

DIRECT AND INDIRECT CARBON EMISSIONS IN A PRODUCTION FACILITY

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Abstract: Since the last century many of the governmental and nongovernmental organizations have recognized the need of reducing the greenhouse gas (GHG) emissions and were taking measures to mitigate the effects on the global warming. The manufacturing industry leaders have started to act on GHG reduction and set up specific targets and mitigation measures to contribute to limiting the global warming as much as possible. Identifying the corporate carbon footprint by emission scope classified in: Scope 1, 2 and Scope 3 is very challenging and really demanding process but at the same time is the key step to reduce the carbon emissions. The Greenhouse gas protocol (GHG protocol) is a global standard framework for emission management in operations and supply chain. The purpose of this paper is to identify and calculate the carbon footprint in a production facility according the GHG protocol. The paper covers direct emissions generated by sources owned or controlled by the facility, and indirect emissions generated by purchased electricity monitored during a period of one year. The data are analyzed and after mitigation measures to reduce carbon footprint are proposed. The results present that emissions generated by purchased electricity have the largest contribution to the overall company direct and indirect emissions. Based on the results the recommendations for improvement are focused on reducing electricity consumption and use of renewable energy sources. This approach and the proposed actions can be implemented in manufacturing facilities operating in various types of industries.

Keywords: GHG protocol, carbon emissions, mitigation measures

1. INTRODUCTION

The companies regardless the size and industry are intensively working on identifying and reducing their carbon emissions and implement sustainability practices within their operations and supply chain to become carbon neutral businesses. Acting on climate change means establishing short-term and long-term strategies and mitigation measures. The organizations around the world, governmental, nongovernmental, associations and research centers have recognized the need to reduce the carbon emissions and contribute to stop the global warming. In 1992 climate change was first considered as a problem by the United Nations due to its negative effect on the world. In 1997 the Kyoto Protocol was agreed and specific targets, and mitigation measures were established. Based on this agreement was established the Greenhouse Gas Protocol (GHG) in 1998.

The GHG Protocol serves as a global framework enabling the companies from the private and public sector track and manage their carbon emissions in all the areas of activity, own processes and through the supply chain. It was found by the World Business Council for Sustainable Development and the World Resources Institute. The Greenhouse Gas Protocol presents calculation methods, tools, and instructions to help companies to monitor their carbon emissions that affect the environment. It also provides guidance to companies, enabling them to identify and calculate the carbon emission generated by the direct and indirect sources.

The unit of measure used for the concentration of carbon dioxide is carbon dioxide equivalent (CO₂-eq). This has increased over the recent years and is reflected in rising temperatures that have significant implications to the ecosystem and the environment overall.

The basis for each effective climate action is identifying, tracking, and allocating the GHG emissions. Having calculated the carbon emissions values by scope, 1, 2 and 3, can be really a demanding process, but this is the key action to start acting and contribute in reducing the industry's footprint on climate change.

Scope 1 GHG emissions are direct emissions which are generated from owned and controlled sources. Scope 1 emissions are generated into the environment as a direct result of the company activities (consumed fuel, heat sources, company cars). Scope 1 covers all the fuel consumption that produce carbon emissions.

The Scope 2 carbon emissions are indirect emissions from the purchased electricity coming from electricity providers. The carbon emissions generated in the environment, from the purchased electricity, steam, heat and cooling consumption belong to Scope 2 emissions. The recent energy consumption is a significant challenge for the climate change mitigation, and additional increases in the energy consumption leads to risk of decreasing the effects of emissions reductions from energy-efficiency improvements and using sustainable technologies (Bjørn et al., 2018, Pörtner et al., 2022, Rogelj et al., 2018).

The emissions under Scope 3 are indirect emissions which are not included in the scope 2 that occur in the supply chain of company. These emissions include company upstream and downstream emissions. In line with the GHG protocol, total 15 different categories exist under the scope 3 emissions.

In this paper a framework for monitoring and reporting Scope 1 and 2 GHG in a production facility will be presented. The framework includes process of identification, monitoring, analysis of the GHG and recommendations for mitigation actions to reduce the company carbon footprint.

2. LITERATURE REVIEW

The impact of the global warming is becoming a concern all over the world. Not only the manufacturing industry but also the other sectors (e.g. education, services, logistics) have begun to evaluate their GHG emissions and take actions to reduce their Carbon footprint. Having a commonly used process to identify the sources and monitor the emissions will help the companies to understand where they are and what can be improved.

The carbon footprint was defined as "a measure of the exclusive total amount of carbon dioxide (CO₂) emissions that are directly and indirectly caused by an activity or accumulated during the lifetime of a product" by Wiedmann and Minx in 2008. This approach is important for collecting environmental data that will improve the sustainable position of the companies. The carbon footprint and the proper process for explaining and measuring have been subject for research by many experts. An overview of one method which considers carbon emissions throughout the product life cycle by quantifying and displaying emissions was given by Weidema in 2008.

The unit of measure for the concentration of carbon dioxide is carbon dioxide equivalent (CO₂-eq). Alvarez, S state that this has increased exponentially over the past years and lead to increased temperatures that had impact to the climate changes. In the 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines, were presented carbon emissions inventories to track, convert and measure GHG and to present the emissions into the unique unit of measure which is CO₂ equivalent. The content of the guidelines mentioned above is divided depending on the area under monitoring, which can be an institution, company, or separate production department (IPCC, 2007). The most widely used framework for measuring and managing greenhouse gas emissions is the Greenhouse Gas Protocol (GHG) which was established in 1998.

Therefore, using the carbon footprint approach, all the emissions can be monitored and reported, and will provide the total company footprint to the environment. Based on the knowledge around the footprint mitigation measures will be applied.

3. MATERIALS AND METHODS

The goal of the research is to determine the environmental impact of industrial facilities and to understand the main sources of carbon emissions that contribute to global warming. For all carbon emissions sources, direct or indirect, in the manufacturing facilities there are alternative solutions that can support in emission reduction or complete elimination. In today's competitive market, in addition to quality, the industry must be committed to sustainable development and optimal use of resources to maintain competitiveness in the market.

The research was carried out in several steps:

- Literature research to understand the importance of reduction and prevention of carbon emissions in industrial facilities from direct sources (Scope 1) and indirect sources (Scope 2). The literature includes papers, scientific journals from this field, standards, and protocols for monitoring carbon emissions.
- GHG monitoring in a specific manufacturing facility during full calendar year. The focus was to identify the existing sources of energy in production facility and determining the status of carbon emissions from direct energy sources as well as opportunities for their optimization.
- The "Greenhouse gas protocol" will be used for the calculation of direct carbon emissions from all energy sources used in industrial production facilities.

The emission factors used in the research come from the UK government's Department for Environment, Food and Rural Affairs. Regular update of the emission factors is published once per year. These factors are widely accepted and used in different countries in the world (Greenhouse gas conversion factors for company reporting, 2013). A framework will be created for the needs of industrial production plants which later can be used for calculation of emissions in other companies/institutions.

When the current consumption of all energy sources used for heating, cooling or directly used in the production process is determined and the state of carbon emissions is known, measures will be proposed to reduce or eliminate emissions where possible. The following equation was applied during the research.

$A \times Fg = Eg.$

According to the standard, the two most important parameters when calculating CO₂ emissions are activities (A) and GHG emission factors (Fg). Activity is a measure of the level of activity that results in greenhouse gas

emissions for example, activity data could be the amount of fuel consumed. After to convert the data into emissions we need an emission factor (Fg). Emission factors are unique for all sources and are expressed in terms of CO₂/per unit of measure Greenhouse gas emission factors are obtained from various sources of well-recognized institutions mentioned above.

4. RESULTS AND DISUSSION

In addition, the obtained results by scope are presented. The assessed period is one calendar year. Results are obtained by the above-described calculation process in tCO₂e. In the calendar year total nine company cars were included in the research. The emissions by the cars represent 10% of total Scope 1 emissions for the company. The other fuel consumed in the facility, diesel or fuel oil contribute with 9% to Scope 1 emissions. The biggest portion of Scope 1 emissions belongs to natural gas consumption. This facility is using natural gas for heating, and usually in the winter period the emissions achieve the highest level.

Table 1. Direct emissions by source

Source	Emissions in %
Natural gas	81%
Company cars	10%
Other	9%

During the monitored calendar year, the 100% Scope 2 emissions have been generated by purchased electricity in the facility. No other sources that could produce Scope 2 emissions were identified in the plant. The electricity consumption was identified as largest contributor to the total emissions with 81%.

It is very difficult to compare the obtained results with other organizations because first we need to be sure if the same calculation methodology is used and all sources of carbon emissions are identified, and second it is new research filed and there is limited data available on it.

Based on the current literature available the results correspond to Scope 1 and 2 emission of the University Metropolitana (UAM) in Mexico City (Townsend, J.; Barrett, J. (2015). The percentage of contribution to the total emissions by scope have almost the same proportion as the results in our research. The calculation at this university is made according the GHG protocol which makes the values comparable.

The University of Talca in Chile also has published their Carbon footprint results which have been calculated according GHG protocol with almost same proportion of Scope 1 and 2 emissions but with double tCO₂e in total (Yanez P., Sinha A., Vásquez M., 2019).

When reviewing the data available in the literature we found, similar trends could be seen regarding Scope 1 and 2 emissions in the industry, electricity consumption identified as the biggest contributor in emission generation. This is not always the case, a lot of the organizations around the world are installing power plants, shifting the impact of energy production to Scope 1 (Grindsted, T. 2011). When the electricity is generated on site based on renewable energy sources it is considered as a stationary combustion and the carbon emissions are zero.

Understanding the crucial sources is base to implement strategy for emission reduction. Having in consideration the results an action plan was adopted by the manufacturing plan.

The two main actions identified as priorities are implementing LED lightening and motion sensors. After research on opportunities to renewable energy should be done as a long-term strategy that could help in becoming net-zero business. Based on the discussion above, the following points are recommended:

- Additional research on the opportunities to decrease Scope 1 and 2 carbon footprints (availability of renewable energy sources, adopt energy targets, increase efficiency)
- As soon as Scope 1 and 2 emissions have been identified we need to focus on Scope 3 emissions sources and understand their impact to the overall carbon footprint and
- Increase the awareness, by trainings and campagnas on Sustainability, explaining how important role and contribution has everyone in the organization.

5. CONCLUSION

Sustainability awareness and education for the employees are the crucial activities in involving all sectors in a manufacturing industry in the proces of implemting and maintaining sustainable practices for carbon footprint reduction. The emissions generated by purchased electricity are the highest contributor to the company Scope 1 and 2 emissions. Based on the obtained results and the availability of alternative resources, mitigation actions can be determined in order to reduce the emissions.

One of the biggest challenges that the companies are facing with is data accuracy. It is really crucial to establish data gathering process in all areas of the business and provide accurate data for each emission source. The framework that was created based on the most popular standards and protocols for calculation and monitoring of emissions can be followed by other industries for successfully identifying the emission sources and finding optimal solutions.

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