Corporate Carbon Footprint – the Case of Caetano Coatings

Francisco Osório do Amaral Aparício Lopes
faparicio.lopes@gmail.com

Instituto Superior Técnico, Universidade de Lisboa, Portugal
November 2018

Abstract

Now more than ever there is a growing concern about the global warming issues, consequence of the greenhouse gas emissions, as a result of the human species' activity. With this concern, the need to evaluate a company's carbon footprint arises, having to disclose this information not only to the proper authorities but also to a more informed and environmentally aware public, more and more companies are starting to take initiatives in this field. Besides, the increment in legislation and the raise in carbon emissions permits' prices makes this study essential to a modern company. One of these companies is Caetano Coatings.

To perform the calculation of the Caetano Coatings corporate carbon footprint, it was chosen the method proposed by the GHG Protocol and the value obtained was **8359,97** ton CO_2e. The type of emission source that was most responsible for this value was the use of natural gas and electricity, which contributed with 46% and 49%, respectively. A line of production which contributed the most was the Line 7 – Anodization, with about 30%, followed by Line 8 – Liquid Painting, with 23%, Lines 1 and 2 – Powder Painting, with 16%, and Line 6 – Liquid Painting, with 12%.

Besides this calculation, it was developed for the company a digital tool and respective instructions manual. The tool allows, not only the monitoring of the carbon footprint, but also the ability to predict and diagnose the total value of these emissions, when it's predicted that the consumption patterns are going to change. This way, the company can monitor the progress of current reductions projects, as well as immediately evaluate the impact of energy consumption reduction measures and changes on the production volume.

At last, it was made a reflexion on the method and approach used, using the gathered experience. With this reflexion it was intended to identify advantages and disadvantages, contributing to futures works, by pointing improvement aspects, as well as recognising strong features that give consistency to the protocol.

Key Words: **Corporate Carbon Footprint, GHG Emissions Assessment, GHG Protocol, Greenhouse Gases, GHG**

I. Introduction

Nowadays, global warming is one of the most serious concerns of the humanity. The last report of the Intergovernmental Panel on Climate Change (IPCC) reinforced this reality, indicating the evident warming our planet is suffering. Since 1950, the climate changes we are seeing are unprecedented over the last thousands of years. In this report it is pointed that the cause of this warming is almost certain to have anthropological reasons, consequence of the huge amount of carbon emissions the human species emits to the atmosphere. The amount of emissions has been raising since the pre-industrial age due to population and economic growth and the concentrations of carbon dioxide, methane, and nitrous oxide hit unprecedented levels since over 800 000 years [1]. This information is evident on the Figure 1.

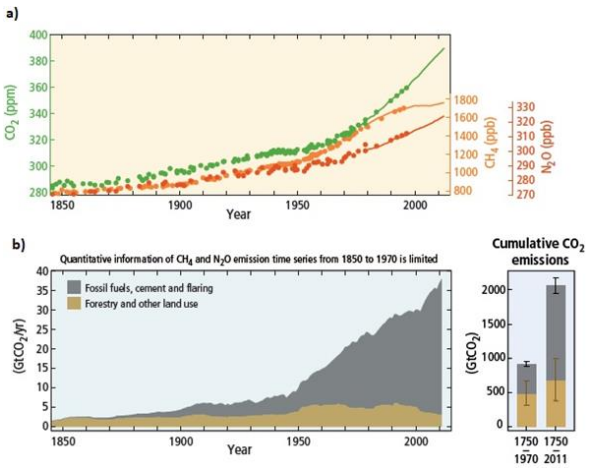

Figure 1 - a) Globaly averaged greenhouse gas concentrations b) Global anthropogenic CO_2 emissions [1]

This issue has generated a global effort to avoid the dangerous consequences of this problem. In 1997, The United Nations Framework Convention on Climate Change (UNFCCC) was responsible for the signing of the Kyoto Protocol, an agreement where almost every country committed itself to limit or reduce their greenhouse gas emissions. It was also defined the main greenhouse gases (CO2, CH4, N2O, HFCs, PFCs, SF6) [2]. In 2015 the Paris agreement was signed, having established a limit of 2 ^{o}C for the current global warming, shifting the strategy to a more flexible and realistic approach [3].

With this in mind, an important thing when facing these issues is to monitor GHG emissions. Caetano Coatings decided to so by calculating its carbon footprint relative to the 2017 fiscal year. According to its website[1], "… the Company presents a wide range of services for the automotive sector and civil engineering, based in different technologies as varied as liquid painting, acrylic powder painting, epoxy powder painting, cataphoresis painting, industrial grit blasting, industrial painting and coatings and special pavements. These technologies are aggregated in two separate business areas: Automotive division and the Steel and Concrete Protection & Industrial Pavements or Divisão de Protecção de Aço e Betão & Pavimentos Industriais (DPAB) division." These technologies are divided by the following lines Line 1 – Powder Coating for Automotive, Line 2 – Powder Coating for Architectural, Line 5 – Electro-Coat Line for Automotive (KTL), Line 6 – Wet Painting Line for Small Parts, Line 7 – Anodization, Line 8 – Wet Painting Line and Stripping Line – Chemical & Pyrolysis.

II. State of the Art

1. GHG and Greenhouse Effect

According to the IPCC [4], greenhouse gas is defined as "Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere." And the greenhouse effect can be defined as "The infrared radiative effect of all infrared-absorbing constituents in the atmosphere. Greenhouse gases, clouds, and (to a small extent) aerosols absorb terrestrial radiation emitted by the Earth's surface and elsewhere in the atmosphere. These substances emit infrared radiation in all directions, but, everything else being equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission.". This is the reason why controlling the greenhouse gas emissions is important, they are a major influence on the earth's surface temperature.

2. Carbon Footprint

The growing concern about the issue of global warming has generated a need to control and monitor the greenhouse gas emissions of multiple entities. The account of this emissions has definitely been linked to the term "carbon footprint", so it is important to understand what it means.

According to Wiedmann and Minx [5], in 2008 the term had been linked to the assessment of the quantity of emissions of CO_2 or GHG, in CO_2 equivalent unit of measure, associated with a given company/organization/product. Even though this relation was obvious there wasn't a definite definition of "carbon footprint" so they suggested the following: "carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product".

This definition settles some disputes. It clearly states that only the CO_2 emissions should be accounted for, proposing another concept, such as "climate footprint", to account for other GHG. It also abandons the idea of an area as the unit of measure, since having to make an estimate of how many m^2 it would be necessary to support that entity brings a vast range of uncertainties to the final value. However, some author, such as Hammond [6] suggest that it should be used the term "weight" instead of "footprint"

[1] URL: http://www.caetanocoatings.pt/en/empresa

since it is a better way to express this concept. He also states that there should be a clear definition of the scopes of the study.

In 2011, Wright *et al.* [7] made a new revision of this definition. They article expressed that there was still some uncertainty about what the really means. There was still some confusion whether to include only the CO_2 emissions or other GHGs and whether the term was a measure of the whole climate impact of in only an indicator of human influence on the GHG concertation in the atmosphere. About this, it is said that in order to settle this dispute, a lot of organizations have been using the Kyoto protocol, considering all the GHGs mentioned in the agreement. It is also mentioned the importance of the Global Warming Potentials, suggested by the IPCC, as a way to convert the impact of other GHGs to the impact of a unit of CO_2.

Having this in mind, they define "carbon footprint as a "…measure of the total amount of CO2 and CH4 emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as CO2e using the relevant 100-year global warming potential (GWP100).". With this definition, the authors hoped to have settled all the confusion that had surrounded this term, adding the CH_4 as a GHG to consider, since it's effect on the global warming is considerable and it is fairly easy to gather the needed information. This way the authors try to make a balance between relevance and feasibility, since making this assessment too complicated would deter some companies from doing it.

This was the last paper found about the review of the definition of this term, which may suggest some lack of interest in this area or that the definition has been sufficiently clear. However, there are still many proposed methods to asses the amount of emissions for which an entity is responsible. All these methods depend on the type of entity being analyzed, since it is that that determines the scopes of the study, as well as the GHGs to take in account [8].

3. Methodologies

The type of methodology proposed varies with the kind of system that is being analyzed. The most common are nations, regions and cities, economic sectors and companies/organizations, products and services, and individual carbon footprint or per household.

3.1. Nation, Regions and Cities

The assessment of the carbon footprint of a nation is a complicated endeavor and is still in debate whether to account the emissions on the producer nation or the consumer. This study is usually done with an input-output analysis called Multiregional Input-Output model. According to Kanemoto *et al.* [9], this model analyzed the complicated economic links between nations and economic sectors, using available databases and distributing the emissions between the producer and the consumer. The result is an intensity map of the globe of the emissions caused by the demand of a specific country such as the map on Figure 2.

When the object of the study is a city, the type of analysis changes. According to Minx *et al.* [10] a difficulty in this type of assessment is the lack of information about the consumption in different sectors inside the city and in the rural economic sectors.

The approach the authors take, consists on considering all the emissions upstream and downstream of the various products lifecycles, focusing mainly on the energy consumption and only assessing the CO_2 emissions.

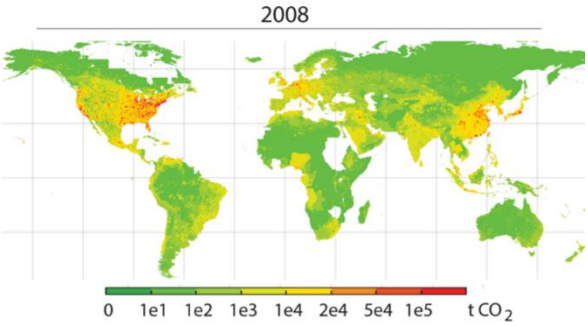

Figure 2 - Map of the CO2 emissions caused by the USA demand around the globe [9]

Mi *et al*. [11] also mention the advantage of focusing the analysis on the consuming city, since it forces the more consumer cities to take larger responsibilities. This type of studies split the emissions is different categories such as production bases emissions or household emissions, facilitating the definition of priorities when there is a need to intervene.

3.2. Sectors and Organizations/Companies

Nowadays, companies and organizations are starting to feel the need to asses the GHG emissions they are responsible for. This is due to a growing concern about these issues by the general public, and an increase in regulation who might affect some unprepared companies [7, 8].

This interest has generated a vast array of studies in an effort to develop a methodology that can be applied to the vast majority of companies. There has also been an increase in the effort to standardize and clearly define the method that should be followed in order to give coherency and consistency to the information that is released to the public.

In March of 2006 the International Organization for Standardization (ISO) finished the development of a norm, whose number is ISO 14064. This norm includes requirements to the creation of an inventory of GHG emissions, in such a way that allows for internal audits to be made in a more consistent and reliable way. By doing this, the ISO organization gave the companies more freedom and flexibility hoping that it would motivate and stimulate them to perform this kind of study [12].

This norm defined a series of principles that should be followed by the organizations who wanted to perform this kind of studies. Those values were the **relevance**, the **completeness**, the **consistency**, the **accuracy** and the **transparency** not only of the gathered data but also of the methodologies used.

It also proposes a method for the definition of the scopes of this study, both on the organizational and operational level. For the operational level, it establishes two approaches, one considering the activities where the company has decision power, either financial or operational, and the other considering an equity share approach, which means accounting the emissions of the ventures where the company has invested capital according to the percentage that it detains. The choice between these two approaches should be made accordingly to the structure of the company undertaking the study. For the operational scope, the norm splits the emissions between two categories, direct and indirect. The direct emissions should always be included in the study and are a direct result of the company's processes. The indirect ones may or may not be included, however the ones related to the emissions associated with the production of the consumed electricity should always be included.

After defining all the study scopes, data should be gathered about the consumption and intensity of the company's processes and the emissions are calculated with the help of emission factors. In the end, all the emissions are summed together and thus obtaining a carbon footprint [12]. This method can be visualized on Figure 3.

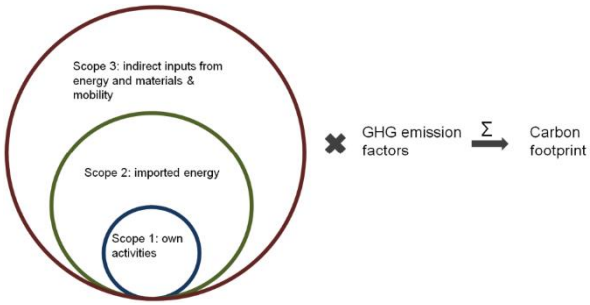

Figure 3 – Simplified scheme of the ISO 14064 proposed methodology [13]

This norm is based on an international protocol created by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) which for the first time introduced the methods to undertake such study. This initiative is responsible by the making of the guide *A Corporate Accounting and Reporting Standard*. This guide had a first version in 2001 and a revision in 2004 and has been an international success with a great amount of companies and organisations adopting its guidelines [14].

3.2.1. GHG Protocol

The GHG Protocol is the name of the initiative created by the WRI and the WBCSD. This protocol fills a void on the legislation regarding the assessment and reporting of GHG emissions. First appearing in 2001, after three years of work between consulting firms and organizations related to the environment, this protocol has been growing, producing various guides on how to assess the amount of, whether in products or in big corporations. This initiative has had the goal to create a reliable platform that allows the interested companies and organizations to undertake this analysis, besides giving important information on how to improve their situation [15].

According to Green [14], this standard's success is due to three fundamental reasons which are common when it

comes to private regulation. These reasons consist on the fact that the cost of making undertaking these studies are relatively low, the advantage on being the first, and the ability to improve the company's image. Besides, the fact that this protocol gives easy to use proceedings and reporting principles, with the addition of technical support, made it simpler for the companies interested in performing these endeavors. The guide's workability, together with a growing concern of more legislation to come in this area resulted in a widespread use of this guide by companies all over the globe.

3.3. Products and Services

A carbon footprint assessment of a specific product of service has its origins on Life Cycle Assessment (LCA) being one of his components. The LCA is being developed for several years and has had important roles on lawmaking policies, being widespread accepted in the scientific community [7, 8].

An LCA consists on assessing all the environmental impacts caused along a supply chain of a product or service. Nowadays, there are currently five ISO norms regarding this theme. It analyses all the steps of a product lifecycle, from the production of the needed resources, through the production of the product itself, its usage, all the way to the waste disposal. This process can be seen on **Erro! A origem da referência não foi encontrada.**.

In this type of assessment, the first step is to define the goal and the scopes of the study. Then it is necessary to analyze and create an inventory that consists on the gathering of all the inputs and outputs of each process established in the first step. After that, all the emissions and resources are grouped accordingly to the impact they produced in the environment and converted to common units so that they can be compared. As mentioned before, on the impact of the GHGs, these are all converted into CO_2e through the use of their corresponding GWP in order to obtain a value that can represent them all together. At last, the results are interpreted, and the questions asked during the definition of the goals of the study are answered [16, 17].

3.4. Individuals or per Household

The individual carbon footprints have been an object of interest to several organizations, having the main goal of bringing awareness to the general public about the global warming issues [7, 8]. Usually these types of studies are made using online calculators that, through an individual set of questions, return the impact of an individual on the GHG concentration on the atmosphere [16, 17].

The majority of models that are available online follow a similar pattern. They start by asking the user information about his consumption habits, being the most common electricity, oil, natural gas, and coal and calculating the corresponding emissions through emission factors. According to Kenny and Gray [18], there is a lack of standardized methods to these online calculators, that results in a lack of transparency and consistency between them. The authors reinforce the need to set this kind of standards so that individuals can calculate their impact in a more serious and reliable manner.

Having checked the available information on the different methodologies that exist, it is clear that type of approach varies significantly with the type of object of the study. The relation between them can be seen on where it is possible to conclude that systems with large dimensions are usually analyzed trough top-down approaches and input-output models while smaller ones are analyzed through bottom-up or LCA analysis.

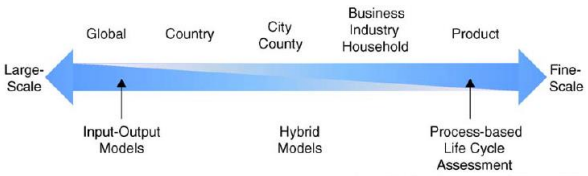

Figure 4 - Relation between the object of the study and the preferred method [8]

III. Methodology

As said in chapter II when it comes to analyze the GHG emissions of a company, the method proposed by the GHG Protocol is most commonly used. With this in mind, it will be used the approach presented in the guide *A Corporate Accounting and Reporting* [19] to assess the GHG emissions resulting from the Caetano Coatings' activities.

1. GHG Accounting and Reporting Principles

First, it is necessary to establish the principles by which the entity performing the study should guide itself. These principles are similar to the ones a company must follow while performing financial reports. They consist on

relevance, which guarantees that the results truly reflect the company's situation, as well as assure that they are useful, both internally and externally, **completeness**, whose goal is to guarantee the total inclusion of all possible emission sources or activities, **consistency**, to allow reliable comparisons between years, **transparency** giving reliability through the use of truthful reports and database, and being as clear as possible while defining the calculation methods used, and **accuracy**, that guarantees that the value of the emissions is not neither over nor underestimated, allowing the company to take solid and informed decisions.

These principles have the objective of guiding the company through the application of the method proposed by the GHG Protocol.

2. Setting Organizational Boundaries

The protocol suggests two approaches to define these boundaries, the equity share approach, where the GHG emissions are accounted for using the percentage the company owns of the emitting venture, and the control approach, where all the GHG emissions from operations that are controlled by the company are accounted for.

When a company owns the whole of its operations the choice between the two approaches is irrelevant, this is what happens with the Caetano Coatings company. The only precaution that should be taken is regarding the other companies that own operations in the industrial complex owned by Caetano Coatings, since the emissions arising from those operations should not be accounted for.

In conversation with the board of the company, it was settled that the branches of the company that were going to be inside the boundaries would be the operations inside the Carregado industrial complex, and the DPAB division. This can be seen on Figure 5.

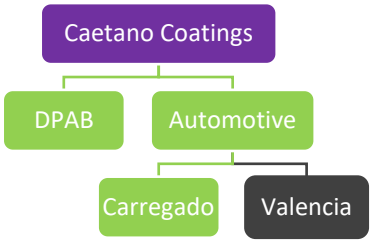

Figure 5 - Operational Boundaries - in green the ones that were included and in black the ones that were excluded

3. Setting Operational Boundaries

This phase of the methodology consists on identifying all emission sources associated with the operations that are included in the organizational boundaries. The emissions are separated between direct and indirect and are grouped in different scopes. There are three scopes in the guide.

Under scope 1 are accounted all the direct emissions. These emissions are a result of combustions, such as the ones in oven or boilers, vehicles that are owned by the company, or any other process that has as a waste a GHG. Under scope 2 are all the indirect emissions that arise from the production of the consumed electricity. Under scope 3 are all the other indirect emissions which may be the emissions resulting from the production and extraction of the resources the company needs, the transportation of these resources, the emission arising from the waste disposal or any activity that result in emission where the company has some kind of influence. These scopes can be seen on Figure 6.

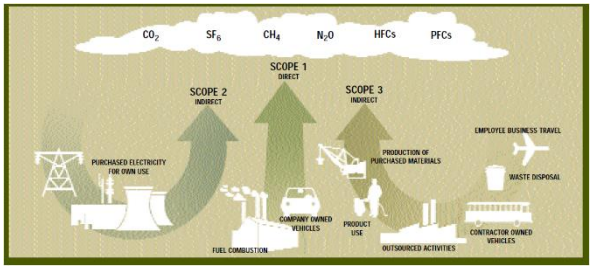

Figure 6 - GHG Protocol Scopes [19]

In the case of the Caetano Coatings, it was decided that only the scope 1 and 2 were going to be included, given the use the company wanted to give to this study, which was to control the emissions that are directly related to their activity, and the time frame of the project, since to analyse the scope 3 in six months would be an impossible task to just one individual.

4. Identifying and Calculating GHG Emissions

This phase is usually done in six stages:

- Identify GHG emissions sources
- Select a GHG emissions calculation approach
- Collect activity data and choose emission factors
- Apply calculation tools
- Roll-up GHG emissions data to corporate level

4.1. Identifying GHG Emissions Sources

In this section, all the emission sources should be listed and included in each of the scopes mentioned on section 3.

Besides these emission sources it also decided to account for the emissions arising from the fixed emissions sources around the factory since the company already had that information and wanted to know its relative impact in the overall carbon footprint. However, the type of GHGs that arise form these sources are not predicted in the guide and should not be included in neither scope.

4.2. Select a GHG emissions calculation approach

The method chosen in this case was the most commonly used, since it asks for information the company usually has for management issues or is easily gathered. This method consists in gathering all the information about the consumption of each emission source identified in the last section and multiplying that value by a corresponding emission factor. The only exception are the fixed emission sources since the company performed periodic monitorizations on these sources and already had the data of the amount of emissions produced.

4.3. Collect activity data and choose emission factors

For the calculations of the emissions under scope 1 usually it is collected information about the fuel bought such as natural gas or oil and the emission factors are published by the authorities. For the calculations on scope 2, the emissions are made using the financial records on the consumption of electricity. As for the emission factor the producers usually publish the amount o CO_2 released by each kWh generated so the guide suggests that this factor should be used.

For the calculation of DPAB's scope 1 the data gathered was the oil purchased to use in the generators or in the vehicles. The data gathered was of **7991,06** l of oil used for the generators and **48150,80** l for the vehicles.

For Carregado's scope 1 there are more data to be collected. First, to analyze the stationary combustions due to natural gas usage, the records made by the maintenance team in 2017 of the consumption patterns were used. To give more consistency to these values, it was made a verification using the records from 2015 and 2016 to identify possible human errors through the observation of unusual patterns. These values will not be shown since they would occupy too much space. Also, on Carregado's scope 1 there are mobile combustions on the forklifts. The amount of oil spent on these forklifts was **15 000** l. At last, the data need for the calculation of the emissions resulting from the leaks on the refrigeration system were gathered via the purchase records of the refrigerant liquid and can be seen on Table 1.

Table 1 - Refrigerant Fluid Purchased

Automotive	
Refrigerant Liquid	**Purchased Quantity (kg)**
R-407C	0
R-404A	0
R-410A	79,4
R-410A	0
R-134A	23,75
SF_6	0

For Carregado's scope 2, the data gathered was similar to the one used on the natural gas. Since the maintenance team also monitors the electricity consumption, these data were uses to make the needed calculations. It was also gathered the information relative to the 2015 and 2016 years for the reasons mentioned above and the data would not be presented since it would occupy too much space.

As mentioned in section 4.1 the data used to analyze the fixed emission sources was the one gathered on the periodic monitorizations made by the company.

As for the emission factors, for the oil use, it was used an emission factor developed by the Agência Portuguesa do Ambiente (APA). From the *National Inventory Reporting* it was used the value for the oil density which was **0,84** kg/l and the value for the energetic content which was **0,0427** GJ/kg. From this publication the emission factors relative to the use of vehicles by the DPAB division were also used as well as the ones for the use of forklifts. Since there are three main GHGs associated with these vehicles, a total of six emission factors were used. For the DPAB' vehicles the values were **70,3**, **0,0061** and **0** kg/GJ, for the CO_2, the CH_4, and the N_2O, respectively. For the use of forklifts, the values were **70,3**, **0,00631** and **0,006** kg/GJ, also for the CO_2, the CH_4, and the N_2O, respectively [20]. Regarding the use of generators, the APA has a publication with emission factors associated to the use of this equipment. From this document the values of **74,1**, **0,0015** and **0,0025** kg/GJ, for the CO_2, the CH_4, and the N_2O, respectively were used [21].

Since the data relatively to the leaks on the refrigeration system already are in mass units we don't need any emission

factor. Therefore, there is only the natural gas and electricity factors left.

For the natural gas, also from the publication [21], the value of energetic content, **0,03844** GJ/m^3 was used as for the emission factors **56,6**, **0,0014** and **0,0014** kg/GJ, for the CO_2, the CH_4, and the N_2O, respectively.

For the calculations relative to the use of electricity, the emission factors were the ones calculated by the energy producer. These values vary from month to month for the year of 2017 were **0,3418** - January, **0,2908** - February, **0,1937** - March, **0,3037** - April, **0,4088** - May, **0,4264** - June, **0,4065** - July, **0,4179** - August, **0,4509** - September, **0,3983** - October, **0,4506** -November and **0,3837** - December.

Relatively to the GWP100, the values were taken from the latest IPCC report [22], and can be seen on

Table 2 - GWP100 of the GHGs included in this study [22]

GHG	GWP100 kg CO_2e/kg	GHG	GWP100 kg CO_2e/kg
CH_4	30	**R-407C**	1773,85
N_2O	265	**R-404A**	3921,6
CO	1,6	**R-410A**	2087,5
NO_x	-15,6	**R-134A**	1430
COT	5,6	**SF_6**	22800

4.4. Apply calculation tools

For this phase, a digital tool was developed, so that it would make it easier for the calculations to be made. The tool was developed using Excel and was made in such way that the user only has to insert the data corresponding to the consumption and purchase of resources (oil, natural gas, refrigerant fluid, and electricity) as well as the data relative to the fixed emission sources. Having this data, the tool calculates automatically the carbon footprint and returns a series of plots and indexes to help the user to visualize and better comprehend the results obtained.

This tool makes it easier for the company to track its emission through the years. It also offers the ability to predict and diagnose the total value of these emissions, when it's predicted that the consumption patterns are going to change. An instructions manual was also developed to make the understanding of the tool easier for someone who is not familiarized with this subject.

4.5. Roll-up GHG emissions data to corporate level

The tool mentioned on the last section also gathers all the result of each individual emission source and sums it up, returning the final value. Besides this, it offers a series of plots for the to user to understand how the emissions are distributed through the different scopes and resources used as well as through the different production lines.

IV. Results and Discussion

After all the calculations made, the value of the Caetano Coatings corporate carbon footprint is **8359,97** ton CO_2e. This number now sets a base value to which the company can compare its performance on the years to come. This value can also be divided by different categories in order to help the board in the decision-making process, when it comes to prioritizing efforts in reducing these emissions.

1. Division by scope and production lines

First, it is important to understand which type of emission (natural gas, oil, refrigeration and electricity) is the most responsible for this value. This division can be seen on Figure 7.

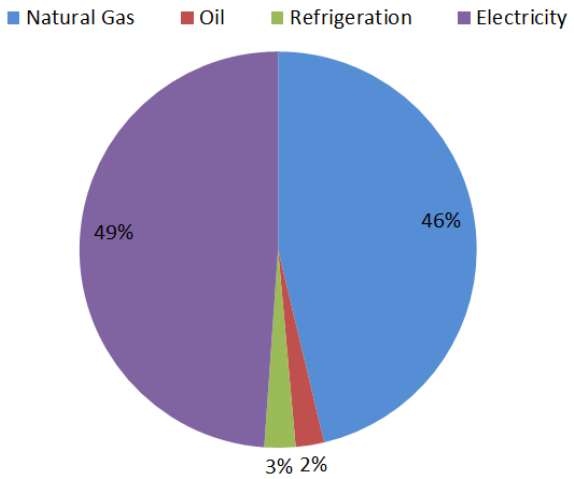

Figure 7 - Distribution by the different scopes - Scope 1 includes natural gas, oil and refrigeration, while Scope 2 includes electricity

As can be seen above, the natural gas and the electricity are the one who have the largest influence on the final value. With this information, the board should prioritize these forms od energy consumption when trying to reduce its carbon footprint. When the fixed emission sources are taken into account, they represent 6% of the total value.

It is also important to understand how theses emissions are divided by the different production lines. This information can be seen on Figure 8.

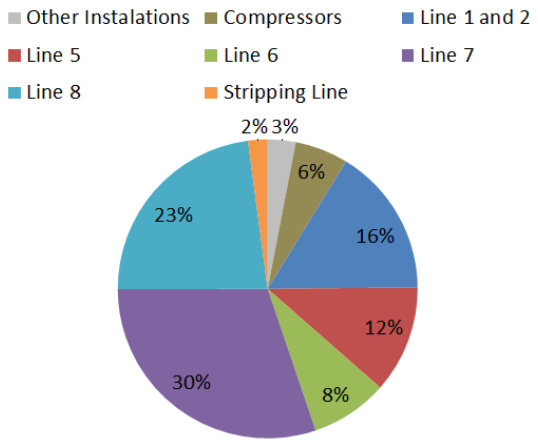

Figure 8 - Distribution of the emissions caused by the consumption of electricity and natural gas by the different production lines

With this information, we can see that the most influential line is line 7, followed by line 8, and 1 and 2. With these results it is recommended to the company that it should focus its reduction effort on line 7 and lines 1 and 2. Line 8 is the most recent one and has more efficient equipment as well as better isolation. The high value of this line is due to a larger production level instead of more polluting processes. Lines 1 and 2 are two of the oldest lines in the factory and have great room for improvement.

Besides this division, it also important to understand how the natural gas and electricity emissions patterns change between lines and along the year.

2. Division of the natural gas and electricity consumption by production line and month

First the natural gas and electricity emissions are divided by line and by production intensity, transforming this value in kg CO_2e/painted m^2. The painted m^2 is and index of the production volume. This way the production volume does not influences the results. The distribution of the emissions of the natural gas can be seen on Figure 9.

With this information it is possible to see that Line 7 has the more emitting processes. This happen mostly due to the need to heat a lot of liquid baths, which consumes a lot of natural gas. Besides, it is also possible to notice an increase in the ratio on the cooler months. This happen due to the need to burn more natural gas to heat water and maintain the ovens at their working temperature throughout the factory.

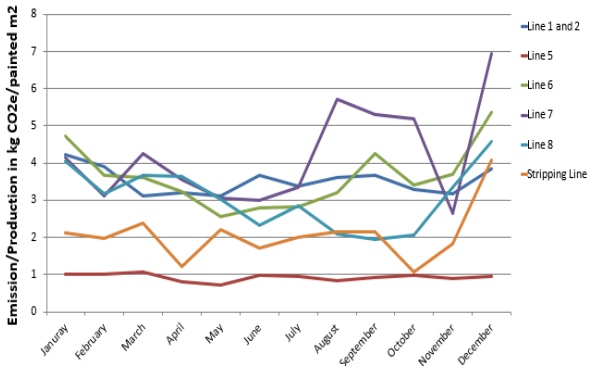

Figure 9 - Emissions/Production ratio from the consumption of natural gas by production line

Also, it is important to analyse the emission from the electricity consumption. This information can be seen on Figure 10.

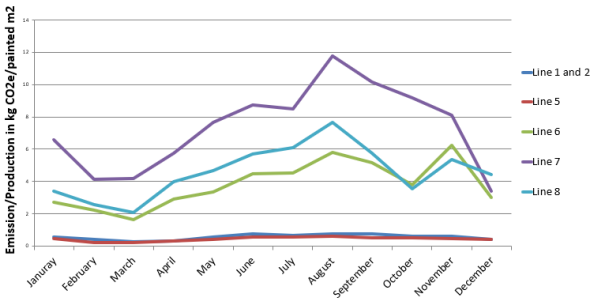

Figure 10 - Emissions/Production ratio from the consumption of electricity by production line

Here it is possible to see that line 7 is still the most intensive. This is mostly due to two large rectifiers that are needed for the painting process. Also, there is an increase in the ratio on the hotter months, this is due to the increase of the electricity consumption in the refrigeration system's equipment. In lines 7, 8 and 6, there are high power air treatment units and chillers which contribute to this pattern. Lines 1, 2 and 5 do not show this pattern since they don't possess this equipment.

V. Conclusion

In conclusion, the objectives set for this study were achieved, obtaining the value of **8359,97** ton CO_2e. This value was analysed understanding how it is divided through the different forms of emission and production lines.

A digital tool was also developed, allowing the company to track its emissions through the years to come and to make assessments about variation of the emissions due to reduction projects or changes in the production volume.

This guide has its advantages and disadvantages. As strong points, the simplicity and user friendliness of the guide. The boundaries definition of the organization and the operations is made in a simple and intuitive way, contributing to the clarity of the study, besides giving a base method to all companies, from the small ones to the multinationals. Also, the way the calculation is made, through consumption records and emission factors is very practical for most companies since the majority of them already compile similar data.

As weak points, by wanting to address all kinds of companies, the study may become somewhat superficial to smaller companies, since the approach proposed collects the consumption data via financial records. This happens because big companies don't have the capacity to analyse in great detail all the operations they own, and this effort would too long and expensive. However, for smaller companies, this can and should be done. By understanding how the emissions are divided between the different aspects of the operation the company produce important information to help the decision-making process.

Acknowledgements

The author would like to thank Instituto Superior Técnico, in particular the professors Samuel Niza and António Luís Moreira, and all my colleagues.

He would also like to than Engº Luís Matias for the help given inside Caetano Coatings.

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