuel options, such as ethanol. By optimising logistics planning, it is possible to reduce the distance covered by vehicles, thus minimising fuel consumption and CO_2 emissions. The search for transport companies that use NGV (Natural Gas Vehicle) or electric vehicles is also an option, as these technologies have a lower environmental impact compared to traditional fossil fuels.

Renewing the fleet with more efficient and low-emission vehicles is also a strategy. Investing in renewing the vehicle fleet replacing older models with vehicles with cleaner and more efficient technologies, can also provide significant benefits. Modern vehicles generally have more advanced emission reduction systems, releasing less polluting gas.

Business travel presents a relatively straightforward measurement but signifies a potential future increase in emissions post-Covid-19, reflecting a global trend towards business travel resumption. Significant emissions stem from employee commuting, emphasising the importance of transportation-related emissions. Promoting more sustainable travel practices, such as adopting public transport by employees, sharing trips between them and using video conferences for remote meetings, can be a viable alternative. Furthermore, it is necessary to raise awareness among employees about the impacts of GHG emissions during travel. To this end, it is recommended that training sessions be held.

6 FINAL CONSIDERATIONS

This study aimed to map and quantify GHG emissions from footwear industries located in the southern region of Brazil, with the aim of subsequently proposing reduction strategies. A qualitative and quantitative approach was used to achieve this purpose.

Often, strategies to reduce GHG emissions are implemented on a global scale. However, when analysing data from Brazil, the United States and China, there is a disparity in the emissions profiles of each country. For example, the approaches applied in Brazil may not be the most appropriate for implementation in China and the United States. This same consideration must be applied at the organisational level, recognising the diversity of contexts and adopting strategies adapted to each reality.

Since Brazil already has an advanced energy matrix, characterised by renewable and clean sources, which differentiates it from many other countries, reducing emissions requires a specific focus on other areas, making the challenge even more complex. When analysing the results of this study, it is clear that the category with the highest energy emissions is the burning of fossil fuels to generate movement, whether through the transport and distribution of raw materials or through the commuting of employees.

Among the study's limitations, it is necessary to highlight the difficulty in accessing data for the categories in which organisations do not have direct control, which restricts companies' comprehensive analysis of emissions. However, it is important to understand that emissions are still incipient for many companies in Brazil, and the difficulty in accessing data is acceptable. It is recognised that awareness and implementation of emission measurement and control practices are in the early stages, which may impact the availability of detailed information.

Another limitation observed was that, at the national level, emissions data do not allow for an individual analysis of the footwear sector, a gap also highlighted in the BGHGPP (2023) report, which does not devote specific attention to this sector. The lack of particular emphasis on the footwear industry restricts a detailed understanding of its specific contributions to Brazilian and global emissions.

Even without official data on greenhouse gas emissions from the footwear industry in Brazil, multiplying the value of 840 million pairs by 14 kilograms of carbon dioxide equivalent, based on data provided by China, results in a total of 11.760 billion kilograms of carbon dioxide equivalent or 11.760 megatonnes of CO_{2eq}.

Given the aforementioned gaps, it is possible to develop recommendations that aim to fill this lack of emphasis in the sector, such as: research with the sector to seek an understanding of emissions and the development of workshops, courses and training to increase awareness of the issue by encouraging everyone to prepare an inventory to fully understand the sector's emissions.

Despite the limitations mentioned, it is crucial to highlight that they do not disqualify the relevance of this study. On the contrary, it plays a fundamental role in providing insights into GHG emissions in the footwear industry and identifying areas that require further development for a more comprehensive understanding of the topic. In this sense, the study offers an updated view of the scenario and points to the gaps to be filled, contributing to continued progress in understanding and tackling emissions in the footwear industry.

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