Organizational Carbon Footprint: A Case of Study in an Electrode Company

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Abstract

The objective of the research is to determine the organizational carbon footprint of a company that produces welding electrodes, based on the Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (World Business Council for Sustainable Development and World Resources Institute 2004) in order to establish strategies to reduce Greenhouse Gases (GHG). The type of research is applied and uses the GHG Protocol methodology. The study considered scopes 1 and 2 established by the methodology. Scope 1 represents the direct emissions produced by the consumption of Natural Gas, Liquefied Petroleum Gas (LP gas), and the generation of organic waste within the company. Scope 2 considered the indirect emissions resulting from the consumption of electrical energy. The results showed that the largest amount of CO_2eq was generated within Scope 1 (1,807.34 Ton CO_2eq), followed by the emissions considered in Scope 2 (1,694.03 Ton CO_2eq), generating a total carbon footprint of 3,501.38 Ton CO_2eq. The proposals to reduce CO_2eq focused on reducing the consumption of natural gas because it is the fuel with the highest generation of CO_2eq. In conclusion, this study can be used for companies interested in applying this methodology to calculate their organizational carbon footprint. The research gap is that there was no GHG inventory, and the ideal would be to have an annual GHG inventory emitting less than 15,000 Tons of CO_2eq.

Keywords
Organizational Carbon Footprint, Greenhouse Gas Emissions, GHG Protocol, Electrode Factory, and Natural Gas.

1. Introduction
Global warming has become one of the growing concerns of global society, surpassing the concern caused by the international financial crisis. In this context, more and more consumers want to quantify their contribution to the growing GHG emissions (Benavides and León 2007).

The carbon footprint is emerging as an indicator capable of synthesizing the impacts caused by human activities in terms of GHG emissions, presenting itself as a management tool and an incentive to adopt a proactive strategy in achieving organizational sustainability (Wiedmann and Minx 2007; Boiral 2006; Wittneben and Kiyar 2009). Using the Carbon Footprint has found an important field of contribution in energy efficiency and its impact on operational costs in companies, a situation that improves their profit margin, contributing not only to environmental sustainability but also to economic profitability (Foran et al. 2004).

Wiedmann and Minx (2007) define the carbon footprint as the amount of GHG emissions associated with the production or consumption activities of human beings, although the spectrum of definitions varies from a simplistic view that considers only direct emissions of CO_2 to other more complex ones, associated with the complete life cycle of GHG emissions, including the production of raw materials and the final destination of the product and its respective packaging. The existing definitions in the literature focus on CO_2 as the main axis of analysis, the great difference between them being, in addition to the scope of the footprint, the inclusion of other GHG (Carbon Trust 2008). The property to which the carbon footprint frequently refers is the weight in kilograms or tons of greenhouse gas emissions emitted per person or activity (Haberl et al. 2001).

The organizational carbon footprint consists of collecting the data referring to the consumption of a certain entity or organization and converting them to equivalent CO_2 emissions to have the most complete emissions inventory possible. For this conversion, there are different techniques depending on the type of resource consumed (Jiménez 2014).

Companies perceive that they will soon face an economy with CO_2 reduction obligations, where GHG emissions will be subject to taxes, restrictions, or regulations, recognizing that there will be winners and losers, and clearly, the first challenge for a company is to make an inventory of their emissions (Kleiner 2007). The reduction of emissions and the analysis of carbon footprint throughout the production and supply chain by companies is highly relevant for sustainable development, being an increasingly important issue for the business sector (Schaltegger and Csutora 2012).

Corporate carbon accounting aimed at calculating organizational carbon footprint helps to increase transparency and in this context, has been developed as a means of ensuring the legitimacy of companies. The sustainability objectives of companies are mainly related to competitiveness, costs, facing regulatory risks, consumer perception, and market position (Bastante-Ceca et al. 2011).

GHG emissions estimates allow companies to identify benchmarks regarding the level of impact and clarify the sources of emissions (Schaltegger and Csutora, 2012); It also allows the management of risks associated with gas emissions, the identification of reduction opportunities, public reporting and participation in voluntary GHG programs, participation in mandatory reporting programs, participation in GHG markets and recognition by acting early (World Business Council for Sustainable Development and World Resources Institute 2004).

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According to the National Inventory of Greenhouse Gas Emissions (2015), the contribution of GHG emissions from the different categories in terms of CO_2 equivalent is as follows: the transportation category represented 25.1% (171 Mt of CO_2eq); energy Industries 24.1% (165 Mt of CO_2eq); earned 10.3% (71 Mt of CO_2eq); manufacturing and construction industries 9.3% (64 Mt of CO_2eq); Industrial Processes and Product Use (IPPU) 7.9% (54 Mt of CO_2eq); Waste 6.7% (46 Mt of CO_2eq); Fugitive emissions 6.5% (44 Mt of CO_2eq); Other sectors 5.4% (37 Mt of CO_2eq) and aggregate sources and non-CO_2 emission sources from the land 4.6% (31 Mt of CO_2eq) giving a grand total of 683 Mt of CO_2eq (Instituto Nacional de Ecología y Cambio Climático 2018).

The main policy instrument that the country has to face climate change is the General Law on Climate Change and its respective regulations (Diario Oficial de la Federación 2012). This system aims to regulate, promote and enable the implementation of the national climate change policy and incorporates adaptation and mitigation actions with a long-term, systematic, decentralized, participatory, and comprehensive approach (Comisión Económica para América Latina 2018). The regulation of the general law on climate change also provides other tools such as the GHG emissions inventory, the national emissions registry, the climate change information system, the climate change fund, economic instruments, official Mexican standards, and national atlases, state and municipal risk, (Diario Oficial de la Federación 2014)

Companies in Mexico have begun to get involved in environmental conservation and care by implementing CO_2 emission mitigation programs. This is a competitive advantage for those companies that have begun implementing emission mitigation measures and are in a position to make them known (Forbes México 2014).

Based on the above, this document determines the organizational carbon footprint. Two phases are considered. The first phase: Scope 1, represents the direct emissions produced by the consumption of Natural Gas, LP gas, and the generation of organic waste within the company, and the second phase: Scope 2, is the indirect emissions produced by the consumption of electrical energy.

1.1 Electrode Company

The welding electrode company belongs to a corporation that has several plants around the world, it is the largest producer of electrodes at the national level and one of the most important at the international level, it is within the metal-mechanical business, within the industrial branch 54, "Manufacturers of welding and welding alloys", (Cámara Nacional de la Industria de la Transformación 2016). Therefore, in the national GHG inventory, it is found within the generation branch of manufacturing and construction industries, which contributes 9.3% of the total GHG emissions in the country (Instituto Nacional de Ecología y Cambio Climático 2018).

The company is located in Mexico City. It has four manufacturing lines for conventional electrodes and 1 line for aluminum and special electrodes, with 384 employees (Lincoln Electric Mexicana 2010). In 2016, 18,019,157 kg of electrodes were produced. Its main energy consumption is natural gas in the drying ovens and electrical energy within the entire process and administrative facilities (García 2014). The corporate seeks to consolidate ecological awareness in all its plants, involving staff at all levels to improve environmental management and promote actions to better use of natural resources (renewable and non-renewable). For this reason, its goal is to reduce its GHG emissions by 15% in all its plants, although it does not have a methodology to carry out the GHG emissions inventory that applies to all its plants (Lincoln Electric 2018).

1.2 Objectives

The research objective is to determine the carbon footprint of an organizational type in a company that produces welding electrodes, based on the GHG Protocol Corporate Accounting and Reporting Standard (World Business Council for Sustainable Development and World Resources Institute 2004), to establish strategies to reduce GHG.

To achieve this objective, the following phases are carried out:

1. Scope 1. Represents the direct emissions produced by the consumption of natural gas, LP gas, and the generation of organic waste within the company, the estimation of CO_2eq emissions is made based on the emission factors of the guidelines of the Intergovernmental Panel on Climate Change (IPCC) and the Stationary Combustion Tool of the GHG Protocol.
2. Scope 2. Considers the indirect emissions resulting from the consumption of electricity, the estimate of COeq emissions is calculated using the national electricity emission factor, given by the la Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

2. Literature Review

This section presents a revision of the literature to identify research disparity and obtain thorough information to organizational carbon footprint.

GHGs mainly include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and other gases (Kweku et al. 2017). Emissions of these gases, mainly carbon dioxide, are the cause of the greenhouse effect, which is the main factor leading to climate change (Rehan and Nehdi 2005). The carbon footprint is used to measure and understand the main sources and levels of GHG emissions (Chan 2021). The term "Carbon Footprint" was declared word of the year in 2007 and according to the British Oxford University Press (2021) it is defined as the amount of carbon dioxide released into the atmosphere as a result of individual, organizational, or community actions. On the other hand, the carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions caused directly or indirectly by activity or the accumulation of carbon dioxide throughout the life or generation stages of a product (Wiedmann and Minx 2008).

The carbon footprint has become a topic of public debate on climate change, attracting the attention of consumers, companies, governments, Non-Governmental Organizations, and international organizations (Hertwich and Peters 2009), causing changes in the competitive environment of the companies. The debate on the merits of climate change and the carbon footprint has gone beyond international trade and is being driven by countries committed to emission reductions under the Kyoto Protocol (Plassmann et al. 2010). This is mainly due to concerns in these countries that their producers may lose the competitive advantage of competing with other exporters whose emissions cost less than their climate commitments (De La Torre et al. 2009).

There are currently two basic methods for calculating the carbon footprint: the first focuses on companies and the second on products (Jiménez-Herrero and De la Cruz-Leiva 2010). The calculation of the carbon footprint of a company mainly consists of collecting data on the materials and energy consumed directly and indirectly by the organization and converting them into the corresponding CO_2 emissions in order to prepare the emissions declarations in the most efficient way possible (Jiménez-Herrero and De la Cruz-Leiva 2010). The calculation of the organizational carbon footprint is a tool that helps reduce the costs involved in energy consumption and, on the other hand, contributes to the reduction of GHG emissions and greater environmental awareness (Frohmann and Olmos, 2013). However, the entity that calculates the carbon footprint, in addition to contributing to the fight against climate change, has the advantage of identifying GHG reduction opportunities, being part of voluntary, national, regional, or private schemes, improving corporate reputation, and identifying new business opportunities (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2014).

For the calculation of the carbon footprint, there are various international standards and guides, all these tools have the objective of giving credibility and assurance to the GHG emission reports. The GHG Protocol (2004). It is an initiative launched by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), also supported by numerous companies, non-governmental organizations, and public administrations. Provides in-depth guidance for companies interested in quantifying and reporting their GHG emissions. The MC3 methodology, 2009, is based on the ecological footprint and presents an "Organizational approach" that includes a "Bottom-up" approach for input products and a "Top-down" approach for output products, allowing simultaneous calculation of the footprint of organizations and products. All the data is obtained from the accounting accounts of the organization, which allows a complete relationship between the economic aspect and the environmental aspect of the organization (Penela, Carme, and Doménech, 2009). On the other hand, ISO 14064 (2010), aims to give credibility and assurance to GHG emission reports and GHG reduction or elimination statements, it can be used by any organization, since it has the principles and requirements for the design, development, and management and preparation of a carbon footprint report.

3. Methods

The type of research is applied and the methodology of the GHG Protocol (2004) is used, taking into account Scope 1 and Scope 2. Figure 1 shows the methodology used to calculate the carbon footprint according to the estimated scope of GHG Protocol Corporate Accounting and Reporting Standard, which establishes a structure for the calculation and reporting of the carbon footprint, this is the main difference from the other calculation tools used by national and international companies.

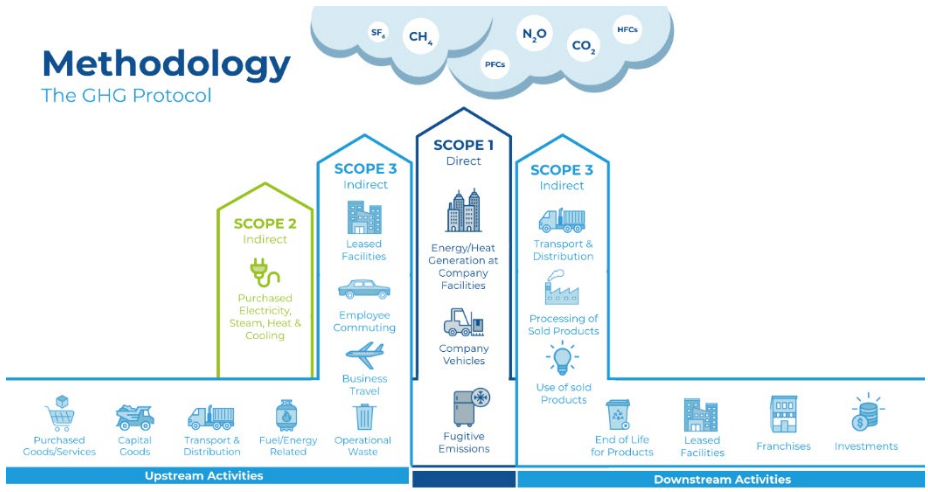

Figure 1. Methodology for calculating the carbon footprint, according to the estimated scope.
Source: GHG Protocol (2004).

The estimation of the calculation of the carbon footprint consists of two phases, in the first stage the scope to which you want to reach is defined:

Phase 1. Scope 1, GHG emissions calculations are made using the emission factors of the IPCC guidelines and the Stationary Combustion Tool of the GHG Protocol for scope 1 (LP Gas, Natural Gas, and Waste).

Phase 2. Scope 2, the national electric emission factor is used, given by the SEMARNAT. In this phase, the calculation of the carbon footprint is carried out, separating the emissions in scope and emissions generated in offices and the production plant to generate proposals to reduce GHG emissions based on the results obtained.

3.1. Phase 1

To apply an emission estimate (Scope 1) the following is required for each source and fuel category:

a) Data on the amount of fuel burned in the source category.
b) A default emission factor.

Equation 1 is used:

(1) Greenhouse gas emissions = Fuel consumption x GHG emission factor

To calculate Scope 1 emissions, the Stationary Combustion Tool Version 4-1 of the GHG Protocol was used for the thermal energy and waste categories. This tool calculates CO_2, CH_4, and N_2O emissions from fuel combustion in boilers, furnaces, and other stationary combustion equipment and converts them to CO_2eq. It can be used by organizations from any sector; uses default emission factors from the IPCC Guidelines for national greenhouse gas inventories (Table 1).

Table 1. IPCC emission factors

Default emission factors for stationary combustion in the manufacturing and construction industries (kg greenhouse gas per TJ on a net caloric basis)			
	CO_2	CH_4	N_2O

	Emission Factor	Lower	Higher	Emission Factor	Lower	Higher	Emission Factor	Lower	Higher
LP gas	63100	61600	65600	1	0.3	3	0.1	0.03	0.3
Natural gas	56100	54300	58300	1	0.3	3	0.1	0.03	0.3
Waste Municipal	100000	84700	117000	30	10	100	4	1.5	15

Source: Intergovernmental Panel of Experts on Climate Change (2006)

3.2 Phase 2.

The calculation of GHG emissions for electrical energy (Scope 2) is calculated using equation 2 given by the SEMARNAT:

$$(2)\ \text{GHG emissions from electricity consumption} = \frac{\text{Electric consumption (MWh)National emission factor TocCO2}}{\text{MWh}}$$

The electric emission factor that is used to estimate indirect emissions coming from the use of purchased electricity, varies each year according to the mixture of fuels used in the generation of electricity distributed by the National Electric System.

The calculation of the average emission factor of the national electricity system is based on the total fuel consumption and the net electricity generation delivered to the network. The national emission factor of the last year was calculated given by SEMARNAT. The organizational carbon footprint is estimated by dividing the emissions into the corporate offices and the production plant, once the carbon footprint is obtained, proposals are made to reduce the GHG emissions generated.

4. Results and Discussion

Phase 1. From the collection of information from the period of thermal energy consumption (natural gas and LP gas), and electric energy, the following results were obtained (see table 2)-

Table 2. Energy sources used

Month	Natural Gas (GJ)	LP gas (Litters)	Electric energy (KWH)
July	2468.56	5066	334218
August	1890.02	8271	287303
September	2271.52	3966	307019
October	2426.62	5346	329345
November	2781.91	3923	299811
December	1805.88	3785	240078
January	3177.24	4485	335443
February	2607.01	5082	324535
March	2606.28	4000	320781
April	2388.32	4600	308738
May	2130.24	4522	290838
June	2564.42	4178	320646
Total	29118.04	57224	3698646
Total, GJ	29118.04	1521.36*	13315.518**

Source. Own elaboration based on the collection of company data

Natural gas generated a consumption of 29118.04 GJ in the year, which is used in the electrode drying ovens, water heaters for showers, and the dining room (consumption of these last two is marginal), LP gas consumed 57224 L in the year they were used as fuel for forklifts, electrical energy is used in lighting, power equipment and miscellaneous, generating an annual consumption of 3,698,646 kWh per year. Table 3 shows the generation of organic waste.

Table 3. Generation of organic waste

Month of the previous year r	Kg	Month of the year of the calculation	Kg
July	6762	January	5313
August	6270	February	4830
September	5798	March	5313
October	6279	April	4830
November	4830	May	6279
December	4830	June	6279
Total			67620

Source. Self-made

100% of the organic waste (67,620 KG/year) is generated inside the dining room because the plant only generates particular handling waste (lined and rod), most of which is recycled and has therefore been discarded for this studio.

The total GHG emissions generated for the company that manufactures welding electrodes was 3,501.38 Tons of CO_2eq, of which 48% corresponds to electricity, 47% to natural gas, 2% to LP gas, and 2% remaining to organic waste, which can be seen in table 4 annual GHG emissions inventory.

Table 4. GHG emissions inventory of a company that manufactures welding electrodes.

Ton CO_2eq	Total
Sector	Ton CO_2eq/year
Natural gas	1635.11
LP gas	92.31
Electric energy	1694.03
Organic waste	79.93
Total	3501.38

Source. Self-made

Phase 2. Table 5 shows the total carbon footprint data for the welding electrodes industry, adding the scopes and emissions within the operational limits. Scope 1 emissions (direct emissions) are the highest, in this case, followed by Scope 2 (indirect emissions). Therefore, the organizational carbon footprint for the welding electrodes industry is 3,501.38 Ton CO_2eq.

When generating the separation by areas (offices and production plant), it was obtained that 6% of the total CO_2eq emissions are generated inside the offices and the dining room, with a total of 197.93 Ton of CO_2eq generated by the consumption of electrical energy and organic waste from the dining room. In comparison, the remaining 94% was generated in the production plant, 3303.46 Ton de CO_2eq, generated by the consumption of electricity in the plant, the consumption of natural gas in the drying ovens, and the consumption of LP gas used as fuel in forklifts (figure 2).

Table 5. Total carbon footprint of the company

Carbon footprint	Total by scope
Scope	*Ton CO_2eq*
Scope 1	1807.34
Scope 2	1694.03
Total	3501.38

Source. Self-made

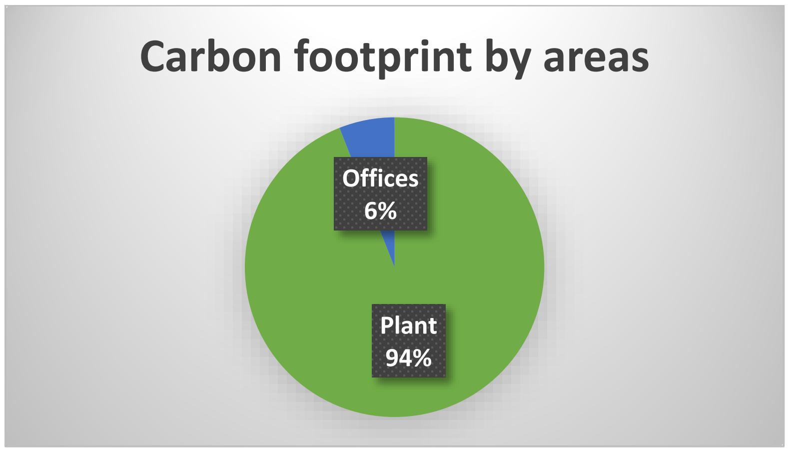

Figure 2. Carbon footprints of the welding electrode manufacturing company by consumption area
Source. Self-made

The carbon footprint calculation for the electrode company showed that the consumption of electrical energy and the consumption of natural gas are the main generators of GHG, so mitigation proposals must be generated for these two sources. However, by separating energy consumption within the production plant and the administrative area, it was found that the consumption of natural gas in the drying ovens is the primary source of GHG emissions, so it is proposed to take actions to reduce the consumption of natural gas, new drying cycles, maintenance of the drying ovens, updating of the drying ovens, inspection of pipes to verify that there are no leaks, etc.

5. Conclusion

Due to the fact that the carbon footprint obtained from the company turned out to be less than 25,000 tons of CO_2eq, it is not obliged to report its emissions before the Ley General de Cambio Climático, through the Annual Operation Certificate or the National Registry of Emissions. When separating the carbon footprint in the office area and processing plant, it is observed that this area represents the highest energy consumption, being the largest generator of emissions, so the reduction strategies must continue to focus on this area.

The contribution of this study is that your corporate obtains more harmonious relations between society and the environment, generating initiatives that seek to gradually promote a low-emission management model that helps reduce GHG.

Obtaining the carbon footprint for the welding electrode manufacturing company, as well as the total data obtained, is a valuable tool since in addition to having elements to implement the proposed emission reduction measures, the information will be useful for the request of the necessary data to improve the accuracy of future calculations.

When generating a literature review of similar studies for a comparison of results, it was obtained that there are no works on the calculation of the carbon footprint for companies that manufacture welding electrodes, so this study is relevant and can serve as a guide so that other welding electrode companies generate the calculation of the carbon footprint and their respective mitigation proposals.

5.1 Research Limitations

One of the main limitations found when calculating the carbon footprint for the welding electrode company in Mexico was obtaining data on gas consumption in each production line due to the lack of meters installed in each oven and specifications for each oven that would help estimate gas consumption.

5.2 Recommendations for Future Research

Gas meters must be installed in each production line to know the amount of gas consumed by each oven to carry out special mitigation measures for each drying oven. Likewise, carry out temperature measurements and energy balances in the drying ovens on a monthly basis to estimate the consumption of natural gas in each production line, obtain a more detailed carbon footprint, and generate new strategies to reduce GHG emissions without causing impact in plant production. New moisture tests must also be generated on all products to obtain new drying cycles that help reduce GHG emissions. On the other hand, data must be generated to obtain Scope 3 emissions (travel, supplier energy consumption, etc., to generate a more detailed carbon footprint. Monitoring the application of the proposals for the reduction of GHG in all production lines and offices will help reduce energy consumption, which will allow companies and the entire organization to achieve economic savings and a higher quality status It is important to develop a climate change awareness methodology for all company employees company, in order to implement mitigation measures in the generation of GHG in their work areas.

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Biographies

Oscar Eduardo Rivas- Aguilar is a research professor in the Postgraduate Research Department and Department of Environmental Engineering of the Instituto Tecnológico Superior de Álamo Temapache of Veracruz, Mexico. He has led climate change projects in municipalities and companies in the metalworking area for compliance with applicable regulations and projects to reduce greenhouse gas emissions, he is an advisor to the Secretary of the Environment of the State of Veracruz, for carrying out municipal agendas on climate change for the municipalities of the north of the state of Veracruz. Master Oscar is responsible for the electrical energy consumption area and is an internal auditor for the ISO 14001:2015 Environmental Management System. His research is applied in climate change, quality management, and business sustainability.

Lila Margarita Bada-Carbajal is a Senior Lecturer of Management at the Postgraduate Research and Department of Engineering in Administration at Tecnológico Nacional de México, Instituto Tecnológico Superior de Álamo Temapache Veracruz, Mexico and Visiting Lecturer at the Department of Postgraduate Research at Instituto Politécnico Nacional, Escuela Superior de Comercio y Administración USTO in Mexico City. She is a Member of the National System of Researchers (SNI), of the National Council of Science and Technology (CONACYT), with the

Distinction of National Researcher Level I. She has led projects of business sustainability to help organizations implement sustainability and research projects funded by the Program of Faculty Professional Development for Higher Education (PRODEP) in Mexico. Dr. Bada-Carbajal has published over 18 articles and scientific journals and participated in various international conferences. Her research applies to management, competitiveness, supply chain, value chain, clusters, quality management, and business sustainability.

Gabriela G. Escobedo-Guerrero is a Researcher and Associate Professor at Instituto Politécnico Nacional, she has a degree in Industrial Administration from UPIICSA, a Master in Policy and Management in Technological Change from CIECAS, and holds a Ph.D. in Administrative Sciences from ESCA UST-IPN; she has held several positions of Planning and Organization, in addition, Ph.D. Gabriela has been a member of the National Research System of CONACYT. She coordinated the Environmental Leadership project of ESCA-UST, achieving the Honorable Mention. She has also published two books about sustainability and innovation, and she was the coordinator of the Master's program in Business Administration for Sustainability, during her tenure, the program achieved one of the top five MBAs in Mexico (rating awarded by the magazine "Sánchez"). Her research interests include Sustainable Development and Technological Innovation to promote its application in Mexican companies, in addition to proposing a viable model for a responsible society with a view to a sustainable future.

Zarahemla Ramírez-Hernandez is a full-time professor at the Instituto Tecnológico Superior de Álamo Temapache. She has participated in developing projects related to the use of industrial waste to improve companies' sustainability. She has collaborated in the publication of scientific articles and international presentations. She is currently CEO at the Instituto Tecnológico Superior de Álamo Temapache.

Ignacio García- Sánchez is a research professor for the Centro Mexicano para la Producción más Limpia of the Instituto Politécnico Nacional, teaching energy efficiency in the Postgraduate Master's program in Cleaner Production Engineering, he has been thesis director on energy efficiency issues energy, life cycle analysis, carbon footprint, sustainable building, and process efficiency. Master Ignacio is deputy director of Industrial Liaison for the Centro Mexicano para la Producción más Limpia of the Instituto Politécnico Nacional, providing services in specialized technical assistance, research-innovation, and technological development, he has carried out industrial diagnoses on issues of pollution prevention, energy efficiency, and reduction of GHG emissions greenhouse effect for the national and international industries.