AMBIENTE & SOCIEDADE
25 anos años years

Opportunities for GHG Emission Reductions in the Brazilian Graphic Industry Through a Mitigation Plan

Rafael da Silva Caldeira [I]
Simone Lorena Quiterio de Souza [II]
Eduardo Monteiro Martins [III]
Sergio Machado Corrêa [IV]

Abstract: The Graphics Industry has existed for many years and its operations include digital printing services, visual communication, packaging supplies and advertising materials, while being involved in the trade of goods and services worldwide. This unprecedented study presents the quantification of greenhouse gas (GHG) emissions from a printing industry in Brazil over the three years 2016, 2017 and 2018. From the results of these three years, the base year was defined as the reference for analyzing the results of a GHGs mitigation plan. The simulated Mitigation Plan foresees a potential reduction of up to 50.3 % of these emissions. The methodology follows the recommendations of the Intergovernmental Panel on Climate Change (IPCC). The work aims to encourage the study of opportunities for a low-carbon economy and production, to improve performance in good sustainability practices in the face of environmental demands to contain the intensification of the greenhouse effect and global warming.

Keywords: GHG Protocol; Greenhouse Gas Emissions; Mitigation Plan; Graphics Industry; Climate Change.

[I] *Universidade do Estado do Rio de Janeiro, Rio de Janeiro – RJ, Brazil.*

[II] *Instituto Federal de Educação, Ciência e Tecnologia do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.*

[III] *Universidade do Estado do Rio de Janeiro, Rio de Janeiro – RJ, Brazil.*

[IV] *Universidade do Estado do Rio de Janeiro, Resende – RJ, Brazil.*

São Paulo. Vol. 25, 2022

Original Article

DOI: http://dx.doi.org/10.1590/1809-4422asoc20200210r2vu2022L3OA

Introduction

In the world scenario, one can observe the efforts and challenges of the scientific community in formulating alternatives to reduce anthropogenic emissions of greenhouse gases (GHGs) in the troposphere, in order to control the intensification of the greenhouse effect and consequently maintain global warming at a temperature level that does not exceed the global average temperature by 2.0 ºC, based on the pre-industrial period (ADEDEJI *et al.*, 2020; IPCC, 2018; NOBRE; MARENGO; SOARES, 2018). Scientific predictions show that the intensification of the greenhouse effect and thus global warming contribute to climate change and its negative and irreversible environmental impacts (IPCC, 2014b; STEFFEN *et al.*, 2015; STEFFEN; CRUTZEN; MCNEILL, 2007). Therefore, the importance and brevity of developing and meeting GHG emission reduction objectives emerge (UNFCCC, 2015).

In 2015 at the United Nations Framework Convention on Climate Change (UNFCCC, 2015), Paris Agreement, it was agreed by the mechanisms of the Nationally Determined Contribution (NDC) national goals for reducing GHG emissions. Brazil, a signatory country of the Paris Agreement, presented its NDC with two reduction targets, the first of 37 % by 2025 and the second of 43 % by 2030, both about the levels of the base year of 2005 (BRAZIL, 2016; UNFCCC, 2015).

Strategies to reduce GHG emissions require the correct and consistent formulation of GHG emissions inventories of economic activities. GHG inventories are quantification reports of GHG emissions, which can be generated by any economic activity within a given period (AGUIAR; FORTES; MARTINS, 2016; CHANDRAKUMAR *et al.*, 2019; DING *et al.*, 2019; IPCC, 2014a). The results of GHG inventories assist countries in decisions and formulation of climate politics and are technically founded by means of recognized methodologies (ABREU; ALBUQUERQUE; FREITAS, 2014; FGV, 2019, 2020; SINGH *et al.*, 2014).

The GHG inventory calculation methodology most applied in Brazil is by the Brazilian GHG Protocol Program of the Getúlio Vargas Foundation, which also publishes, annually, the inventories of the companies that voluntarily participate in the program and the Public Emissions Registry of the GHG Protocol Brazil.

According to the GHG Protocol Program, the sources of GHG emissions are categorized into three Scopes: Scope 1 represents the direct emissions, produced by stationary combustion and mobile combustion, and fugitive emissions from the use of coolant gases; Scope 2 refers to the consumption of electricity, and Scope 3 the indirect emissions associated with goods and services and activities of third parties. Scope 1 and Scope 2 emissions are controlled by the company's management. Scope 3 emissions from transportation and waste treatment services are contracted and managed by third parties. These emissions are in the category of transportation services by a subcontracted fleet (FGV, 2019; IPCC, 2006; ISO, 2007).

In Brazil, according to data from the Public Emissions Registry of the Brazilian GHG Protocol Program, in 2016 a total of 37 companies participated and in 2019 this number increased to 152 companies. It is observed an increased adhesion of companies in conducting GHG inventories in the last 5 years. For 2021, there is a great expectation of a further increase, to carry out these inventories, motivated by a market reaction to the return of US government politics to the Paris Agreement (FGV, 2020).

In the context of this scenario, we highlight the development of mitigation plans by companies to meet sustainability indicators, encouraged by self-regulation of international trade, aiming at the carbon footprint of products and services (CARO, 2019; HICKMANN, 2017; SEROA DA MOTTA, 2019).

This article is a case study conducted in a graphic industry located in the city of Rio de Janeiro, Brazil, where GHG inventories were conducted for the years 2016, 2017 and 2018 and a Mitigation Plan for emissions reduction was proposed, considering as base year or reference year for comparison, the average emissions of these three years.

The study considers a small graphic industry because it proposes the inclusion of the entire production chain to engage in the issue of GHG emissions mitigation. Furthermore, it can contribute to the inventories of large companies, measuring the indirect GHG emissions more accurately in their network of suppliers of products or services.

Based on the Public Emissions Registry of the Brazilian GHG Protocol Program, it was found that GHG emissions from printing industries in Brazil showed similarity in terms of emission sources, and depending on the size of each printing industry and the technologies employed, GHG emissions vary in the range of 10^2 to 10^3 tons of carbon equivalent (FGV, 2019) .

The unpublished selection of the case study was based on the fact that the graphic industry provides goods and services to several, if not all, industrial and commercial sectors, including advertising materials, such as posters, banners, display material, and even packaging for consumer goods in general (ABIGRAF, 2020; FIRJAN, 2018). Thus, its presence in the carbon footprint or life cycle of any product in the consumer market is globally significant (CARO, 2019; HICKMANN, 2017).

2. Methodology

2.1. Case Study Characterization

According to data from the Brazilian Graphic Industry Association in 2018 there were 19,142 graphic industries in Brazil, being 97 % small and micro-sized companies. In the same year, the representativity of the graphic industry in the GDP of the transformation industries was 2.8 % (ABIGRAF, 2020; FIRJAN, 2018). According to data from the Federation of Industries of Rio de Janeiro, in the state of Rio de Janeiro there were 1,852 companies in operation. These quantitative figures show the relevance of a service market that serves various sectors of industry and trade (ABIGRAF, 2020; FIRJAN, 2018).

The printing industry is one of the oldest in the world and presents as a characteristic few technological diversities in its operations. The case study approaches a print shop located in the city of Rio de Janeiro with its main technology being digital printing.

2.2. GHG Inventory

Methodologies for quantifying and measuring GHG emissions consider that the main GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6) hydrofluorocarbons (HFCs) (ISO, 2007a; SEINFELD and PANDIS, 2016). Emissions of CO_2, CH_4, N_2O and chlorodifluoromethane (HCFC-R22) and biogenic CO_2 were considered in the inventories. All included GHGs were converted into tons of carbon dioxide equivalent (t CO_{2eq}) using the following GWP (global warming potential) values: 1 for CO_2, 25 for CH_4, 298 for N_2O, and 1810 for HCFC (IPCC, 2007; FGV, 2020)

The methodology for calculating the emissions of the inventories followed the steps below:

1) Identification of emission sources by the assessment of environmental aspects and impacts - classification of sources within the operational limit of the printing plant (IPCC, 2006, 2019).

2) Collection of input and activity data (ISO, 2007a). Records of vehicle fuel consumption controls, electric power purchase, refrigerant gas consumption and waste generated in operations.

3) Use of the GHG Protocol Program calculation tool Microsoft Office 365 Excel spreadsheet: Tool_GHG_Protocol_v2019.3xlsx, Brazilian GHG Protocol Program Tool (FGV, 2019; WRI, 2014), and the Guidelines for National Greenhouse Gas Inventories, IPCC (IPCC, 2019).

4) Accounting for emissions based on the application of emission factors and pre-established standard data, default, in the absence of more empirical data (ISO, 2007a).

The selection and identification of the GHG emissions sources was possible through an assessment of environmental aspects and impacts of the operations and activities of the graphic company. A comparison was also done with 3 other companies who published their GHG inventories in the Public Emissions Registry of the Brazilian GHG Protocol Program between the years 2017 and 2019.

2.2.1 Scope 1 Emissions Inventory - Mobile Combustion.

The emission factors used by FGV GHG Protocol methodology were those based on the Guidelines for National Greenhouse Gas Inventories Chapter 3 Mobile Combustion and 2nd National Inventory of Atmospheric Emissions by Road Motor Vehicles - 2013, January 2014, of the Ministry of Environment (BRAZIL, 2014).

The estimates of these emissions were calculated based on the annual volumetric consumption of gasoline, ethanol, and diesel, based on the distance traveled (km) by vehicles, considering type, model, and year of each vehicle (BRAZIL, 2014; FGV, 2019). GHG emission factors for gasoline consumption were CO_2 fossil 2.210 kg L^{-1}; CO_2 biogenic 1.526 kg L^{-1}; CH_4 8.080 x 10^{-4}; N_2O 2.580 x 10^{-4} kg L^{-1}. While for ethanol they were fossil CO_2 2.600 kg L^{-1}; biogenic CO_2 2.431 kg L^{-1}; CH_4 1.390 x 10^{-4}; N_2O 1.390 x 10^{-4} kg L^{-1} (FGV, 2019).

2.2.2 Scope 1 Emissions Inventory – Fugitive Emissions.

The methodology for calculating fugitive emissions used by the GHG Protocol, is an adaptation of the U.S.EPA methods called "Direct Emissions of HFCs and PFCs from the use of Refrigeration and Air-Conditioning Equipment" (U.S. EPA, 2014) and the "Calculation of HFC and PFC emissions from the manufacture, installation, operation and disposal of refrigeration and air-conditioning equipment" from the GHG Protocol guidelines.

In addition to these gases, the fugitive emissions of the gases of the HCFC hydrochlorofluorocarbon groups are estimated. Although not regulated by the Kyoto Protocol, these gases, from the groups of halogenated organic species, have a high global warming potential and participate in the depletion of the ozone layer (IPCC, 2007).

The refrigerant gas used in the accounting was the R22, which is HCFC-22 (chlorodifluoromethane) (ASHRAE, 2021). The emissions are quantified by the product of the volume of gas consumed, according to its GWP, to obtain CO_{2eq}. (FGV, 2019), as expressed in Equation 1.

$$E = (EUN + EUE + EUD) \times GWP$$

Where:

E = Emission of CO_2eq (kg).

EUN = emissions from the installation of new units: the gas used for loading the new equipment less the capacity of the equipment (the difference corresponds to losses to the atmosphere).

EUE = the gas added to existing units, such as for maintenance by the company or supplier (this does not include preloads supplied by the manufacturer).

EUD = disposal emissions of old units: unit capacity dispensed minus the amount of gas recovered (the difference corresponds to losses to the atmosphere).

$GWP_{\text{HCFC 22}} = 1.810$.

In this study, the approach taken to find the consumption of HCFC, R22, is based only on the refillable cylinders used, in the periods when refilling took place.

2.2.2 Scope 2 Emissions Inventory Electricity Consumption.

The methodology for calculating indirect GHG emissions from energy consumption is based on a location-based approach. A location-based method involves quantifying Scope 2 GHG emissions by taking the average GHG emissions intensity of the network where energy consumption occurs and using mainly average emission factor data from the generation transmission network in a given period (FGV, 2018).

In Brazil, emission factors are based on the National Interconnected System - SIN, made available by the Ministry of Science, Technology, Innovations and Communications (MCTIC) (Brazil, 2019).

The Brazilian electrical grid has a low GHG emission factor, compared with other electric power installations. This is because the Brazilian electrical grid is generated by energy that is 67.6 % hydroelectric; 8.9 % wind power; 8.3 % biomass; 2.9 % oil; 7.9 % gas; 1.1 % solar; and 1.2 % nuclear, according to data from (IPCC, 2006, 2014a; ONS (BRAZIL), 2019).

The calculation of the CO_2 emission from Scope 2 is defined by Equation 2 (Brazil, 2019).

$$E_{CO2} = f_{CO2\text{-}SIN} * EE$$

Where:

E_{CO2} = Emission of CO_2 (Mg t^{-1}) monthly or annual.

f_{CO2} – SIN = CO_2 (Mg MWh^{-1}) emission factor, monthly or annual average.

EE = Acquired Electrical Energy (MWh t^{-1}).

2.2.3 Scope 3 Inventories - Waste Generated in Operations

The methodology for quantifying the emissions of $CO_{2eq.}$, CO_2, CH_4, and N_2O, resulting from the waste treatment generated in the operations considered two important points that ensure consistency and assertiveness of the choice of GHG calculation: segregation of waste, according to ABNT Standard 10004, into Class I (Hazardous Waste) and Class IIA (Non-Hazardous and Non-Inert Waste), and each waste treatment technology.

The case study considered the destination of waste for the treatment technologies in landfill or incineration.

Class IIA waste destined for the landfill was, utilizing wood waste, plastics, paper, cardboard, organic waste, and regular trash.

GHG emissions from the treatment of class IIA waste in landfills originated from the anaerobic decomposition of this waste, according to the methodology of the Brazilian GHG Protocol Program was applied the regional parameters of the landfill located in the city of Seropédica, which in previous studies showed significant emissions of CH_4 gas (BORBA et al., 2018; FGV, 2019, 2020).

The Class I residues destined for incineration were cleaning materials for printers with rags, contaminated rags, as well as paint and solvent packaging.

These residues are mixed and can be destined for blending in co-processing units or incineration furnaces.

In this case, we considered conservatively that all these residues went to incineration, thus avoiding underestimating the results of the emissions in the inventory.

During the treatment of hazardous waste by incineration, the estimates were based on the method recommended by IPCC (2006) Guidelines for National Greenhouse Gas Inventories Volume 5 Waste and IPCC Waste model spreadsheet (MS 100 Excel) and applied default reference date of: V5_5CH5_IOB pdf Incineration and Open Burning of Waste (IPCC, 2006). The methodology was based on a) the estimation of the fossil carbon content in the co-processed waste and b) the respective emission factors (IPCC, 2006, 2019), and following the equations below:

The fossil CO_2 emissions are calculated by means of Equation 3.

Fossil CO_2 Emissions (t CO_2) = T_{Waste} x Dm x CF x FCF x OF x Conversion Factor

Reference:

T_{Waste} = Total Amount of Waste Incinerated (wet weight).

Dm = Dry Matter content, fraction 70 %.

CF = Carbon Fraction in Dry Matter, fraction 50 %.

FCF= Fraction of Fossil Carbon in total Carbon, fraction 90 %.

OF = Oxidation Factor, fraction 100 %.

Conversion Factor = 44/12 (ratio of C in CO_2).

The CH_4 emissions are calculated by means of Equation 4.

CH_4 Emissions = Amount of Waste Incinerated (t_{Waste}) x CH_4 EF

CH_4 EF = 6 (kg t^{-1} waste incinerated on a wet weight basis).

The N_2O emissions are calculated by means of Equation 5.

N_2O Emissions (t N_2O) = Amount of Waste Incinerated (t Waste) x N_2O EF

Nitrous Oxide Emission Factor = 1 x 10^{-4} t N_2O / t West Waste.

2.3. Mitigation Plan Preparation

According to ISO14064 the base year is defined as a specified historical period for the purpose of comparing GHG emissions and removals or other information. The emissions or removals from a base year can be quantified by reference to a specific period (for example, one year) or an average of several periods (for example, several years) (ISO, 2006).

After conducting the inventories for the years 2016, 2017 and 2018 a significant variation in emissions was observed and to obtain a fairer scenario for comparing emissions the average of the 3 years was conservatively adopted to define its base year.

The comparison of the emissions of the mitigation plan with the defined base year was conclusive in enabling a fair average scenario that represents the emissions of that industry, considering external events that occurred in the city of Rio de Janeiro influenced the productivity of this printing industry such as the Olympic Games in 2016 and the elections in 2018.

The indications of alternatives for emission reductions were compared to the defined base year for understanding their effectiveness.

The mitigation plan indicated the substitution of emission sources with lower emission factors through activities, product consumption, electricity generated, and waste treatment and management.

In the interest of reducing Scope 2 CO_2 emissions, the mitigation plan considered two scenarios: I) the choice of the electric energy source with the lowest emission factor, in terms of $tCO_2 \cdot MWh^{-1}$; and II) geographical advantage, considering that the region of Brazil receives for long periods of the year a favorable amount of solar radiation for the use of photovoltaic systems (CARSTENS; DA CUNHA, 2019; GOOD et al., 2016; NWAIGWE; MUTABILWA; DINTWA, 2019).

In the estimates of Scope 1 reductions the mitigation strategies indicated the replacement of fossil fuels with biofuels. Reduction strategies were applied as per the following procedure:

- 30 % of gasoline consumption must be replaced with the same proportion of ethanol in the flex fuel vehicle fleet in the year defined for mitigation.
- B10 diesel consumption must be replaced with the same proportion defined for mitigation with B30.

The mitigation scenario for emissions from the treatment of non-hazardous waste is based on two alternative schemes: the first is the recycling of plastic wastepaper (PVC) and wood and the second is the composting of organic waste (i.e., food waste).

3. Results and Discussion

3.1. GHG Inventories of the Graphic Industry

It was found that the sources of GHG emissions are concentrated in the consumption of electricity by the paper printing equipment, the transportation of raw materials and products and the destination and transportation of waste generated in these industries. Table 1 shows the sources of GHG emissions chosen for this study. The sources are divided into three categories and then subdivided into categories, under the GHG Protocol.

Table 1 - Survey of the graphical company studied showing the main GHG emissions sources and the classification by Scope 1, 2 and 3

Environmental Aspect	Emission Sources GHG	GHG	Input consumed	Scope	Category (Program GHG Protocol)
Distribution of products with own vehicles	Mobile combustion emissions	CO_2, CH_4, N_2O and CO_2biogenic	Diesel and Gasoline Fuel	1	Mobile Combustion
Refrigerant gas refill in air conditioners	Fugitive Emissions of R-22	HCFC-22	HCFC-22	1	Fugitive Emissions

Purchase and Consumption of Electric Energy	Purchase and Consumption of Electric Energy	CO_2	Electric Energy originating from the National Interconnected System - SIN	2	Electric power purchase. Location-based approach
Contracting waste transport services for final disposal and treatment by third parties	Mobile combustion emissions	$CO_{2,}$ $CH_{4,}$ N_2O and CO_2biogenic	Diesel Fuel	3	4 -Transport and distribution (upstream)
Contracting non-hazardous waste treatment services by incineration	Incineration of hazardous waste in furnaces	$CO_{2,}$ $CH_{4,}$ and N_2O	hazardous waste generated in the operation	3	5- Waste generated in operations
Contracting non-hazardous waste treatment services by incineration	landfill waste disposal	$CH_{4,}$ $CO_{2,}$	non-hazardous waste generated in the operation	3	5- Waste generated in operations

Source: Adapted by the authors; Brazilian Program GHG Protocol,(FGV, 2019);

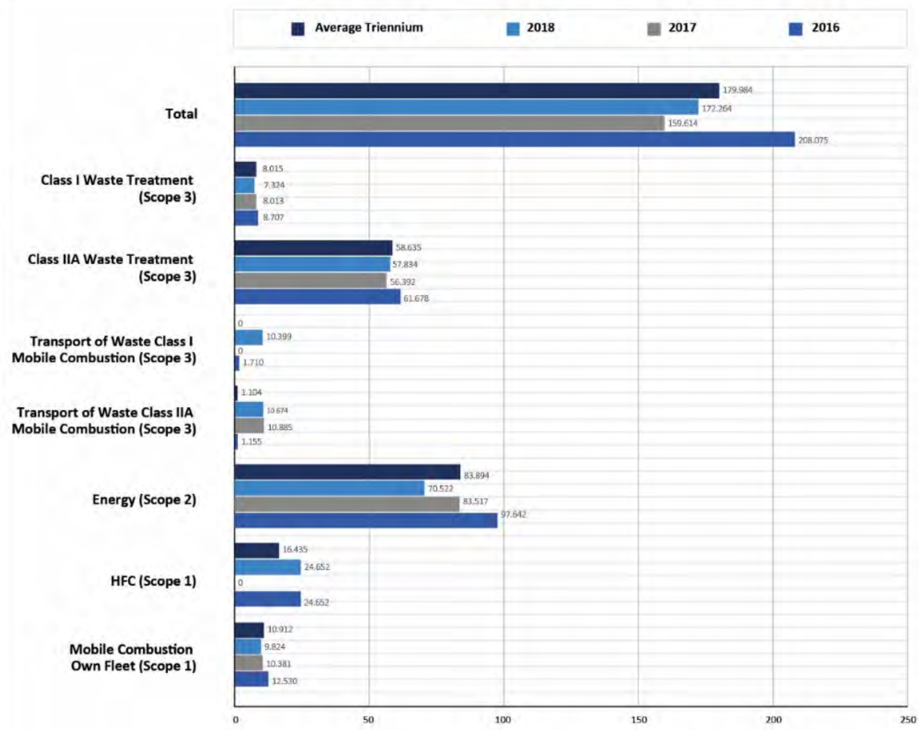
The results of the total GHG emissions occurred as expected, i.e., the emissions for the small size of the activity on the scale of 10^2 tons in the 3 years are as follows: 208.075, 159.614 and 172.264 t $CO_{2eq.}$ for 2016, 2017 and 2018, respectively.

The average total emissions for the three years were 179.984 t$CO_{2eq.}$, distributed as follows: 46.61 % for Scope 2 (electricity consumption) and 32.58 % for Scope 3 (treatment of non-hazardous waste in landfills).

Figure 2 presents the GHG calculations for the 3 years considering CO_2, CH_4, N_2O and HCFC converted into $CO_{2eq.}$ by their respective GWP, with reference to the 7 sources described: Mobile Combustion; Fugitive Emissions; Energy Consumption; Class I Waste Transport; Class II Waste Transport and Class IIA Waste Treatment.

In the Scope 1 results, Figure 1 presents the fugitive emissions from HCFC consumption that exceeded the Scope 1 mobile combustion emissions. Fugitive HCFC emissions accounted for 9.29 % of the emissions compared to 6.17 % from its transport fleet. As there was no R22 refill in 2018 and fugitive HCFC emissions were zero, emissions from this source did not remain constant and were not included in the mitigation plan. The results of fugitive emissions generated by the consumption of refrigeration gases (HCFC-22) were 24.652 t $CO_{2eq.}$ during 2016 and 24.625 t $CO_{2eq.}$ during 2018, while during 2017 no gas was recharged. The average emission rate in those years was 16.435 t CO_{2eq}. These emissions corresponded to an average consumption rate of 9.072 kg of HFC-22 gas per year.

Figure 1 - Total Emissions in t CO_2eq, for 2016 to 2018 and Triennium Average (base year). Annual emissions in metric tons of CO_2eq, in the Graphic Industry



	2016 (tCO2eq)	**2017** (tCO2eq)	**2018** (tCO2 eq)	**Averge Trienium-base Year** (tCO_2 eq)
Mobile Combustion Own Fleet (scope1)	12.530	10.381	9.824	10.912
Fugitive-HCFC (scope 1)	24.652	0	24.652	16.435
Energy (scope 2)	97.642	83.517	70.522	83.894
Transport of waste Class II A Mobile Combustion (Scope 3)	1.155	1.088	1.067	1.104
Transport of waste Combust treatment (scope3)	1.710	0.223	1.039	0.991
Class II A Waste Treatment (scope 3)	61.678	56.392	57.834	58.635
Classe I Waste Treatment (scope 3)	8.707	8.013	7.324	8.015
Total	208.075	159.614	172.264	179.984

Source: Prepared by the authors.

The inventory results of GHG emissions generated in Scope 1 by mobile combustion considered fossil CO_2, CH_4, N_2O and biogenic CO_2, produced by the activities of deliveries and road transport of commercialized products by automotive vehicles. The GHG emissions, averaged over the three years, by mobile combustion, were calculated based on the consumption of 4,360 liters of gasoline that resulted in emissions of 4.547 t $CO_{2eq.}$ and 1,901 liters of diesel that resulted in emissions of 6.421 t $CO_{2eq.}$

In Scope 2 emissions, it was found that the average annual electricity consumption over the three years was 1,064,067 KWh, corresponding to indirect emissions of 83,894 t CO_{2eq}. In the analysis of the three-year historical series, it was observed that the emissions of this Scope varied from 97.642 t$CO_{2eq.}$ in 2016 to 70.522 t $CO_{2eq.}$ in 2018. The reduction in this period was also found in the other emission sources and was justified by the high productivity in 2016 due to the Olympics Games in the city of Rio de Janeiro that demanded the production of banners, posters, and various advertising materials.

The emission factors for the National Interconnected System (SIN) and FGV (FGV, 2018) in the study period were: 0.0740, 0.0927, and 0.0817 tCO2MWh-1, for the years 2018, 2018, and 2016, respectively.

In calculating Scope 2 emissions, monthly electricity consumption data were collected for the periods January to December of the three inventoried years. From the total consumption of each year, the average of the annual consumption for the three years period was taken, which was used to define the base year. Thus, the average annual energy consumption for the base year was 1,064,067 MWh.

According to the GHG Protocol Program, Scope 3 emissions are indirect sources produced by the acquisition of services The GHG inventories of this printing industry considered CO2, CH4, N2O, and biogenic CO2 and included the following GHG sources:

Mobile combustion emissions from road transport of Class I and Class IIA waste by third parties.

- Emissions from final waste treatment and disposal methods, in landfills for non-hazardous and non-inert waste (Class IIA), as well as by incineration of hazardous waste (Class I), by third parties.
- In the case of road transport of non-hazardous waste to a landfill, the average emissions for the years 2016 to 2018 were estimated at 1,104 t $CO_{2eq.}$ while in the transport of hazardous waste to an incineration plant, the emission estimates for the three-year average were 0.991 t CO_{2eq}.

The study showed that in the case of class II waste treatment in landfills, there was an average of 58,635 t CO2eq. corresponding to CH4 emissions of 2,467; 2,256 and 2,313 t CH4 for 2016, 2017 and 2018, respectively.

Regarding the treatment of hazardous waste, the printing industry decided to send the waste to the Incineration Waste Treatment Center at São Paulo State. The annual results from 2016 to 2018 were 8,487; 7,811 and 7.140 t CO_{2eq}., respectively and resulted in an average of 8.015 t$CO_{2eq.}$ (three-year average), while CH_4 and N_2O emissions were far below the CO_2 values.

GHG emissions in waste incineration processes are concentrated in CO_2 gas, accounting for 97 % of emissions. According to Hwang et al. (2017), measurements at waste incineration plants in South Korea showed that CO_2 emissions were much higher than CH_4 and N_2O gases, which were insignificant.

Analyzing the total results of the 3 annual GHG emission inventories, it is possible to conclude that the highest emission of GHGs in the Scope 2 source is from electricity consumption. This fact is typical of the printing industry, unlike other industrial activities, in which emissions are concentrated in Scope 1 or 3. Every economic activity, due to its operational specificities, presents characteristic emissions profiles. Table 2 shows the GHG emissions in Scopes 1, 2, and 3 in various industrial activities and two other printing industries in Brazil.

Table 2: Comparison of emissions from different types of industrial

Industrial type	Year 2019		
	Scope 1	**Scope 2**	**Scope 3**
Graphic Industry (Box Print)	198.79	464.22	30.32
Graphic Industry (Antilhas)	227.58	949.69	54.90
Commerce, retailing	5,231.46	7,241.72	36,254.52
Manufacture of pulp, paper, and paper products	804,651.37	2,827,28	230,334.35
Food Industry	28,633.94	1,279,18	428.82
Steel Industry	43,466,.81	13,462,37	33,596.15
Mining	687,002.94	67.562,34	16,844.10
Extraction of oil and natural gas	58,465.217.74	282,374.55	504,522,827.57

Source: Adapted by the authors; Brazilian Program GHG Protocol(FGV, 2019).

As seen in Table 2, GHG emissions in graphic industries individually are lower than in other activities, however, it is observed that the contribution to GHG emissions to the atmosphere will be relevant considering the thousands of graphic industries, and this quantity is not proportional in other types of industries. For example, considering that each of the 19,000 small graphic industries emitted approximately 180 t $CO_{2eq.}$ per year to the troposphere, the accumulated result would be 3,420,000 t $CO_{2eq.}$ per year. This comparison is reasonable because of the following factors:

- The seven GHG sources selected are common to any graphic company in Brazil.
- It was considered the hypothesis that these emissions in t $CO_{2eq.}$ obtained in the study is the minimum that a printing industry can emit into the atmosphere.

3.2. Mitigation Plan of the Graphic Industry

The Mitigation Plan for the reduction of GHG emissions in the three Scopes is:

- Scope 1: Increased consumption of biofuels by mobile sources.
- Scope 2: Use of photovoltaic energy.
- Scope 3: Waste management with incentives to recycle and compost organic waste.

The results of the mitigation plan, referring to scope 1, are presented in Figure 3. The mitigation plan projected the substitution of 30 % in liters of gasoline by ethanol, resulting in a reduction of 1,919 t $CO_{2eq.}$ The mitigation plan is considered even more effective considering that the Brazilian gasoline has 27% of ethanol in its composition.

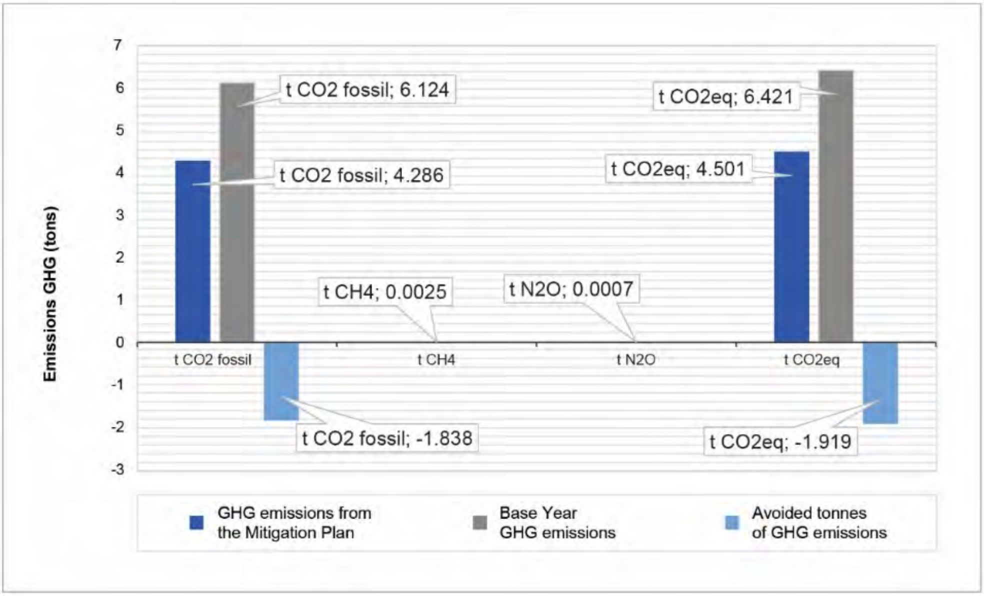
The substitution of B10 by B30 corresponded to a 22 % reduction concerning the average of the three years. The result was satisfactory, as it avoided the emission of 1,004 t $CO_{2eq.}$ into the atmosphere. The simulation of the mitigation plan in this case of the addition of B30 to its effectiveness will depend on decisions and studies by the National Petroleum Agency, the regulatory agency for the production and commercialization of fuels.

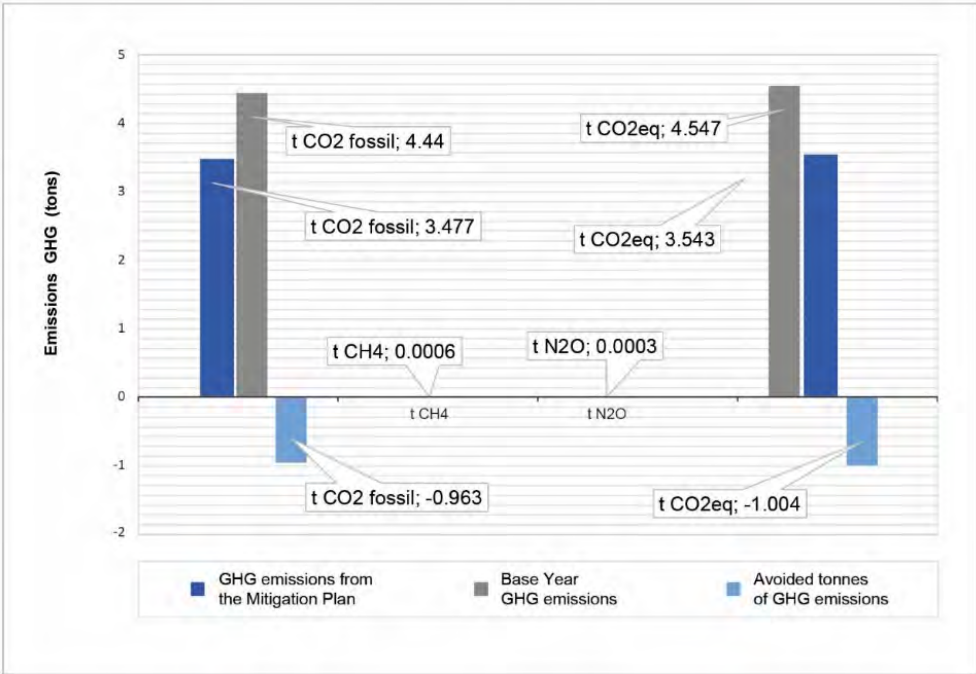
Due to the high potential for agricultural production in Brazil, it is feasible the use higher biofuel content compared to other countries (BÖRJESSON HAGBERG; PETTERSSON; AHLGREN, 2016).

According to Benvenutti et al. (2019), mitigation strategies adopted by increasing biofuel consumption produce to the reduction of CO_2 emissions from vehicular sources in a short period of time. Based on estimates made by the GHG Protocol's calculation tool, increasing biofuel consumption over fossil fuel consumption, for example increasing the use of biodiesel by up to 30%, is an effective means of reducing GHG emissions from mobile combustion sources (DULLIUS et al., 2017). In the short term, the use of biofuels leads to reduced GHG emissions from mobile sources, such as trucks, and has been successfully carried out in EU countries such as Sweden and the Netherlands (MÅNSSON; SANCHES-PEREIRA; HERMANN, 2014). In the case of the printing industry, there is a benefit in the use of biofuels in transportation, to reduce GHG emissions.

The results of the Mitigation Plan at the sources are described in Figure 2, using the strategies of the replacement of diesel (a) and gasoline (b) by biodiesel and ethanol, expressed in metric tons of GHG.

Figure 2: Results of mitigation strategies with the replacement of diesel (a) and gasoline (b) by biodiesel and ethanol, expressed I metric tons of GHG





Source: Prepared by the authors.

Considering the Scope 2, the replacement of the energy matrix was addressed based on the scientific and technical literature that points out the advantages of the alternative use of photovoltaic energy to reduce GHG emissions (JÄGER-WALDAU et al., 2020; LIMA et al., 2020; COUTINHO and VIANNA, 2020). Another important point is that this energy source has lower GHG emission factors compared to other energy matrices (IPCC, 2014b). In a study conducted in the state of Minas Gerais (MG), which compared GHG emissions by replacing conventional energy (hydroelectric) by photovoltaic energy generation, a 57.16 % reduction in CO_2 emissions was obtained (APARECIDA et al., 2017). Considering that the emission factors of solar energy are 0.020 to 0.050 kg $CO_{2eq.}$ kWh^{-1}, while the average factor of the National Interconnected System was 0.0817 t $CO_{2eq.}$ kWh^{-1}.

Wu et al. (2017) demonstrated that in Asia and Southern Europe, emissions factors for photovoltaic systems were investigated through a system life cycle analysis, which ranged from panel manufacturing to system balancing (equipment installation and operations).

During the quantification of GHG emissions for mitigation using photovoltaics, a CO_2 emission factor (EF) was selected based on the research conducted by Wu et al. (2017). The choice of EF was determined by the solar radiation rate, similar to that of Rio de Janeiro, and the emission factor of 0.045 kg $CO_{2eq.}$ kWh^{-1} was applied. The emission result was 47,883 t $CO_{2eq.}$, which resulted in a 42.9 % reduction in Scope 2 emissions in the projected year for the start of mitigation compared to the average emissions in the triennium.

The substitution of the energy source besides reducing the GHG emissions favors economic and sustainability aspects. In this Graphical Industry, an investment of approximately 475,079 dollars was estimated to meet the energy demand. The investment anticipates a payback of two and a half years to cover the project costs and energy consumption.

Several incentives for waste composting are being widely disseminated around the world and these are being encouraged by various researchers (AWASTHI et al., 2020). As a result of this waste management, the emissions projections showed a reduction of 87.9 % in CH_4 emissions from the treatment of non-hazardous waste compared to the base year. This corresponds to a reduction of 28.7 % in total inventoried emissions in terms of t CO_{2eq}.

Through this mitigation plan study, the reduction in waste disposal would avoid the emissions of 51,564 t CO_{2eq}, per year. Waste management in the printing industry, based on waste recycling, reuse, and composting provides short-term GHG emission reduction in addition to contributing to reducing methane generations in landfills (BORBA et al., 2018).

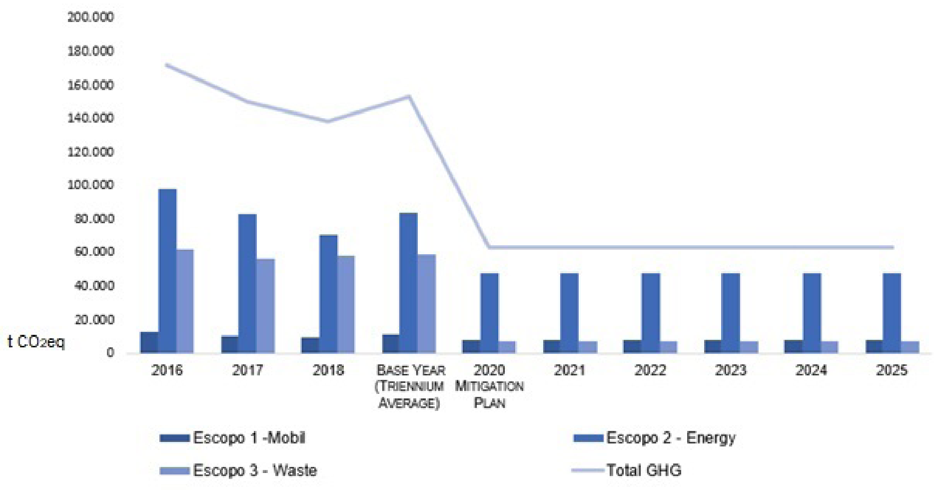
The technical feasibility of recycling plastic waste is based on the mechanical and chemical conversion into new materials, such as accessories, rolls, and material for banners and posters, which avoids sending this waste to landfills.

The opportunity to recycle plastic materials was the subject of a study in Spain (SEVIGNÉ-ITOIZ et al., 2015) and the authors point out that the type of polymer and level of plastic material contamination is a limiting factor for the replacement of virgin plastic.

Several incentives for waste composting are being widely disseminated around the world and these are being encouraged by various researchers (AWASTHI et al., 2020). Composting offers many benefits in addition to causing lower GHG emissions, such as the use of compost byproducts that can serve as fertilizers. In addition, they are the most viable alternative means of diverting this waste from landfills, where they are large emitters of CH_4 (VERAS, 2018).

The results of the mitigation plan show an estimated reduction in GHG emissions of 90,489 t $CO_{2eq.}$, which corresponds to a 50.3 % reduction from the base year emissions, as shown in Figure 3 based on the ISO14064 standard (ISO, 2007b).

Figure 3: Results of the GHG emission mitigation plan for the three Scopes analyzed



Description: Results of the percentage of emissions prevented through the mitigation plan in the Graphics Industry.

Scope	Source	Contribution of emissions to the general inventory Triennial average	Reduction in The General Inventory of Emissions	Emissions avoided to atmosphere ($tCO_2eq.$)
Scope 1	Mobile Fuel	6.1 %	- 1.6 %	- 2.924
Scope 2	Energy	46.6 %	- 20.0 %	- 36.001
Scope 3	Treatment of non-hazardous waste	32.6 %	- 28.6 %	- 51.564
Total	**Mobile Fuel, Energy and Waste**	**85.3 %**	**- 50.3 %**	**- 90.489**

Source: The authors, based on research data.

The methodology adopted was dependable and ensures the possibility of meaningful comparisons of GHG-related information considering that the calculations of emissions are identified, consistent over the years, available to stakeholders, and in a traceable and justified form.

Conclusion

The methodology applied in the GHG estimates in the Mitigation Plan Proposal is materially effective and feasible, obtaining satisfactory results in a short period.

Moreover, according to the calculations based on the GHG Protocol Program Tool from Fundação Getúlio Vargas and the references of the GHG emission factors based on IPCC, the reduction of GHG emissions by 50.3 % was evidenced, and its maintenance will avoid the emissions of 90,489 t CO2eq per year to the atmosphere.

Once the inventory calculation methodology and mitigation plan are clearly defined, with limits and sources established, it is believed that the study of the GHG reduction estimates technically allows the reproduction of the proposed actions in other graphic industries and other industrial activities, strengthening the sustainable development of the graphic industry worldwide.

This paper analyzed the strategies for reduction and mitigation of GHG emissions for the printing industry focusing on its main environmental aspects: energy consumption, waste management and transportation. These aspects are common to printing industries all over the world. Also fill the gaps on research about solutions to adapt small businesses and the printing industry sector to the climate agenda.

Finally, it is expected that this study will motivate further research on GHG emissions mitigation plans and contribute to the development of new projects to control GHG emissions and contain the increase in global warming.

References

ABIGRAF. **Numbers of the Brazilian Graphic Industry - Profile of the Brazilian Graphic Industry Companies** in 2019. *[S. l.]*, 2020.

ABREU, Mônica Cavalcanti Sá De; ALBUQUERQUE, Aline Mota; FREITAS, Ana Rita Pinheiro De. **Strategic positioning in response to regulatory constraints on greenhouse gas emissions**. Revista de Administração, *[S. l.]*, v. 49, n. 3, p. 578–590, 2014. DOI: 10.5700/rausp1169.

ADEDEJI, Adedayo Rasak; ZAINI, Fauzi; MATHEW, Sathyajith; DAGAR, Lalit; PETRA, Mohammad Iskandar; DE SILVA, Liyanage C. **Sustainable energy towards air pollution and climate change mitigation**. Journal of Environmental Management, *[S. l.]*, v. 260, n. December

2019, p. 109978, 2020. DOI: 10.1016/j.jenvman.2019.109978.

AGUIAR, Lídia Vaz; FORTES, Julio Domingos Nunes; MARTINS, Eduardo. **Carbon compensatory neutralization – case study: mechanic metal industry, Rio de Janeiro (RJ), Brazil.** Engenharia Sanitaria e Ambiental, *[S. l.]*, v. 21, n. 1, p. 197–205, 2016. DOI: 10.1590/S1413-41520201600100116414.

APARECIDA, Larissa; OLIVEIRA, Nascimento; RAMOS DE SOUZA, Marcella; PEREIRA; MAURO LÚCIO FILHO MEDINA. **CO2 reduction potential through the use of electric power in motor pumps used in the irrigation in the Municipality of Dona Euzébia – MG (Brazil): a comparative study of hydroelectric and photovoltaic matrices.** [s.l: s.n.].

AWASTHI, Sanjeev Kumar; SARSAIYA, Surendra; AWASTHI, Mukesh Kumar; LIU, Tao; ZHAO, Junchao; KUMAR, Sunil; ZHANG, Zengqiang. **Changes in global trends in food waste composting: Research challenges and opportunities Bioresource Technology**Elsevier Ltd,, 2020. DOI: 10.1016/j.biortech.2019.122555.

ASHRAE **Refrigerant Designations.** Disponível em: <https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations>. Acesso em: 8 jul. 2021.

BENVENUTTI, Lívia M.; URIONA-MALDONADO, Mauricio; CAMPOS, Lucila M. S. **The impact of CO 2 mitigation policies on light vehicle fl eet in Brazil**. Energy Policy, *[S. l.]*, v. 126, n. April 2018, p. 370–379, 2019. DOI: 10.1016/j.enpol.2018.11.014.

BORBA, Priscila Falcão de Sá; MARTINS, Eduardo Monteiro; CORREA, Sergio Machado; RITTER, Elisabeth. **Greenhouse gases emissions from a landfill in Rio de Janeiro**. Engenharia Sanitaria e Ambiental, *[S. l.]*, v. 23, n. 1, p. 101–111, 2018. DOI: 10.1590/S1413-41522018167438.

BÖRJESSON HAGBERG, Martin; PETTERSSON, Karin; AHLGREN, Erik O. **Bioenergy futures in Sweden - Modeling integration scenarios for biofuel production**. Energy, *[S. l.]*, v. 109, p. 1026–1039, 2016. DOI: 10.1016/j.energy.2016.04.044.

BRAZIL. **2019. Average factor - Corporate inventories. CO_2 Emission Factors for uses that require the average emission factor of the National Interconnected System of Brazil, such as, for example, corporate inventories. Ministry of Science, Technology and InnovatiMinistry of Science, Technology and Innovations. 2020.** [s.l: s.n.].

BRAZIL. **National Inventory of Atmospheric Emissions By Road Automotive Vehicles**. 2013. *[S. l.]*, 2014.

BRAZIL. **Intended Nationally Determined Contribution**. Towards Achieving The Objective Of The. United Nations Framework Convention On Climate Change. Pursuant to decisions 1/CP.19 and 1/CP.20, the Government of the Federative Republic of Brazil is pleased to communicate to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) its intended Nationally Determined Contribution (iNDC) in the context of the negotiations of a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties. Brazil, 2016.

CARO, Dario. **Carbon Footprint**. 2. ed. [s.l.]: Elsevier Inc., 2019. DOI: 10.1016/b978-0-12-409548-9.10752-3.

CARSTENS, Danielle Denes dos Santos; DA CUNHA, Sieglinde Kindl. **Challenges and opportunities for the growth of solar photovoltaic energy in Brazil**. Energy Policy, *[S. l.]*, v. 125, n. February 2018, p. 396–404, 2019. DOI: 10.1016/j.enpol.2018.10.063.

CHANDRAKUMAR, Chanjief; MCLAREN, Sarah J.; MALIK, Arunima; RAMILAN, Thiagarajah; LENZEN, Manfred. **Understanding New Zealand's consumption-based greenhouse gas emissions: an application of multi-regional input-output analysi**s. International Journal of Life Cycle Assessment, *[S. l.]*, 2019. DOI: 10.1007/s11367-019-01673-z.

COLLING, A. V.; OLIVEIRA, L. B.; REIS, M. M.; DA CRUZ, N. T.; HUNT, J. D. **Brazilian recycling potential: Energy consumption and Green House Gases reductionRenewable and Sustainable Energy Reviews**Elsevier Ltd,, 2016. DOI: 10.1016/j.rser.2015.12.233.

COUTINHO, G. L., VIANNA, J. LALCA: **Emissões de GEE evitadas em Cabo Verde: estimativa em um cenário de adoção de fontes energéticas renováveis em 2025** Revista Latino-Americana em Avaliação o Ciclo de Vida. *Instituto Brasileiro de Informação em Ciência e Tecnologia*, v. 4, p. e45077–e45077: <http://lalca.acv.ibict.br/lalca/article/view/5077>.

DING, Ning; LIU, Jingru; KONG, Zike; YAN, Li; YANG, Jian Xin. **Life cycle greenhouse gas emissions of Chinese urban household consumption based on process life cycle assessment: Exploring the critical influencing factors.** Journal of Cleaner Production, *[S. l.]*, v. 210, p. 898–906, 2019. DOI: 10.1016/j.jclepro.2018.10.242.

DULLIUS, Alexandre; DE OLIVEIRA, Erick Renan Xavier; DA SILVA, Maclóvia Corrêa; SANQUETTA, Carlos Roberto. **Sustentabilidade Urbana por Meio de Análise de Tecnologias Renováveis no Transporte Público da Cidade de Curitiba.** Revista de Gestão Ambiental e Sustentabilidade, *[S. l.]*, v. 6, n. 2, p. 73–88, 2017. DOI: 10.5585/geas.v6i2.883.

EPA. **Greenhouse Gas Inventory Guidance: Fugitive Emissions Environmental Protection Agency, Us Protection Partnerships Division, Climate**. [s.l: s.n.].

FGV. **Guidelines for accounting for scope 2 emissions in corporate greenhouse gas inventories under the Brazilian GHG Protocol Summary Program.** Greenhouse Gas Protocol, *[S. l.]*, v. 2, 2018.

FGV. **Programa Brasileiro GHG Protocol. Specifications of the Brazilian GHG Protocol Program.** 2019. Disponível em: http://ghgprotocolbrasil.com.br/o-programa-brasileiro-ghg--protocol?locale=pt-br. Accessed: 16 Feb. 2020 Accessed: 16 Feb. 2020.

FGV. **Public Emissions Register Brazilian GHG Protocol Program.** 2020. Disponível em: http://www.registropublicodeemissoes.com.br/participantes. Acesso em: 8 fev. 2020.

FIRJAN. 2018 **Annual Report Rio de Janeiro Graphic Industries Union**. Firjan Federation of Industrialists of Rio de Janeiro, *[S. l.]*, 2018.

GOOD, Clara; KRISTJANSDOTTÍR, Torhildur; HOULIHAN WIBERG, Aoife; GEORGES, Laurent; HESTNES, Anne Grete. **Influence of PV technology and system design on the emission balance of a net zero emission building concept.** Solar Energy, *[S. l.]*, v. 130, p. 89–100, 2016. DOI: 10.1016/j.solener.2016.01.038.

HICKMANN, Thomas. **Voluntary global business initiatives and the international climate negotiations: A case study of the Greenhouse Gas Protocol.** Journal of Cleaner Production, *[S. l.]*, v. 169, p. 94–104, 2017. DOI: 10.1016/j.jclepro.2017.06.183.

HWANG, Kum Lok; CHOI, Sang Min; KIM, Moon Kyung; HEO, Jong Bae; ZOH, Kyung Duk. **Emission of greenhouse gases from waste incineration in Korea.** Journal of Environmental Management, *[S. l.]*, v. 196, p. 710–718, 2017. DOI: 10.1016/j.jenvman.2017.03.071.

IPCC. 2006 IPCC Guidelines for National Greenhouse Inventories – **A primer, Prepared by the National Greenhouse Gas Inventories Programme**. Eggleston H.S., Miwa K., Srivastava N. and Tanabe K. Iges, *[S. l.]*, p. 20, 2006.

IPCC. **Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC**. Geneva, Switzerland.

IPCC. **Climate Change 2014 Mitigation of Climate Change**. [s.l: s.n.]. DOI: 10.1017/cbo9781107415416.

IPCC. **Special Report on global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathwaysSpecial Report, Intergovernmental Panel on Climate Change**. [s.l: s.n.].

IPCC. **2019 REFINEMENT TO THE 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES**. [s.l: s.n.].

ISO. ISO 14064-1 **Greenhouse gases - Specification with guidance at the organizational level for quantification and reporting of greenhouse gas emissions and removals.** International Organization, *[S. l.]*, v. 2007, p. 32, 2007. a.

ISO. ISO 14064-2:2007. **Greenhouse gases Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.** 2007b. p. 36.

JÄGER-WALDAU, A. *et al.* **How photovoltaics can contribute to GHG emission reductions of 55% in the EU by 2030.** *Renewable and Sustainable Energy Reviews*, v. 126, p. 109836, 1 jul. 2020. Acesso em: 8 jul. 2021.

LIMA, M. A. *et al.* **Renewable energy in reducing greenhouse gas emissions: Reaching the goals of the Paris agreement in Brazil.** *Environmental Development*, v. 33, p. 100504, 1 mar. 2020. Acesso em: 8 jul. 2021

MÅNSSON, André; SANCHES-PEREIRA, Alessandro; HERMANN, Sebastian. **Biofuels for**

road transport: Analysing evolving supply chains in Sweden from an energy security perspective. Applied Energy, *[S. l.]*, v. 123, p. 349–357, 2014. DOI: 10.1016/j.apenergy.2014.01.098.

NWAIGWE, K. N.; MUTABILWA, P.; DINTWA, E. **An overview of solar power (PV systems) integration into electricity grids**. Materials Science for Energy Technologies, *[S. l.]*, v. 2, n. 3, p. 629–633, 2019. DOI: 10.1016/j.mset.2019.07.002.

NOBRE, Carlos A.; MARENGO, Jose A.; SOARES, Wagner R. **Climate change risks in Brazil**. [s.l.]: Springer International Publishing, 2018. DOI: 10.1007/978-3-319-92881-4.

NWAIGWE, K. N.; MUTABILWA, P.; DINTWA, E. **An overview of solar power (PV systems) integration into electricity grids.** Materials Science for Energy Technologies, *[S. l.]*, v. 2, n. 3, p. 629–633, 2019. DOI: 10.1016/j.mset.2019.07.002.

ONS (BRAZIL). **Balance of EnergyNational Electrical System Operator (ONS) Brazil.** Rio de Janeiro, Brazil.

SEINFELD, John H.; PANDIS, Spyros N. **Atmospheric Chemistry and Physics: From Air Pollution to Climate Change**. 3ª ed. New Jersey.

SEROA DA MOTTA, R. **Precificação do carbono: do protocolo de Quioto ao Acordo de Paris**. In: FLAVIA WITKOWSKI FRANGETTO, ANA PAULA BEBER VEIGA, G. L. (Org.). *Legacy of the CDM: lessons learned and impacts from the Clean Development Mechanism in Brazil as insights for new mechanisms*. 1. ed. Rio de Janeiro: [s.n.], 2019. p. 341356. <https://www.ipea.gov.br/portal/images/stories/PDFs/livros/livros/191213_legacy_of_the_cdm.pdf>.

SEVIGNÉ-ITOIZ, Eva; GASOL, Carles M.; RIERADEVALL, Joan; GABARRELL, Xavier. **Contribution of plastic waste recovery to greenhouse gas (GHG) savings in Spain**. Waste Management, *[S. l.]*, v. 46, n. 2015, p. 557–567, 2015. DOI: 10.1016/j.wasman.2015.08.007.

SINGH, Neelam; DAMASSA, Thomas; ALARCÓN-DÍAZ, Soffia; SOTOS, Mary. Exploring Linkages Between National and Corporate / Facility Greenhouse Gas Inventories. *[S. l.]*, n. March, p. 1–16, 2014.

STEFFEN, Will; BROADGATE, Wendy; DEUTSCH, Lisa; GAFFNEY, Owen; LUDWIG, Cornelia. **The trajectory of the anthropocene: The great acceleration.** Anthropocene Review, *[S. l.]*, v. 2, n. 1, p. 81–98, 2015. DOI: 10.1177/2053019614564785.

STEFFEN, Will; CRUTZEN, Paul J.; MCNEILL, John R. Week 1-Steffen et al (2007) http://dx.doi.org/10.1579/0044-7447(2007)36[614:TAAHNO]2.0.CO;2. AMBIO: A Journal of the Human Environment, *[S. l.]*, v. 36, n. 8, p. 614–621, 2007. DOI: 10.1579/0044-7447(2007)36[614:TAAHNO]2.0.CO;2.

UNFCCC. **COP 21**. 2015. Disponível em: https://unfccc.int/process-and-meetings/conferences/past-conferences/paris-climate-change-conference-november-2015/cop-21. Acesso em: 16 fev. 2020.

VERAS, Roani Simões. **Composting of food residues and shredded tree prunings on static**

ledges as a Mechanism for geo eduction. 2018. Universidade Federal do Ceará, *[S. l.]*, 2018.

WRI. **Mitigation Goal Standard An accounting and reporting standard for national and subnational greenhouse gas reduction goals World Resources Institute team Advisory Committee members**. [s.l: s.n.].

WU, Peishi; MA, Xiaoming; JI, Junping; MA, Yunrong. **Review on Life Cycle Assessment of Greenhouse Gas Emission Profit of Solar Photovoltaic Systems**. *In*: ENERGY PROCEDIA 2017, **Anais** [...].: Elsevier Ltd, 2017. p. 1289–1294. DOI: 10.1016/j.egypro.2017.03.460

Rafael da Silva Caldeira
rafascald@gmail.com
ORCID: https://orcid.org/0000-0003-1657-4669

Submitted on: 16/11/2020
Accepted on: 10/04/2022
2022;25:e02102

Simone Lorena Quiterio de Souza
simone.quiterio@ifrj.edu.br
ORCID: https://orcid.org/0000-0002-8988-3465

Eduardo Monteiro Martins
edmmartins@gmail.com

Sergio Machado Corrêa
sergio@air.pro.br
ORCID: https://orcid.org/0000-0002-0038-0790

AMBIENTE & SOCIEDADE
25 anos años years

Oportunidades de redução das emissões de GEE na indústria gráfica brasileira através de um plano de mitigação

Rafael da Silva Caldeira
Simone Lorena Quiterio de Souza
Eduardo Monteiro Martins
Sergio Machado Corrêa

Resumo: A Indústria Gráfica existe há muitos anos e suas operações incluem serviços de impressão digital, comunicação visual, suprimentos de embalagens e materiais publicitários, ao mesmo tempo em que está envolvida no comércio de bens e serviços em todo o mundo. Este estudo inédito apresenta a quantificação das emissões de gases de efeito estufa (GEE) de uma indústria de gráfica no Brasil nos três anos de 2016, 2017 e 2018. A partir dos resultados desses três anos foi definido o ano base como referência para avaliação de resultados de um Plano de Mitigação de emissões de GEE. O Plano de Mitigação simulado previu uma redução potencial de até 50,3 % dessas emissões. A metodologia segue as recomendações do IPCC. O trabalho pretende incentivar o estudo sobre oportunidades para uma economia e produção de baixo carbono, melhorar desempenhos em boas práticas de sustentabilidade, diante das demandas ambientais para conter a intensificação do efeito estufa e do aquecimento global.

***Palavras-chave*:** GHG Protocol; Emissões de Gases de Efeito Estufa; Plano de Mitigação; Indústria Gráfica; Mudanças Climáticas.

São Paulo. Vol. 25, 2022

Artigo Original

AMBIENTE & SOCIEDADE
25 anos años years
SciELO

Oportunidades para reducir las emisiones de GEI en la industria gráfica brasileña a través De un plan de mitigación

Rafael da Silva Caldeira
Simone Lorena Quiterio de Souza
Eduardo Monteiro Martins
Sergio Machado Corrêa

São Paulo. Vol. 25, 2022
Resenha

Resumen: La industria de la impresión existe desde hace muchos años y sus operaciones incluyen servicios de impresión digital, comunicación visual, suministros de embalaje y materiales publicitarios, al tiempo que participa en el comercio de bienes y servicios en todo el mundo. Este estudio sin precedentes presenta la cuantificación de las emisiones de gases de efecto invernadero (GEI) de una industria gráfica en Brasil en los tres años 2016, 2017 y 2018. A partir de los resultados de estos tres años, se definió el año base como referencia para evaluar los resultados de un Plan de Mitigación de emisiones de GEI. El Plan de Mitigación simulado preveía una reducción potencial de hasta el 50,3% de estas emisiones. La metodología sigue las recomendaciones del IPCC. El trabajo pretende fomentar el estudio de las oportunidades de una economía y producción bajas en carbono, mejorar el rendimiento en las buenas prácticas de sostenibilidad, dadas las exigencias medioambientales para contener la intensificación del efecto invernadero y el calentamiento global.

***Palabras-clave*:** Protocolo de GEI; emisiones de gases de efecto invernadero; plan de mitigación; industria gráfica; Cambio Climático.