9th North American Conference on Industrial Engineering and Operations Management
Washington D.C., USA, June 4-6, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/NA09.20240102
Published: June 4, 2024

Impact of ISO 14001:2015 on the Carbon Footprint of the Instituto Tecnológico Superior de Álamo Temapache, Veracruz, Mexico

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Abstract

The objective of this research is to evaluate the impact that the implementation of the ISO 14001:2015 standard has had on the reduction of the carbon footprint at the Instituto Tecnológico Superior de Álamo Temapache (ITSAT) during the period 2018-2022. The Greenhouse Gas Protocol methodology was used to quantify direct and indirect emissions of scopes 1 and 2 before and after ISO 1400:2015 certification in 2018. The results show a 36.4% decrease in the footprint. Of total carbon, they are going from 108,868 tons of CO_2 equivalent in 2018 to 69,157 tons in 2022. Although the year-on-year comparison was affected by the atypical drop-in activities in 2020-2021 due to the COVID-19 pandemic, the data reveal a better environmental performance in 2022 than in 2018, before certification. It is concluded that adopting the Environmental Management System based on ISO 14001:2015 has positively impacted the mitigation of Greenhouse Gas emissions in this institution. Some limitations were the lack of data to estimate

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indirect emissions of scope 3. As future work, it is recommended to include scope 3, replicate the study in other educational centres and develop specific decarbonization plans for the sector.

Keywords
Carbon Footprint, ISO 14001:2015, Instituto Tecnológico Superior de Álamo Temapache, Climate Change, and Greenhouse Gases.

1. Introduction
Environmental management has become a fundamental pillar for organisations' competitiveness, sustainability, and social responsibility in recent decades (Boiral 2012). This has driven the adoption of international standards such as ISO 14001:2015, which provides a structured framework for developing effective environmental management systems focused on improving environmental performance and regulatory compliance (Zutshi and Sohal 2004).

The importance of ISO 14001:2015 lies in its ability to guide organisations in reducing their carbon footprint, mitigating greenhouse gas (GHG) emissions and effectively incorporating environmental sustainability practices (Prakash and Potoski 2006). Studies by Yin and Schmeidler (2009) and Pereira-Moliner et al. (2012) highlight the positive contribution of this standard to the reduction of energy consumption, efficient use of resources and waste management, with the consequent impact on the carbon footprint. These benefits are particularly evident in universities and educational campuses. According to Klein-Banai and Theis (2011), ISO 14001:2015 offers an appropriate model for these institutions to manage their environmental aspects and incorporate sustainability into their operations. The meta-analysis by Hens et al. (2018) confirms that ISO 14001;2015 certification in universities is strongly associated with improved environmental performance, including emissions reduction, energy and water management, and waste management.

At the Instituto Tecnológico Superior de Álamo Temapache (ITSAT), implementing ISO 14001:2015 in 2018 constituted a relevant advance towards more sustainable practices and reducing the institutional carbon footprint. As stated by Disterheft et al. (2015), this type of initiative allows for anchoring environmental commitment in the organizational culture of educational institutions. Over the last five years, ITSAT has continuously worked to strengthen its Environmental Management System based on ISO 14001:2015 and improve its sustainability performance.

This article will examine the environmental progress of the ITSAT after the adoption of ISO 14001:2015, explicitly analyzing its impact on the reduction of the institutional carbon footprint between 2018 and 2022. The objective is to analyze the actual contribution of this international certification to the control and mitigation of GHG emissions, identifying achievements and areas of improvement to reinforce environmental management and sustainability.
The results will offer valuable insights for other institutions in the education sector interested in the impact of ISO 14001:2015 on carbon footprint and environmental performance.

1.1. Instituto Tecnológico Superior de Álamo Temapache
Since its founding in 2000, ITSAT has been characterized as an institution close to the needs of the environment. Little by little, it has achieved prestige and identity until it has become a consolidated institution with six educational programs that serve more than two thousand students (Ramirez 2019).

The ITSAT is located in the town of Xoyotitla, Municipality of Álamo Temapache, Veracruz; this institution has trained professionals who manage to achieve their goals and who contribute economically to state and regional development thanks to the academic commitment of the teaching staff and administrative staff, all committed with technological education that requires trained profiles in each area (Instituto Tecnológico Superior de Álamo Temapache 2019). ITSAT is certified in the ISO 9001:2015 (Quality Management System) and ISO 14001:2015 (Environmental Management System) standards. According to the environmental policy, ITSAT is an entity that trains quality professionals with ethical and moral values committed to the prevention and protection of the environment (Instituto Tecnológico Superior de Álamo Temapache 2018).

1.2 Objectives
The objective of this study is to analyze the impact of the implementation of the ISO 14001 standard 2015 in the reduction of the carbon footprint at the Instituto Tecnologico Superior de Álamo Temapache, Veracruz, using scopes 1 and 2 of the GHG Protocol as a reference framework for estimating greenhouse gas emissions.

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

Phase 1. Estimation of the Instituto Tecnologico Superior de Álamo Temapache's carbon footprint using scopes 1 and 2 of the GHG Protocol for the period from 2018 to 2022.

Phase 2. Evaluate the impact of implementing ISO 14001: 2015 on reducing the carbon footprint during the study period, identify areas of opportunity, and propose specific recommendations to strengthen carbon footprint reduction strategies and improve the institution's Environmental performance in the future.

2. Literature Review

Climate change has become one of the biggest environmental, social and economic challenges worldwide (Ramanathan et al. 2016). The accelerated increase in anthropogenic GHG emissions is altering the planet's climate patterns, with already evident adverse consequences such as extreme heat waves, increase in precipitation variability, acceleration in sea level rise, ocean acidification and loss of biodiversity (The Intergovernmental Panel on Climate Change 2021; US Global Change Research Program 2018).

Urgent and forceful mitigation and adaptation responses to climate change must be given to prevent these impacts from reaching catastrophic and irreversible tipping points (Steffen et al. 2018). The window of opportunity to stabilize global temperature rise at less than 2°C (United Nations Paris Agreement 2015) is rapidly narrowing, requiring a 45% reduction in net CO2 emissions globally in the next decade (The Intergovernmental Panel on Climate Change 2018). In this context, the carbon footprint concept has acquired particular relevance as a standardized metric for organizations, cities, and people to measure, report and manage their GHG emissions (Wiedmann and Minx) 2008). According to Järvi et al. (2021), the carbon footprint is becoming a Key Performance Indicator (KPI) determinant to monitor climate progress and guide effective decarbonization strategies.

Higher Education Institutions (HEIs) are called to lead in sustainability and global climate action (United Nations Conference on Environment and Development 1987). Given their leadership and social influence, universities can and should become effective agents of awareness, research and implementation of solutions to the climate crisis (Disterheft et al. 2016).

Quantifying the carbon footprint constitutes a critical first step for HEIs in this transition towards carbon neutrality (Klein-Banai and Theis, 2013; Caeiro et al. 2020). Ozawa-Meid et al. (2013) analyzed the footprint of 21 UK universities, finding wide variations between institutions. The factors most associated with a more significant carbon footprint were the size of the building infrastructure, the student population and energy consumption per square meter. Other works highlight the carbon footprint's usefulness in guiding energy efficiency, renewable energy and sustainable mobility measures specific to the University context (Escrigas et al. 2019; Müller-Christ et al. 2014). Thus, the periodic quantification of GHG emissions makes it possible to monitor climate progress and make decisions focused on those areas with the most significant reduction potential.

There are few studies on carbon footprint measurement in Latin America in higher education (Alonso-Almedia et al. 2015). However, integrating this metric and its public reporting expands trends within HEIs committed to climate change mitigation and the Sustainable Development Goals.

Adopting Environmental Management Systems (EMS) based on the ISO 14001:2015 standard allows educational institutions to have structured processes for measuring, public reporting and reducing their carbon footprint (Disterheft et al. 2016). Likewise, it facilitates the systematization of initiatives in aspects such as energy efficiency, waste management, sustainable purchasing and training of the university community (Alonso-Almedia et al. 2015).

Various studies support the positive effects of implementing ISO 14001:2015 on the environmental performance of universities. A meta-analysis by Hens et al. (2018) examined 60 publications, concluding that this certification has a statistically significant impact on mitigating GHG emissions in higher education institutions. Other research in 162 European universities found that having ISO 14001:2015 is consistently associated with improvements in carbon footprint management and communication of Environmental, Social and Governance (ESG) information (Fonseca et al. 2019).

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Although studies on ISO 14001:2015 in the university environment are still scarce in the Latin American context, a qualitative work by Vázquez and Do Joel Hans de Souza (2018) reported significant benefits in environmental culture and student commitment after implementation of SGA at a Mexican university.

In short, the integration of ISO 14001:2015 allows the environmental and climate dimension to be anchored in the systematic management of higher education institutions. Periodic monitoring of the carbon footprint under this international standard's guidelines facilitates identifying priority areas and targeting measures to advance carbon neutrality.

3. Methods

The study methodology was divided into two phases, following the stated objectives. The widely recognized GHG Protocol was used to estimate corporate carbon footprints (World Resources Institute and World Business Council for Sustainable Development 2015).

The GHG Protocol contemplates emissions from Scope 1 (direct from sources controlled by the organization) and Scope 2 (indirect due to the use of purchased energy). In Scope 1, emissions from the stationary combustion of fuels in the operation of the ITSAT, including gasoline, diesel, and LP gas, were considered, in addition to organic solid waste. Scope 2 considered emissions derived from electrical consumption.

Phase 1 covered quantifying the ITSAT carbon footprint from 2018 (the initial year of the implementation of ISO 14001:2015) until 2022, following the GHG Protocol methodology.

Phase 2 evaluated the impact of ISO 14001:2015 certification on GHG emissions performance, comparing the carbon footprint results and energy eco-efficiency indicators before and after implementing this environmental standard.
The specific methodological aspects of each phase of the study are presented below.

3.1. Phase 1

Carbon footprint estimation

A stationary tool was used to calculate Scope 1 emissions. GHG Protocol Combustion Tool. Consumption data were entered by type of fossil fuel (LP gas, gasoline, diesel), and tons of CO_2 equivalent per year were obtained. Scope 2 emissions due to electrical consumption were estimated by multiplying the annual electricity consumption (kWh) by the national electricity emission factors published by the Ministry of the Environment and Natural Resources (SEMARNAT) (See Figure 1). In this way, the footprint associated with the use of electrical energy in metric tons of CO2 equivalent was obtained. The Institute's total carbon footprint was calculated by adding Scope 1 and 2 emissions from 2018 to 2022 in Table 1

Table 1. National Electricity Emission Factor from 2018 – 2022. Source: SEMARNAT

Year	2018	2019	2020	2021	2022
National Electric Factor	0.527	0.505	0.494	0.423	0.423

3.2 Phase 2

Impact assessment of ISO 14001:2015 on the carbon footprint

In this phase, the carbon footprint totals before and after implementing ISO 14001:2015 are compared, determining the percentage variation.

4. Results and Discussion

Phase 1: Carbon Footprint Estimation

Energy consumption: Table 2 shows the ITSAT's consumption of stationary fossil fuels and municipal solid waste (MSW) from 2018 to 2022, which constitutes Scope 1 emissions.

Table 2. Consumption of Fossil Fuels and Municipal Solid Waste at ITSAT for Scope 1 (2018-2022).

Year	Gasoline (liters)	Diesel (liters)	Gas LP (liters)	MSW (kg)

2018	571.49	251.60	2,800	4,572
2019	287.26	77.73	2,800	4,160
2020	2,256.10	272.60	630	680
2021	2,392.49	73.41	420	100
2022	1,036.87	115.79	2,800	600
total	65,044.21	791.13	9,450	10,112

Table 3 shows the ITSAT electrical consumption for those same years, which was used to calculate Scope 2 emissions.

Table 3. Consumption of Electrical Energy within ITSAT for Scope 2 (2018-2022).

Years	KWH	MWH
2018	182,953	182,953
2019	201,638	192,237
2020	62,830	62,830
2021	71,001	71,001
2022	144,062	144,062
Total	662, 484	653,083

Greenhouse Gas (GHG) Emissions Scope 1 consumption was introduced in the Stationary Combustion Tool of the GHG Protocol to estimate the corresponding emissions in tons of CO_2 equivalent, as shown in Table 4.

Table 4. ITSAT Scope 1 Emissions (Ton CO2eq/year)

Fountain	Ton of $CO_{2\ eq}$ / year					
	2018	2019	2020	2021	2022	total
Gasoline	1,444	0.726	5,700	6,045	2,620	16,535
Diesel	0.677	0.209	0.734	0.198	0.312	2.13
LP Gas	4,525	4,525	1,018	0.679	4,525	15,272
RSU	5,806	5,283	0.864	0.127	0.762	12,842
Total	12,452	10,743	8,316	7,049	8,219	46,779

Regarding Scope 2 emissions due to electricity use, the national electrical emission factors provided by SEMARNAT were applied (Table 5).

Table 5. ITSAT Scope 2 Emissions (Tons CO_2eq/year)

Ton CO $_{2E}$ q						Total
	2018	2019	2020	2021	2022	
Source	Electric Power					
Total	96,416	97,080	31,038	30,033	60,938	315,505

By adding Scopes 1 and 2, the Institute's total carbon footprint was obtained for each year analyzed (Table 6).

Table 6. ITSAT Carbon Footprint 2018 – 2022 (Tons CO_2 Eq / Year)

Scope	*2018*	*2019*	*2020*	*2021*	*2022*	Total
Scope 1	12,452	10,743	8,316	7,049	8,219	
Scope 2	96,416	97,080	31,038	30,033	60,938	
Total	108,868	107,823	39,354	37,082	69,157	362,284

Phase 2: Assessment of the impact of ISO 14001 on the carbon footprint
Figure 1 shows the evolution of the total carbon footprint of the ITSAT during 2018-2022. A significant decrease in GHG emissions is observed in 2020 and 2021, mainly attributable to the reduction in in-person activities due to the COVID-19 pandemic.

However, when comparing the years before (2018) and after (2022) the implementation of the Environmental Management System with ISO 14001:2015, a 36.4% reduction in the carbon footprint is evident, going from 108,868 to 69,157 Tons of CO_2 equivalent.

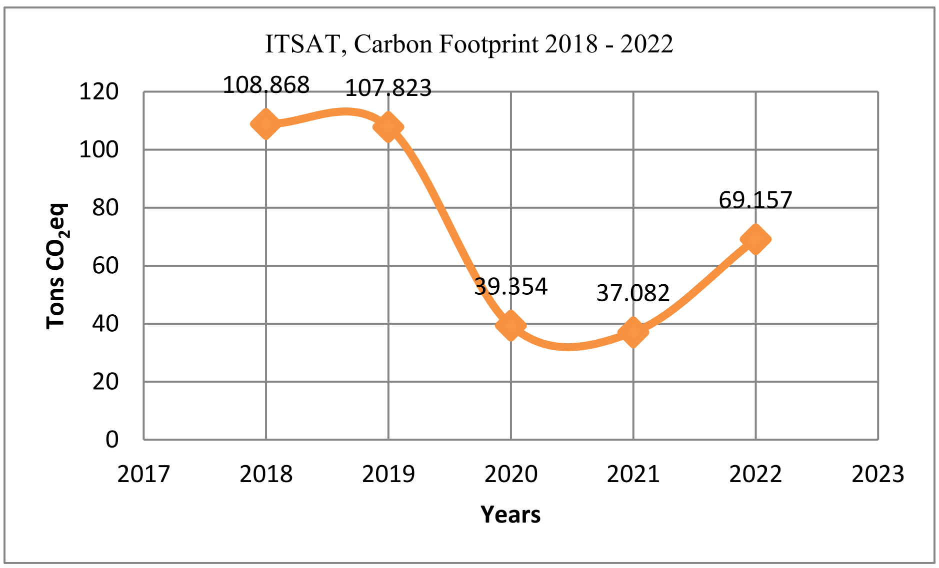

Figure 1. ITSAT, Carbon Footprint 2018 - 2022 (Tons of CO2eq per year)

The results suggest a positive impact of implementing ISO 14001:2015 on controlling and reducing carbon footprint. The establishment of a robust Environmental Management System and continuous improvement processes allowed ITSAT to optimize its operational practices in recent years for more efficient energy use, waste management, and mitigation of GHG emissions.
Although the atypical years 2020 and 2021 partially distort the comparison, it is clear that the institution achieved better environmental performance in 2022 compared to the base period of 2018 prior to its ISO 14001:2015 certification.

5. Conclusion

The present study evaluated the impact of implementing the ISO 14001:2015 standard on reducing the carbon footprint of the Instituto Tecnológico Superior de Álamo Temapache during the period 2018-2022. The results obtained allow us to draw the following main conclusions:

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1. The adoption of the Environmental Management System based on ISO 14001:2015 had a positive effect on mitigating greenhouse gas emissions. Between 2018 (prior to certification) and 2022, the total carbon footprint decreased by 36.4%, from 108,868 to 69,157 tons of CO2 equivalent.
2. This improvement in environmental performance coincided with significant advances in critical eco-efficiency indicators such as energy consumption per square meter, LP gas consumption per student, and percentage of recycled waste.
3. Although the year-on-year comparison was partially distorted by the atypical reduction of activities in 2020 and 2021 due to the COVID-19 pandemic, 2022 presented a better GHG emissions profile than the base period 2018 before ISO 14001 certification:2015.
4. The international standard ISO 14001:2015 is confirmed as a valuable regulatory framework for managing environmental aspects in educational institutions. Its effective implementation and the associated continuous improvement processes contribute to reducing the organizational carbon footprint.
5. Some areas of opportunity identified to deepen the reduction of GHG emissions are: i) More excellent implementation of renewable energies, ii) Sustainable mobility strategies, and iii) Expansion of recycling and recovery programs for solid waste.

This case study shows that adopting ISO 14001 significantly supported the transition towards more sustainable environmental performance at the Instituto Tecnológico Superior de Álamo Temapache. Standardized management systems represent a promising path for the education sector to move decisively towards carbon neutrality.

5.1 Research Limitations

Although this study provides relevant findings on the effects of the ISO 14001:2015 standard on the reduction of the carbon footprint in an educational institution, it is essential to recognize some limitations that must be considered:

1. Scopes of emissions analyzed: According to the GHG Protocol guidelines, the analysis was limited to direct emissions of Scope 1 (stationary fuels and waste) and indirect emissions of Scope 2 (electricity consumption). Scope 3 indirect emissions were not included due to lack of data availability.
2. Lack of data for Scope 3: Scope 3 contemplates other indirect emissions associated with the organization's value chain, such as transportation, travel, purchases, waste disposal, etc. Unfortunately, the ITSAT did not have reliable records or estimates of these emission sources for 2018-2022.
3. Limitation in monitoring activities: The carbon footprint estimation depended on the accuracy of the data recorded on energy consumption, fuel and waste generation in the institution's historical reports. Any lack of rigour or exhaustiveness in monitoring these activities may affect the calculation of emissions.
4. Atypical External Effects: The year-over-year comparative analysis was influenced by extraordinary external effects, such as the COVID-19 pandemic, drastically altering ITSAT's normal operations in 2020 and 2021.

Despite these limitations, the results obtained continue to be a valuable contribution by objectively quantifying the environmental improvement achieved through ISO 14001 certification in this educational institution. The available data were sufficient to evaluate this impact and highlight the importance of adopting solid environmental management systems aimed at carbon neutrality.

5.2 Recommendations for Future Research

The results of this study suggest promising lines for continuing research on carbon footprint management and climate change mitigation actions in the educational sector. The following opportunities for future work are identified:

1. Expand the carbon footprint analysis to Scope 3: Quantify indirect emissions associated with outsourced activities and the Institute's value chain, such as transportation of students and staff, travel, suppliers, solid waste management, etc. This would provide insight into a more comprehensive impact on the environment.
2. Replicate the study in other educational institutions: Conduct similar research in different universities, institutes, and school campuses that allow for the comparison of results, the identification of best practices, and the formation of a sectoral reference bank on carbon footprints.
3. Propose and evaluate decarbonization measures: Based on the findings of this research, design a specific GHG emissions mitigation plan for the ITSAT and implement concrete actions such as energy efficiency, sustainable mobility, waste management, renewable energy, compensation, etc. Monitor and quantify his effectiveness.

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4. Analyze economic and social co-benefits: Estimate the potential economic savings derived from carbon footprint reduction initiatives and evaluate social co-benefits such as improved quality of life, environmental awareness, green jobs, and community engagement.
5. Develop practical tools: Develop standardized methods, guides, software, and technical tools that make it easier for educational institutions to periodically calculate their GHG emissions, identify mitigation opportunities, and implement effective decarbonization actions.
6. Propose policies and incentive schemes: Formulate recommendations on regulatory frameworks, public policies and economic incentives that promote an accelerated transition of the education sector towards carbon neutrality.

The possible lines of future research are broad, and all of them allow capitalizing on the findings of this research to catalyze and multiply efforts towards environmental sustainability in the national and international educational sphere.

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