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INVENTORY OF GREENHOUSE GASES FOR STEEL FOUNDRIES

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ABSTRACT

Concern about greenhouse gases has been a widespread theme among scientific communities in relation to the impacts on the environment over the years. Public policies increasingly tighten their actions to mitigate the damages that man causes to the planet, developing mechanisms of control and monitoring. Companies, in turn, begin to realize the issue, not only for improving the quality of life and sustainability of biological structures, but also as a way to secure their business strategically. From the study carried out at a steel smelter in the city of Sorocaba, the emission sources were mapped and the related data were analyzed according to the parameters established by the Greenhouse Gases Protocol. The emissions of the years 2013 and 2014 were observed, establishing a comparative analysis and pointing out the main actions of greater relevance in the process of reduction of these sources.

Keywords: Casting steel; greenhouse gases; inventory.

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1. INTRODUCTION

It can be seen that in a period of 100 years between the twentieth and the first years of the 21st century, there was an increase in the world temperature between 0.6 and 0.7ºC. Today, this decade has presented, in three consecutive years, the hottest years of the last 1000 years of the recent history of planet Earth (NAE, 2005a).

Through the Intergovernmental Panel on Climate Change (IPCC), there was an increase in greenhouse gases (GHG), specifically aerosols. These emissions are cumulative, with carbon dioxide (CO_2) from burning fossil fuels, such as coal, oil and natural gas being the main causative gas. This history has lasted since the industrial revolution, also linked, to a lesser extent, to deforestation of the vegetation cover.

Thus, climate change has manifested itself in a number of ways, including global warming, extreme climate change, altered rainfall levels, rising ocean levels, and declining glaciers. If effective action is not taken in the coming decades, the current situation may be aggravated (Sant'Anna Neto, 2000).

From this premise emerged the Climate Convention, aiming to mitigate increases in atmospheric emissions, and to understand the problems of climate change and the ecosystems of the planet. This convention was of a universal character, signed and ratified by all countries aiming at minimizing the magnitude of climate change. The third Conference of the Parties (COP 3) was held in Kyoto, Japan in 1997, culminating in the adoption by consensus of the Kyoto Protocol (NAE, 2005b).

The Kyoto Protocol defined that the industrialized countries' goal was to reduce, at least, 5.2% of their combined greenhouse gas emissions from 1990 levels. In order for the protocol based in Japan to enter into force, the ratification of at least 55 countries would be necessary. Together these countries would correspond to, at least, 55% of global GHG emissions (Oliveira, 2008).

The protocol entered into force on February 16, 2005, constituting a legal commitment that binds all parties involved, and failure to observe any part will be subject to penalties within the scope of the protocol. This reinforces the need for emerging countries with emerging economies, such as China, India and Brazil, to join the group and reduce their environmental liabilities, including atmospheric emissions. This issue has been closely watched, as developing countries do not need to have emission targets attached to them. From the economic point of view, these countries can contribute to the Clean Development Mechanism (CDM). Thus, they would receive financial support for projects with sustainable development, scientific knowledge and adoption of technological innovations (NAE, 2005a).

With this guideline, Brazil analyzed and put in debate that the annual emission does not show a good approximation of the common responsibilities in the climate change. Thus, the polluting payer policy is permeated, establishing limits for GHG emissions. Another outstanding condition is the use of "cumulative emissions" instead of "temperature increase", aiming and simplifying the cumulative index and approaching the number of the temperature increase. In this way, it will be possible to verify the responsibilities of each country to increase or decrease the concentration of gases limited and fixed in Kyoto (NAE, 2005a).

Relevant discussions related to atmospheric emissions are occurring in the world. In Brazil, this issue is being discussed as well, but more slowly (Pikman et al., 2015).

In corporate scenarios, there is a commitment among the United Nations to reduce emissions since the Kyoto Protocol. Europe has been leading the decarbonisation process in its emissions. The more simplified shifts have already taken place, and at the present time there remain the burdens that involve greater investment.

There is already a mobilization about the problematic involving the processes of generation of energy with greater emission of carbon for processes of cleaner emissions. An obvious example is the exchange of the thermoelectric process by the use of natural gas; and in the sequence, the exchange of the energy generated by gas by the solar energy, aiming at the reduction of GHG emissions in the atmosphere.

This type of concept has been absorbed by companies not only for sustainability, but also to promote market competitiveness.

It is noted that emissions in the United States have declined by 28% since 2012, while production has grown 1.8% due to the use of shale gas as alternative energy in industrial and domestic processes. This gas has been one of the energy options with lower CO2 emission in relation to fossil fuels and low sale cost, being indicated in the agenda of subjects and discussed in the conference of Paris COP 21. This question refers to the lack of knowledge about the capture of this gas, since any deviation in the process can cause problems, generating environmental impact, which may make the use of this resource impracticable. Studies on this gas are recent, and not all countries adhere to this solution with optimism (Pikman et al., 2015).

For the industry, climate models can generate impacts, such as sea level rise. These can also cause events such as lightning strikes, an increase in epidemiological diseases or even an increase or decrease in rainfall levels in regions where companies are located.

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Companies have been anticipating climate change and have been timely planning for this problem. In the case of the mining industries, they are installed at predefined locations, that is, where the ores are located (Pikman et al., 2015).

Studies conducted with estimates of 40 years always observe the worst case scenario, highlighting how the company would deal with these difficulties while maintaining productive performance. On that occasion, a thorough evaluation involving the financial risks, the processes, and the exposure of the company name occurs, and then the investment decision for the future controls happens (Pikman et al., 2015).

The State of São Paulo, assuming its role through climate change, through Law No. 12,187 of December 2009, implemented criteria for reducing greenhouse gases, indicating conditions, processes or activities that emit gases characterized as GHG, seeking cleaner alternatives. Similarly, State Decree No. 54,487 of June 26, 2009, article 4, refers to the emission points of such gases, where it is necessary to carry out a survey and register, inventorying the primary, fixed and mobile emissions of pollution, obliging companies to submit to Cetesb a complete plan for the release of liquid, solid and gaseous wastes when requested.

This decree, Article 2, makes it clear which gases generate the need for an inventory of GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFC) and perfluorocarbons (PFCs). By characterizing the ratio of the gases mentioned above, Article 3 indicates which possible processes may emit greenhouse gases. For this, there is a list of productive activities that, on an obligatory basis, will require this inventory and environmentally correct measures. Specifically in its section VI it is established that “ferrous foundries with a production capacity greater than 7500 t/year” need to deliver the inventory and propose improvements in its process.

Based on the establishment of the environmental agency in the state of São Paulo and on the need for foundries to issue the established report, we directed our studies to a manganese steel smelter operating for 30 years in the city of Sorocaba, in the state of São Paulo, with productive capacity of, approximately, 18,000 t/year for parts for ore crushing and wear.

2. DEVELOPMENT

The Inventory of greenhouse gases in Brazil

It is argued that the preparation of inventories is one of the steps for an institution or company to contribute to the fight against climate change, a critical phenomenon that afflicts humanity. Knowing the profile of emissions, based on the diagnosis guaranteed by the inventory, can establish strategies, plans and targets for the reduction and management of greenhouse gas emissions, engaging in the solution of this enormous challenge for global sustainability. Conducting GHG inventories also allows organizations to visualize new business opportunities in the carbon market, attract new investments, or even design processes that ensure economic, energy or operational efficiency. It also demonstrates the company’s responsibility to solve problems that afflict society as a whole and makes its commitment transparent and public.

The Brazilian GHG Protocol Program, initiated in May 2008, aims to support and stimulate an “inventory culture” in Brazil, allowing Brazilian organizations to establish GHG emissions management processes and to become competitive in the international market, positioning themselves actively for sustainability. The information reported to the program complies with the objectives described above and is consistent with internationally accepted principles for GHG inventories accounting and elaboration (GHG Protocol, 2008).

In addition, the specifications of the Brazilian Program GHG Protocol (2008) explain what is required of the participants, as well as what is optional for the preparation and publication of this information. The Program may develop new complementary standards to promote periodic changes in specifications so as to follow the evolution of national and international GHG emissions accounting practices, ensuring continuous improvement of its actions. Any complementation or alteration to the content is made available on the website of the Brazilian GHG Program.

Among the various existing methodologies for conducting greenhouse gas inventories, The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard, or simply GHG Protocol, launched in 1998 and revised in 2004, is now the world’s most widely used tool by companies and governments in order to understand, quantify and manage their emissions. The GHG Protocol was developed by the World Resources Institute (WRI) in association with the World Business Council for Sustainable Development (WBCSD). Among the characteristics of the tool, it is worth mentioning the fact that it offers a structure for GHG accounting, the modular and flexible nature, the neutrality in terms of policies or programs, and the question of being based on a broad process of public consultation. The methodology of the GHG Protocol is compatible with the standards of the International Organization for Standardization (ISO) and with the methodologies of quantification of the Intergovernmental Panel on Climate Change (IPCC 2006) and its application in Brazil, from the beginning of the Brazilian GHG Protocol in

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2008, takes place in a way adapted to the Brazilian context. The information generated can be applied to the reports and questionnaires of initiatives such as the Carbon Disclosure Project, the Bovespa Index of Corporate Sustainability (ISE) and the Global Reporting Initiative (GRI) (Brazilian Program GHG Protocol, 2008).

Standards and calculation methodology

Emissions of greenhouse gases shall follow the recommendations of the 2006 IPCC. The calculation shall be made from the product of an activity data by an appropriate emission factor. That is, the amount of fuel used, considering the way it is used.

The activity data is a measure that expresses the intensity of a given source. Examples of activity data are the fuel consumption in a fleet of a company's vehicles, the consumption of diesel oil in electric generators, the number of working hours of a water pump, the quantity (i.e. mass) of graphite electrodes used in welding, the amount of natural gas used in heat treatment furnaces, and so on. In the measure of activity, this is a quantitative and non-qualitative analysis.

Emission factor

The emission factor is directly associated with the source (activity). Emission factors demonstrate the amount of CO_2 equivalent emitted per unit of activity. In this way, it is possible to demonstrate how an activity can contribute to the emission of greenhouse gases, that is, it is a measure of the emission rate. For example, an average emission factor resulting from the combustion of gasoline is 2,135 kg CO_2/m^3 gasoline. This emission factor depends on the composition of the fuel, the content of anhydrous ethyl alcohol in gasoline ranges from 20 to 25%, and also on the engine conditions (IBAMA, 2011).

The calculation of the gasoline emission factor is an example, since it has distinct concentrations of alcohol. In Brazil it varies from region to region and the time of year. These factors give rise to uncertainties for the estimation of the emission factor and, consequently, for the emission of polluting sources.

In the absence of detailed information, there is the option of using emission factors available in the literature. It is important to be careful to employ factors that are closest to reality and, if possible, conservative. Conservative factors are those that overestimate some emission due to lack of knowledge of some information. For example, if the alcohol content in gasoline is not known, the lowest possible value should be adopted, as it results in the highest GHG emission.

Inventories of greenhouse gas emissions

In an inventory of greenhouse gases, emissions from all sources defined in groups of activities associated to a company are counted. It is understood that the limits of activities are fundamental in the performance of a good inventory. An inventory of greenhouse gases should consider widely applied premises, and sources should also be grouped on some general criterion. A typical grouping or scope is to classify sources that are of direct, indirect or associated emissions to the generation of electrical energy (including heat and steam). It is defined to follow as the grouped sources and what assumptions should be used in the calculation of emissions (Brasil et al., 2008).

The application of assumptions is fundamental to ensure that the related GHG information is the result of a safe calculation. The principles (or assumptions) form the basis for the uniformity of methods in the inventory and between inventories of different companies. The principles presented here correspond to the premises presented by the GHG Corporate Protocol (Damassa et Elsayed, 2013) and provided for by ISO 14064.

3. METHODOLOGY

The methodology presented in the Brazilian GHG Protocol Program divides emissions into three large scopes plus biomass emissions. They are:

- **Scope 1:** Direct GHG Emissions - These are from sources that belong to or are controlled by the Organization, which must be divided into: stationary combustion, mobile combustion, emissions of physical and chemical processes, fugitive emissions and agricultural emissions. GHG emissions and precursor gases not covered by the Kyoto Protocol, such as CFCs, HCFCs, NOx and etc., should not be included in Scope 1, but may be reported separately under the GHG Protocol Corporate 2014.

- **Scope 2:** Indirect GHG Emissions - these emissions are attributed to the purchase of electricity, heat or steam, which are emitted at the place of its generation. They can be divided into: purchase of electricity and purchase of heat or steam. For many organizations, purchased energy represents a major source of GHG emissions and the most significant opportunity to reduce such emissions. Accounting for Scope 2 emissions enables us to assess opportunities and risks associated with changing energy costs and GHG emissions. "Another important reason for accounting for these emissions is that information may be mandatory for some GHG management programs," (GHG Protocol, 2008).

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- **Scope 3** (optional): Other indirect emissions of GHG - Indirect emissions related to the activity of the organization, but occurring in sources that do not belong or are not controlled, such as outsourcing of services, transport of raw materials, finished and disposable products, use of fuel by employees to move to the company or other activities. Accounting for Scope 3 emissions need not involve a full GHG life cycle analysis of all products and operations. Usually, it is useful to focus on one or two of the largest GHG-generating activities (Brazilian Program GHG Protocol, 2008).

3.1 Methodology of emission calculations

Manganese Steel

Verifying the scopes presented, through data obtained in a manganese steel smelter, were selected to those referring to the process "in loco", in the sector of the Steelworks.

Through the integrated system of fiscal and tax issues and inventory control, we used the S.A.P system to retain the presented data. Therefore, our scope, extracting the data, refers to the days between January 1, 2014 and December 31, 2014.

In addition to the analysis of the production system, which can be measured by the preparation and transformation of the steel, taking into account that the quantity of materials in each process can be modified according to the characteristic of the part to be cast, we would also inventorise in a spreadsheet the quantity of materials and the amount of CO_2 on the basis of calculations, comparing with the GHG Protocol literature assigned as scope 1. It was used as calculation basis for CO2 emissions GHG Protocol, the equation 4.9 found in Vol. 3, Chapter 4 of the IPCC Guidelines (2006).

To determine the amount of carbon dioxide equivalent in the process emissions, the following model:

$$\frac{\sum Ciu}{\sum Cpp} = EC(kg) \rightarrow \frac{EC}{1000} = EC(t) \qquad (1)$$

Where:

Ciu= carbon sum of the inputs used (kg)

Cpp= Carbon sum of products produced (kg)

EC= Carbon emissions (kg)

We have:

$$I.Fc = QCI$$
$$I.Fc = QCP \qquad (2)$$

Where:

I = Inputs (kg)

Fc = Carbon Fraction (J/cal)

QCI = Amount of input carbons (kg)

QCP = Amount of carbons produced (kg)

Therefore we will have:

$$EC.Ft = te \qquad (3)$$

Where:

EC = Carbon emissions (t)

Ft = Carbon/carbon dioxide conversion factor (kg CO_2/m^3)

te = Carbon dioxide equivalent (t)

In steel smelting processes, the value of 3,66666666666667 is set as conversion factor for the execution of carbon dioxide emission calculations.

Acetylene

In the transformation stage of the steel, data were obtained from the final process of the castings that pass through the deburring after heat treatment in the Deburring and Welding sectors.

As for manganese, the amount of acetylene was inventoried on a spreadsheet and converted to CO_2 according to the predicted GHG Protocol calculations for scope 1.

The emission factor was calculated according to the equation below. This calculation has its own basis, as it does not have specification for this component, determined, according to DD 254 of CETESB (2012).

$$\frac{Fm.CA}{1000} = ECe \qquad (4)$$

Where:

Fm = Mass Factor (kg CO_2/Kg Acetylene)

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CA = Acetylene consumption (kg)

ECe = Carbon emissions (emission of carbon dioxide equivalent) (t)

Natural gas

Natural gas is used in the process of cutting parts, heating pots and tempering, which is part of the production process.

The amount of natural gas was inventoried in a spreadsheet and converted to CO_2 based on calculations of the GHG Protocol assigned to scope 1 (Calculation Basis for CO_2 GHG Protocol emissions for natural gas according to Table 2.3, Chapter 2, Vol. 2, IPCC Guidelines 2006).

$$\frac{(P.FC).((EC)+(Ea.Ga)+(Eb.Gb))}{1000000000} = FEe \qquad (5)$$

Where:

P = Lower calorific value (kcal/m³)

FC = Conversion factor (J/cal)

EC = Emission of carbon dioxide (kg/Tj)

Ea = Methane emission (kg/Tj)

Eb = Emission of nitrous oxide (kg/Tj)

(Ga) = Global warming power of methane (tCO_2e/t)

(Gb) = Global warming power of nitrous oxide (tCO_2e/t)

FEe = Equivalent GHG emission factor $CO_2 + CH_4 + N_2O$ ($kgCO_2e/m^3$)

Thus we have:

$$\frac{\sum Cgn.FEe}{1000} = ECe \qquad (6)$$

Where:

Cgn = Consumption of natural gas in (m³)

FEe = Equivalent GHG emission factor $CO_2 + CH_4 + N_2O$ ($kgCO_2e/m^3$)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Diesel oil

For the process to be placed in a chain of gears there is the use of internal transportation by trucks, cranes, tractors, and some large forklifts. They carry out the entire internal logistics stage, moving hoops or metal boxes, wooden models, finished or semi-finished parts for stock storage.

It was calculated according to the calculation basis for CO_2 emissions of the GHG Protocol for diesel in heavy equipment, according to Table 3.3.1, Chapter 3, Vol. 2, IPCC Guidelines 2006.

Calculating the equivalent GHG emission factor:

$$\frac{(Fe.1)+(Fa.Ga)+(Fb.Gb)}{1000} = FEe \qquad (7)$$

Where we have:

Fe = Emission factor of carbon dioxide (tCO_2/t)

Fa = Methane emission factor (tCH_4/t)

Fb = Nitrous oxide emission factor (tN_2O/t)

(Ga) = Global warming power of methane (tCO_2e/t)

(Gb) = Global warming power of nitrous oxide (tCO_2e/t)

FECe = Carbon emission factor (Emission of carbon dioxide equivalent) (t)

Thus we have:

$$\frac{\sum CD(l).(BDS).(DD).(FECe)}{1000} = ECe \qquad (8)$$

CD(l) = Diesel consumption in liters (L)

BDS = Domestic biodiesel volume (5%)

Dd = Density of diesel (kg/L)

FECe = Carbon emission factor (Emission of carbon dioxide equivalent) (t)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

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Ethanol for Captive Fleet

The captive fleet is used by the company's employees for external locomotion between customers and suppliers. The procedure consists of the register of employees at gas stations, signed in contract with the company under study. From the supply the integrated system of stations is computed and fed, signing values and the amount of fuel supplied by all cars used by the company.

Therefore, we extracted data on the quantity of ethanol fuel consumed from January 1, 2014 to December 31, 2014.

In addition to the analysis, the amount of ethanol was inventoried in a spreadsheet and converted to CO_2 based on calculations of the GHG Protocol assigned for scope 1 (Calculation Basis for CO_2 GHG Protocol emissions for ethanol, according to Table 6 - National Inventory of Emissions by Road Vehicles, MMA, 2011):

Calculating the equivalent GHG emission factor:

$$P.Ea.Ga.FC.0{,}000000001 = FEe \tag{9}$$

Where we have:

P = Lower calorific value (Kcal/m³)

Ea = Methane emission (kg/TJ)

(Ga) = Global warming power of methane (tCO_2e/t)

FC = Carbon Fraction (J/cal)

FEe = Equivalent GHG emission factor CO_2 + CH_4 + N_2O (kg-CO2e/m³)

Thus we have:

$$\frac{\sum CE.d.FEe}{1000} = ECe \tag{10}$$

In which:

CE = Consumption of ethanol (L)

d = Density of ethyl alcohol (kg/L)

FEe = Equivalent GHG emission factor (CH_4 + N_2O) (tCO_2e/t)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Gasoline

From the captive fleet information, we extracted data on the amount of gasoline fuel consumed from January 1, 2014 to December 31, 2014.

In addition to the analysis, the amount of gasoline was inventoried in a spreadsheet and converted into CO_2 based on calculations of the GHG Protocol assigned for Scope 1 (Calculation Basis for CO_2 GHG Protocol emissions for gasoline, according to Table 3.2.1, Chapter 3, Vol 2, IPCC Guidelines, 2006).

Calculating the equivalent GHG emission factor:

$$\frac{P.(ECO_2 + (Ea.Ga) + (Eb.Gb)).FC}{1000000000} = FEe \tag{11}$$

In which:

P = Lower calorific value (Kcal/m³)

ECO_2 = Emission of carbon dioxide (kg/TJ)

Ea = Methane emission (kg/TJ)

(Ga) = Global warming power of methane (tCO_2e/t)

(Gb) = Global warming power of nitrous oxide (tCO_2e/t)

Eb = Emission of nitrous oxide (kg/Tj)

FC = Carbon Fraction (J/cal)

FEe = Equivalent GHG emission factor CO_2 + CH_4 + N_2O (kg-CO_2e/m³)

Thus we have:

$$\frac{\sum (CG.0{,}8.dA.FEeG) + (CG.0{,}2.FEeA)}{1000} = ECe \tag{12}$$

In which:

CG: Gasoline consumption (L)

dA: Density of anhydrous ethyl alcohol (kg/L)

ECe : Carbon emission (Emission of carbon dioxide equivalent) (t)

FEeG: Gasoline emission factor (tCO_2e/t)

FEeA: Alcohol emission factor (tCO_2e/t)

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LPG Gas

GLP gas is used in the internal logistics process of the company, from the receipt of the materials for production, process of transformation, finishing and delivery of the orders, which are carried out with the use of forklifts.

The supply process has its functionality in the raw material warehouse. Generally, the forklifts contain two LPG cylinders of approximately 50 KG, and the fuel system interconnects the cylinder by means of a hose feed to the forklift motor. When the cylinder is finished, the forklift operator performs the exchange of the connection in the reserve cylinder and then performs the exchange of the empty cylinder in the supply center.

Therefore, the amount of natural gas was inventoried in a spreadsheet and converted to CO_2 based on calculations of the GHG Protocol assigned as scope 1 (Calculation Basis for CO_2 Emissions GHG Protocol for LPG in forklift trucks, according to Table 3.2.1, Chapter 3, Vol 2, IPCC Guidelines, 2006):

Calculating the equivalent GHG emission factor:

$$Fe + (Fa.Ga) + (Fb.Gb) = FEe \quad (13)$$

In which:

Fe= Emission factor of carbon dioxide (tCO_2/t)

Fa= Methane emission factor (tCH_4/t)

Fb= Fator de emissão do óxido nitroso (tN2O/t)

(Ga) = Global warming power of methane (tCO_2e/t)

(Gb) = Global warming power of nitrous oxide (tCO_2e/t)

FEe= Equivalent GHG emission factor $CO_2 + CH_4 + N_2O$ ($kgCO_2e/m^3$)

Thus we have:

$$\frac{\sum CGLP.FEe}{1000} = ECe \quad (14)$$

In which:

CGLP: Consumption of liquefied petroleum gas (kg)

FEe= Equivalent GHG emission factor $CO_2 + CH_4 + N_2O$ ($kgCO_2e/m^3$)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Cutting, Welding and Fire Extinguishers

In the transformation of the steel, the finishing process of the casting is contemplated. For this, after the gross melting stage, the steel burrs are removed. After this extraction, the pieces are sent to the thermal treatment sector. After the treatment of the part to obtain the hardness specified in the project, they are sent to the cutting and welding processes.

Regardless of both conditions, the cutting process is the same and the removal of burrs is carried out with the use of torch and gouge if necessary. In the welding process, CO_2 gas Tub is used.

Another gas that is not included in the process, but mentioned in this research, is the sum of the total amount of pressurized CO_2 extinguishers that are used in case of emergency, accident or emergency brigade training.

Specifically for the CO_2 extinguisher, the containers with the extinguishing capacity are analyzed and quantified. Thus, through the system, these variables were inventoried and the sum of the materials used was performed in the year 2014.

The amount of liquid and gaseous CO_2, based on calculations of the GHG Protocol assigned as Scope 1 (Calculation basis for CO_2 GHG Protocol emissions for liquid and gaseous CO_2) was calculated in spreadsheet. As there is no literature on emission factors and it is in natura emission, the calculation was defined as follows:

$$\frac{\sum CCO_2L + \sum CCO_2E + (\sum CCO_2M.0{,}25.dGM)}{1000} = ECe \quad (15)$$

In which:

CCO_2L: Liquid CO_2 consumption (kg)

CCO_2E: CO_2 consumption extinguishers (kg)

CCO_2M: CO_2 consumption and argon mixture (m^3)

d: Density (kg/L)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Fugitive emissions of HFCs for refrigeration equipment

This data was obtained from the supplier who performs maintenance of the refrigeration equipment in the unit. Therefore, the presented data refers to the period between January 1, 2014 and December 31, 2014.

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The calculation base for CO_2 emissions from the GHG Protocol for HFC scope 1 was used, as Table TS.2 - Climate Change 2007: The Physical Science Basis - IPCC.

Thus we have:

$$\frac{\sum CHFC}{1000}.FEHFC = ECe \quad (16)$$

CHFC: HFC consumption (kg)

FEHFC: Leakage of HFC emissions (kg)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Electric power consumption

We measure the general electric power consumption of the unit obtained by Comerc, a company that distributes power to the unit.

From the energy bill in MW/h we measured the monthly sum in the worksheet, showing the monthly consumption and the annual sum.

It is worth noting that electric energy consumption tends to be high because of the steel melting process of two 10- and 20-ton electric arc furnaces, overhead cranes, exhaust systems, welding, gouging, grinding, and grinding wheels.

Therefore, the invoices with the monthly consumption refer to the period from January 1, 2014 to December 31, 2014. The amount of MW/h generated per month was inventoried in a spreadsheet and this was converted into CO_2 in the basis of calculations with the GHG Protocol literature assigned as Scope 2.

The calculation base for CO_2 emissions GHG Protocol was adopted according to Table TS.2 - Climate Change 2007: The Physical Science Basis - IPCC.

Thus we have:

$$\sum CEE.\sum FESIN = ECe \quad (17)$$

CEE: Electric power consumption (MW/h)

FESIN: Emission factor of the National Interconnected System (tCO_2/MW/h)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Combustion of hydrated ethanol used in the dilution of the paint applied to parts of the core making and Molding area.

The process of using ethanol is at the junction of two refractory inks, which form a protective film between steel and sand molding and core making. These paints are based on zirconium and magnesium, having the function of not allowing the sand to adhere to the cast in the moment of solidification of the steel.

In order for the rapid drying process to occur in this paint, the alcohol is inserted and burned from the painted part of the sand mold, before the casting process.

The data were acquired through the integrated system of fiscal and tax issues and inventory control. The S.A.P system was used to retain the presented data. Therefore, our scope extracting the data refers to the period between January 1, 2014 and December 31, 2014.

The calculation basis for CO_2 emissions from the GHG Protocol for hydrated ethanol Scope 1 was used, as shown in Table 3.2.1, Chapter 3, Vol 2, IPCC Guidelines, 2006.

Thus we have:

$$\sum \frac{CE.0,96.d.FEEs}{1000} = ECe \quad (18)$$

In which:

CE: Ethanol consumption (L)

d: Density (kg/L)

FEEs: Stoichiometric emission factor (CO_2/t calculated ethanol)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Combustion of rice hulls in stages of the casting process.

The rice straw is used after the steel tipping in the pouring pots, aiming to maintain the temperature of the steel, forming a film on the surface of the pan, avoiding the loss of the thermal gradient at the moment of the leak.

Data were acquired from the measurement carried out through the integrated system of fiscal and tax issues and stock control, using the S.A.P system to retain the presented data, considering the period from January 1, 2014 to December 31, 2014.

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The calculation basis for CO_2 emissions from the GHG Protocol for hydrated ethanol Scope 1 was adopted, according to table 2.4, Chapter 2, Vol. 5, IPCC Guidelines 2006.

Thus we have:

$$\sum \frac{QP.MS.FC.FO.FCC}{1000} = ECe \qquad (19)$$

In which:

QP: Amount of burnt straw (kg)

MS: Dry mass (fraction)

FC: Carbon Fraction (%C)

FO: Oxidation factor (fraction)

FCC: Carbon dioxide/carbon factor (CO_2/C)

ECe = Carbon emission (Emission of carbon dioxide equivalent) (t)

Analysis of results

After analyzing the data collected, the results of the consumption of all energies, inputs and other sources and their respective equivalent carbon emissions are evidenced, as shown in Tables 1 and 2.

The data obtained in this study, referring to the year 2014, were compared with the data of 2013 and a decrease in the emissions related to the two periods was observed. From 2013 to 2014 there was an emission difference of 0.07 tCe/t of steel produced.

Among the main emission sources, it was observed that there was a significant change in the consumption of natural gas, and several actions were also taken to reduce gas consumption, save on the resource utilization process and increase market competitiveness, which had a positive impact on carbon dioxide equivalent emissions compared to the previous year, according to Figure 1.

Table 1. Statement of emission by sources of emission 2014

EMISSION SOURCES	CO2	CH4	N2O	tCO2e	%
Steel Processing	330,3	-	-	330	3,00%
Acetylene	19,7	-	-	20	0,20%
Natural gas	6.725,40	0,1199	0,012	6.732	60,80%
Diesel (heavy vehicles)	66	0,0037	0,0255	74	0,70%
Ethanol (captive fleet)	-	0,0003	-	0	0,00%
Gasoline (captive fleet)	10,3	0,001	0,0008	11	0,10%
GLP (forklift trucks)	137,9	0,1355	0,0004	141	1,30%
(Cutting / Soldering / Fire Extinguishers)	0,6	-	-	1	0,00%
Electricity	3.761,60	-	-	3.762	34,00%
Total	11.051,90	0,26	0,039	11.069	

Source: The authors

Table 2. Statement of emission by emission sources 2013

EMISSION SOURCES	CO2	CH4	N2O	tCO2e	%
Steel Processing	471,7	-	-	472	3,60%
Acetylene	40,4	-	-	40	0,30%
Natural gas	9.427,60	0,1681	0,0168	9.436	71,70%
Diesel (heavy vehicles)	65	0,0036	0,0251	73	0,60%
Ethanol (captive fleet)	-	0,0005	-	0	0,00%
Gasoline (captive fleet)	13,1	0,0013	0,0011	14	0,10%
GLP (forklift trucks)	148,4	0,1458	0,0005	152	1,20%
(Cutting / Soldering / Fire Extinguishers)	101,7	-	-	102	0,80%
Electricity	2.879,20	-	-	2.879	21,90%
Total	13.147,20	0,32	0,043	13.167	

Source: The authors

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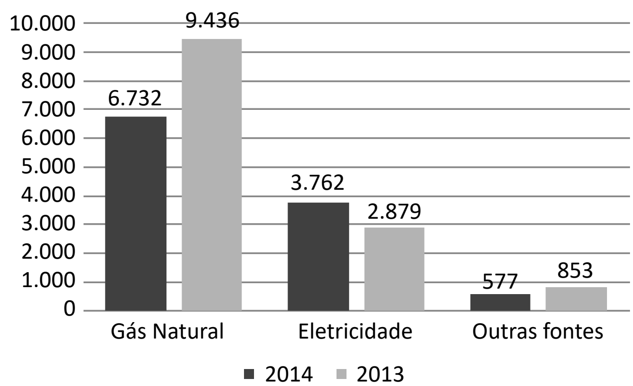

Figure 1. Comparison of emissions in relation to the years 2013 and 2014

Source: The authors

The other sources of emissions also showed a reduction in the period used for comparison, with the exception of electric energy, which presented a 31% increase compared to 2013, due to the emission factor of the *Sistema Interligado Nacional* (SIN - National Interconnected System), shown in table 3.

The CO2 emission factors resulting from the generation of electric energy, an integral source of scope 2, verified in the National Interconnected System (SIN) of Brazil, are calculated from the generation records of the plants centrally dispatched by the National Electric System Operator (ONS) and, in particular, in thermoelectric plants. The 2014 emission factor corresponds to the highest of all the factors already recorded since 2006, the first year of publication of the data by the Brazilian Government. This increase in relation to the previous year is due to the change in the hydrological regime and the consequent increase in the activation of thermoelectric plants to guarantee the national energy supply.

4. CONCLUSION

The reduction in emissions in scope 1 was verified in all the resources used in the period between 2013 and 2014, mainly due to the maintenance of equipment, leakage elimination and the adequacy of the pipeline of the gases mentioned in this study, optimization, exchange of fleet of vehicles with flex engines and better control of the logistics of use, better control of the process of fusion and refining, avoiding alteration of the chemical composition of the alloys and their respective dilutions for correction, reducing the consumption of raw materials in the Steelmaking process. We can observe these results in Tables 4 and 5 below.

Among the most significant results, natural gas was the one that obtained the greatest reduction in terms of consumption, positively impacting the reduction of carbon emissions equivalent in the 2014 report, around 29% in relation to the previous year. This result is due to the suitability of the heat treatment furnaces in the tempering processes, using greenhouses that consume less natural gas according to the variety and availability of pieces to be treated (Table 6).

Table 3. Comparison of results in relation to the years 2013 and 2014

BASE YEAR	2014		2013		2013/2014
EMISSION SOURCES	**tCO2e**	**tCO2e/t**	**tCO2e**	**tCO2e/t**	**TAXA**
Natural gas	6.732	0,35	9.436	0,46	24%
Electricity	3.762	0,20	2.879	0,15	-31%
Other sources	577	0,03	853	0,04	32%

Source: The authors

Table 4. Total emissions statement by scope 2014

TOTAL EMISSIONS BY SCOPE - 2014							
GHG	**GWP**	**t metrics for each GHG**			**t metrics of CO2e**		
		Scope 1	**Scope 2**	**Scope 3**	**Scope 1**	**Scope 2**	**Scope 3**
CO2	1	7.290,30	3.761,60	-	7.290,30	3.761,60	-
CH4	21	0,3	-	-	5,5	-	-
N2O	310	0,04	-	-	12	-	-
HFC (134a)	1300	0	-	-	-	-	-
PFCs	-	0	-	-	-	-	-
SF6	-	0	-	-	-	-	-
			Total (tCO2e)		7307,8	3761,6	0

Source: The authors

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Table 5. Total emissions statement by scope 2013

TOTAL EMISSIONS BY SCOPE - 2013							
GHG	GWP	t metrics for each GHG			t metrics of CO2e		
		Scope 1	Scope 2	Scope 3	Scope 1	Scope 2	Scope 3
CO2	1	10.268,00	2.879,20	-	10.268,00	2.879,20	-
CH4	21	0,3	-	-	6,7	-	-
N2O	310	0,04	-	-	13,5	-	-
HFC (134a)	1300	0	-	-	-	-	-
PFCs	-	0	-	-	-	-	-
SF6	-	0	-	-	-	-	-
			Total (tCO2e)		10288,2	2879,2	0

Source: The authors

Table 6. Emission indicator

EMISSION INDICATOR	2014	2013
Total steel produced (t)	19.161	20.470
E total emissions of Scope 1 and 2 (tCO2e)	11.069	13.167
INDICATOR OF EMISSION (tCO2e/t steel)	0,58	0,64

Source: The authors

There was a massive reduction in the consumption of natural gas, which contributed significantly to the drop in the index of 0.07 tCe / t of steel produced. For the next few years, the company studies a number of other investments in more efficient equipment and also in its energy efficiency program, to improve its processes more and more and to make them increasingly clean.

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