Environmental impact of energy consumption in academic buildings: Case study of the faculty of agricultural sciences at UAEM, Life Cycle Analysis approach

Impacto ambiental del consumo energético en edificaciones académicas: Caso de la Facultad de Ciencias Agropecuarias de la UAEM, un enfoque de Análisis de Ciclo de Vida

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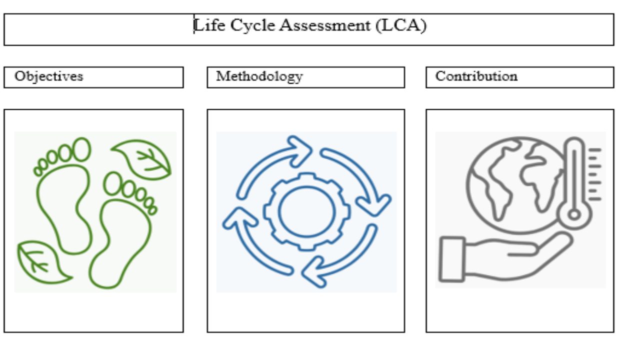
Abstract

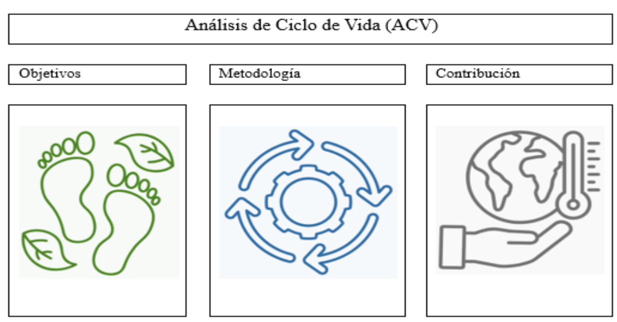
The evaluation of building energy needs during their operational phase is crucial for understanding their energy requirements. This study focuses on analyzing the energy demand of buildings within the Faculty of Agricultural Sciences at the Autonomous University of the State of Morelos during its operational phase. The methodology employed includes Life Cycle Assessment (LCA) to assess electricity consumption and associated greenhouse gas (GHG) emissions. The results revealed a significant increase in energy demand between 2022 and 2023, with significant environmental implications in terms of resource depletion and GHG emissions. These results underscore the urgency of implementing energy efficiency measures and adopting more sustainable practices in academic environments to mitigate environmental impacts and contribute to the fight against climate change.



Energy, Life Cycle Assessment (LCA), Building

Resumen

Es necesario evaluar las necesidades energéticas de los edificios, especialmente durante su proceso de operación, es decir, los requerimientos energéticos para su funcionamiento. Este estudio se centra en analizar la demanda energética de los edificios que conforman la Facultad de Ciencias Agropecuarias de la Universidad Autónoma del Estado de Morelos durante su fase operativa. Se utilizó la metodología del Análisis de Ciclo de Vida (ACV) para evaluar el consumo de energía eléctrica y las emisiones de gases de efecto invernadero (GEI) asociadas. Los resultados revelaron un aumento significativo en la demanda energética entre 2022 y 2023, con implicaciones ambientales destacadas en términos de agotamiento de recursos y emisiones de GEI. Estos hallazgos resaltan la importancia de implementar medidas de eficiencia energética y adoptar prácticas más sostenibles en entornos académicos para mitigar los impactos ambientales y contribuir a la lucha contra el cambio climático.



Energía, Análisis de Ciclo de Vida (ACV), Edificio

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Introduction

Our globalized way of life is based on an energy model focused on the consumption of fossil sources such as oil, coal and natural gas, as well as the irrational use of fuels for the generation of electrical energy.

This model is not only unsustainable in the long term due to the depletion of natural resources, but also contributes significantly to climate change through the emission of greenhouse gases (GHG). In 2022, worldwide, 63% of electrical energy was generated from fossil sources, and in Mexico this figure reached an alarming 77% (IEA, 2022).

Universal access to an affordable, reliable, sustainable and modern level of energy is essential to meet other Sustainable Development Goals (SDGs), established by the United Nations (UN) in 2015. These goals form the axis of efforts. to address climate change through the 2030 Agenda.

Climate change, defined as long-term changes in the Earth's climate, includes an increase in global average temperature, sea level and changes in precipitation patterns. GHG emissions, produced mainly by the burning of fossil fuels, are one of the main drivers of these changes.

The impacts of climate change are profound and varied, affecting both the environment and human health. Extreme weather conditions such as heat waves, droughts and floods are becoming more frequent, as are vector-borne diseases and a decline in air and water quality. These phenomena have direct and indirect consequences on the health and well-being of people, especially the most vulnerable populations.

In this context, it is crucial to evaluate and reduce the energy consumption of buildings, especially in the academic sector, which can serve as a model for other institutions. This study focuses on the Faculty of Agricultural Sciences of the Autonomous University of the State of Morelos (UAEM), using the Life Cycle Analysis (LCA) methodology to evaluate the environmental impacts associated with the consumption of electrical energy during its operational phase.

The use of LCA in this analysis allows for a comprehensive assessment of the environmental impacts of the energy consumed.

This provides a solid basis for identifying key areas for improvement and developing effective strategies for reducing energy consumption and GHG emissions. This approach is essential to promote sustainability in academic buildings and contribute to global efforts to combat climate change.

Objectives

In the context of sustainable development and the contribution to global climate change mitigation, it is essential to identify through a specialized methodology the Greenhouse Gas contributions (La Roche, 2010) associated with buildings. Firstly, the energy consumption of the object of study and then the assessment of annual GHG emissions generated by the demand for electricity in buildings for their operation.

These studies are the basis for proposing actions that contribute to stabilizing the increase in the global average temperature to 1.5 °C proposed in 2015 through the Paris Agreement in the United Nations Framework on Climate Change (UNFCCC, 2015). In 2022, Mexico emitted 407 $MtCO_2$, ranking 15th in terms of countries contributing to global emissions (GCA, 2022).

Environmental problems today, involve discovering the incidence of construction and the impacts generated through habitability. Therefore, as global trainers of leaders in technological innovation, universities must lead the transition to the management and planning of renewable energy in their physical and natural environments, the implementation of projects to mitigate environmental impacts caused by direct emissions (WEF, 2022) from electricity consumption of students, faculty and staff in the buildings they use.

The Autonomous University of the State of Morelos is a public university founded in 1953, has more than 150,000 m2 of construction, the enrolment for 2022 amounts to 40,000 high school, undergraduate and graduate students and has a presence in more than 20 municipalities of the 34 in the state of Morelos, which represents 60% of the total Zapatista territory.

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It has 9 academic units at the secondary level and 35 at the higher level that make up the research centers and institutes, schools, faculties and regional headquarters. It has a teaching staff of 2,000 unionized teachers and close to 1,000 trust academics. To support institutional activities, there are more than 2,000 people, half of them unionized and the rest trustworthy.

Since 2002, the UAEM has been working to promote an environmental culture among its university, civilian and general community, founding the "University Environmental Management Program" (PROGAU by its Spanish capital letters) (UAEM, 2024), which main objective was to reduce environmental effects derived from anthropogenic activities, to finally implement actions to develop a culture of care, conservation and protection of the environment in favor of climate change mitigation.

The PROGAU generated strategies and lines of action through five aspects: integrated waste management, environmental education, natural environment and landscape architecture, efficient water and energy management, health and safety (PIDE, 2018).

By 2017 it became the General Directorate of Sustainable Development, "Dirección General de Desarrollo Sustentable" (DGDS by its Spanish capital letters); with activities to regulate the "Unidad de Desarrollo Sustentable", in terms of their behavior to face of environmental problems within the UAEM itself. And finally, as of 2024, it has become the Sustainable Development Unit, attached to the Faculty of Agricultural Sciences. It is responsible of carrying out activities for the use of resources, the composting center and a zero-waste policy.

The objective of this study is to identify electrical energy demand of the buildings that make up the Faculty of Agricultural Sciences through the energy consumption of its students, faculty and staff, its most energy intensive components of this type of service buildings, verification with the consumption register before the Federal Electricity Commission "Comisión Federal de Electricidad" (CFE, by its Spanish capital letters), to subsequently quantify the GHG emissions with the support of the international and specialized methodology of Life Cycle Analysis (LCA).

Finally generate the corresponding GHG report, as other universities have done for their GHG inventories (Saavedra, 2020) (Bautista et al., 2022).

Methodology

The LCA methodology evaluates the possibility of environmental hazards, measures the amount of materials, energy and waste released into the environment, and assesses the effects of processes on human health, the general quality of the environment and the depletion of raw materials; it is possible to identify potential environmental impacts (Larrey-Lassalle et al. 2017) (Guerin-Schneider et al., 2018).

Each phase of the life cycle of a specific product or service is covered by the analysis, starting with the first step of the life cycle assessment, which involves obtaining data on the raw materials needed for production, and then moving on to the manufacturing, distribution and consumption phases, as is the case of the latter stage, which is the focus of this study.

The ISO (International Organization for Standardization) 14001-14043 (ISO, 2006) define the four components of the LCA framework, as shown in Figure 1, starting with the definition of the objective and scope, the inventory analysis, i.e., the set of inputs and outputs that make up the investigated process, to move on to the impact assessment phase and finally the interpretation of the results. As can be seen, there is a correlation in each of them; the results in any of the components can be used as the main source of data for the previous or following phases of the LCA.

Box 1

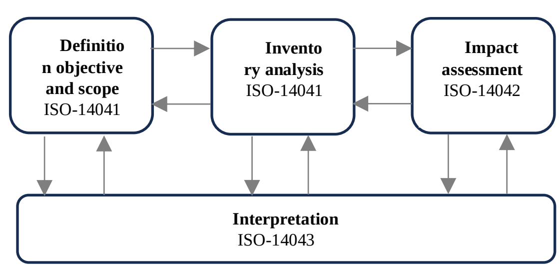

Figure 1
Principles and framework of the LCA methodology
Source: ISO. (2006). International Organization for Standardization

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Currently, most of the research and life cycle analysis in the field of buildings is mainly concentrated in Europe. This continent is the epicenter of much of the life cycle analysis studies due to the presence and significant participation of companies and institutions supplying data necessary to carry out this type of evaluations (Leda et al., 2023). In general, buildings are designed to have an operational life that can range from 20 to 50 years, although they can last much longer with proper maintenance and periodic renovations (Hernández-Moreno, 2010) (Hernández-Moreno, 2011) (Macías-Bernal, et al., 2014) (Aguirre et al., 2024).

The cut-off points for the analysis of the electrical energy demand of the buildings that make up the academic unit will be set at 0.06% in relation to the average useful life of a building. The study of electrical energy consumption was carried out for the buildings of the Faculty of Agricultural Sciences, belonging to the Autonomous University of the State of Morelos, activities inherent to the Academic Unit, in this case to the activities of higher and postgraduate students, professors and staff. The buildings are used as part of its professional training, research, development and innovation activities Two annual consumption scenarios were analyzed, as shown in Table 1, corresponding to the years 2022 and 2023. The information was requested from the Academic Unit's management and later verified through the internal *"commercial system"* (SICOM, by its Spanish capital letters) server of the electricity supplier, the CFE.

Box 2

Table 1

Electrical energy consumption, Faculty of Agricultural Sciences

Month / Year	Consumption kWh anual	
	2022	2023
january	3,967	6,132
february	3,728	7,225
march	5,705	8,490
april	5,205	6,309
may	8,375	8,716
june	5,958	7,503
july	4,253	6,225
august	7,063	6,741
september	8,288	7,944
october	8,113	7,629
november	8,128	7,246
december	6,096	5,925
Total	74,879	86,085

Source: Own elaboration with data provided by the Faculty of Agricultural Sciences

The emissions quantification was carried out considering the system boundary from door to door; that is, in the operation and energy consumption stage of the building, using the OpenLCA software (Green Delta, 2022) because it is free, fast and reliable in the evaluation of Life Cycle Assessment (LCA) (Mutel et al., 2009), have a large database such as Nexus and Ecoinvent (Rodríguez et a., 2016) (McCarl et al., 2017), essential in this type of studies (Atmaca et al., 2015) (Molina-Moreno et al., 2017) (Nydahl et al., 2019).

Then midpoint impact categories were analyzed including: Abiotic Depletion Potential (ADP kg Sbeq), Fossil Fuel Depletion Potential (FDP MJ), Acidification Potential (AP kg SO_2eq), Eutrophication Potential (EP kg PO_4eq), Freshwater Ecotoxicity Potential (FAETP kg 1,4-DBeq), Global Warming Potential (GWP kg CO_2eq), Human Toxicity Potential (HTP kg 1,4-DBeq), Ozone Depletion Potential (ODP kg CFC-11eq), Photochemical Ozone Creation Potential (POCP kg C_2H_4eq) and Terrestrial Ecotoxicity Potential (TETP kg 1,4 DBeq), considering the midpoint CML-IA (baseline) impact assessment method as endpoint (CML-IA Baseline, 2016) because it is the assessment method mostly used in LCA studies (Ortíz et al., 2022).

Results

The results of the midpoint impact analysis for the selected 2022 and 2023 scenarios reveal that the most affected categories are Fossil Fuel Depletion Potential (FDP), Global Warming Potential (GWP100a), Freshwater Ecotoxicity Potential (FAETP) ann Human Toxicity Potential (HTP).

The CML-IA endpoint analysis showed that resource depletion was the most affected category, followed by climate change, human and ecosystem health, which aligns with the findings of the midpoint analysis.

It is notable that both analyses indicate impacts to all four endpoint aspects, which is of concern. These results are shown in Figure 2.

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Box 3

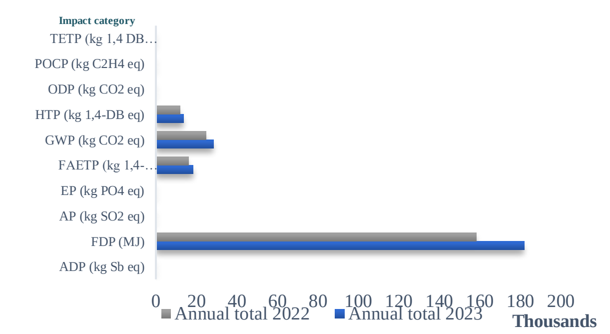

Figure 2

Results of the analysis by category of impact in the 2022 and 2023 scenarios for energy consumption in the Faculty of Agricultural Sciences of the UAEM.

The results for the category of Fossil Fuel Depletion Potential (FDP) are shown in Figure 3, the average result of energy resource consumption is just over 13,000 MJ for the year 2022, while for the year 2023 it recorded resource depletions of just over 15,000 MJ, for the months of September and November 2022 and also March 2023. This indicator is up to 18% above the average. Coincidentally, for the month of May in both years the indicator is 20% above the average, the hottest month for the geographical area of the UAEM.

The months with the least impact in both years are the months of December and January, coinciding with one of the most important vacation periods for the University. The months with the lowest impact in both years are December and January, coinciding with one of the most important vacation periods for the University. For this impact category, the endpoint analysis indicates the depletion of fossil fuel sources by up to 158,000 MJ for 2022 and 182,000 MJ for 2023, representing a difference in increase of up to 15%

Box 4

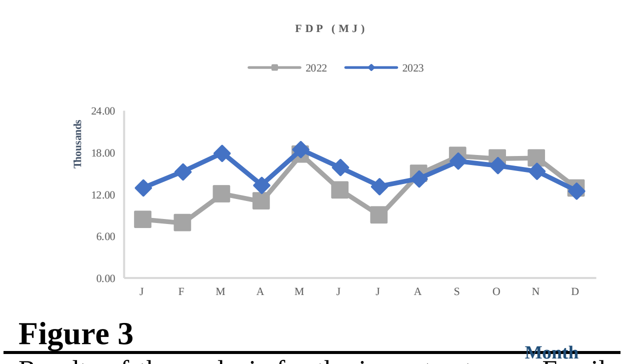

Figure 3

Results of the analysis for the impact category Fossil Fuel Depletion Potential (FDP MJ) in the 2022 and 2023 scenarios for energy consumption in the Faculty of Agricultural Sciences of the UAEM.

The results for the Freshwater Ecotoxicity Potential (FAETP) impact category are shown in Figure 4, although the impacts produced at the midpoint level are minor compared to other categories such as Fossil Fuel Depletion Potential (FDP) or Global Warming Potential (GWP), they do have significant effects on ecosystems. The figures indicate equivalent Dichlorobenzene emissions of up to 16,000 kg for 2022 and 18,500 kg for 2023, representing a 16% difference between the scenarios analyzed. The months of May, September and November 2022 and March and May 2023 are the most affected months, coinciding with the impact category of Fossil Fuel Depletion Potential (FDP).

Box 5

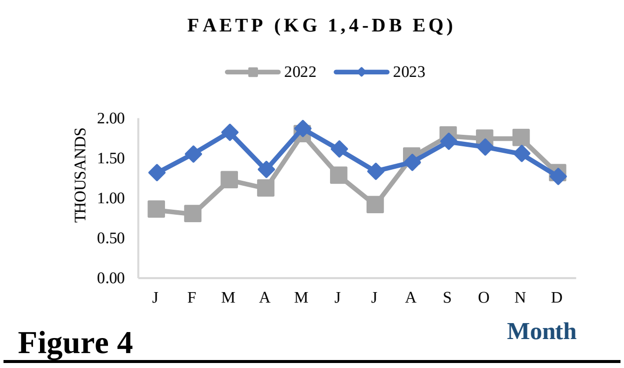

Figure 4

Results of the analysis for the impact category Freshwater Ecotoxicity Potential (FAETP kg 1,4-DB eq) in the 2022 and 2023 scenarios for energy consumption in the Faculty of Agricultural Sciences of the UAEM

The CO_2eq emissions from electricity consumption for the scenarios 2022 and 2023 are shown in Figure 5. The results amount an average to 24.7 tones CO_2eq for the first scenario, while for 2023 the average is 28.4 tones CO_2eq.

For this category, coincidentally with Fossil Fuel Depletion Potential (FDP) and Freshwater Ecotoxicity Potential (FAETP) categories, the months of least impact are January and February 2022 and December 2023, for which the Mexican winter school holiday period occurs. This is the category of greatest interest in this study, the results indicate the carbon footprint due to electricity consumption in the Faculty of Agricultural Sciences, which will be reflected not only in CO_2 emissions but also in five greenhouse gases covered by the Kyoto Protocol: Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur Hexafluoride (SF_6).

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For this impact category, the endpoint analysis indicates GHG emissions of up to 24,700 kg CO_2eq by 2022 and 28,400 kg CO_2eq by 2023, representing a 15% difference in emissions for the second scenario.

Box 6

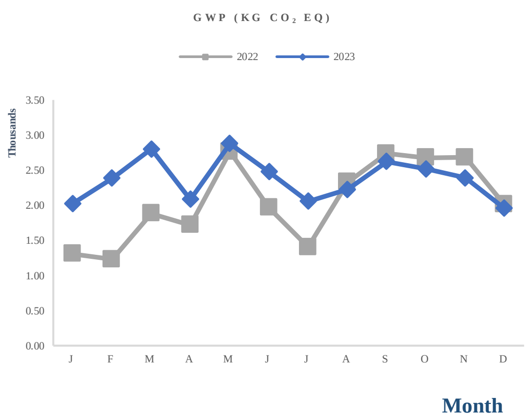

Figure 5

Results of the analysis for the Global Warming Potential impact category (GWP kg CO_2eq) in the 2022 and 2023 scenarios for energy consumption in the Faculty of Agricultural Sciences of the UAEM

Discussion and Conclusions

The Life Cycle Assessment methodology was successfully applied to evaluate the environmental impact of electricity consumption in the Faculty of Agricultural Sciences. Two annual consumption scenarios for the years 2022 and 2023 were analyzed.

The study reveals a significant 15% increase in electricity consumption in the faculty between these two years, which underlines the urgent need to implement effective measures to reduce this demand and mitigate its environmental impact.

The most worrying category is Fossil Fuel Depletion Potential (FDP), with about 200,000 MJ in 2023, indicating a depletion of fossil sources for electricity generation in Mexico. On the other hand, the lower impact categories, such as Abiotic Depletion Potential (ADP), Acidification Potential (AP), Ozone Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP) and Terrestrial Ecotoxicity Potential (TETP), show levels close to zero impact according to the analysis.

The study reveals that electricity consumption in the buildings studied generates a considerable amount of greenhouse gas emissions, especially Carbon Dioxide CO_2 (carbon footprint).

This highlights the crucial importance of reducing these emissions to contribute to climate change mitigation, in line with the targets set out in the Paris Agreement.

It is essential to intensify actions to reduce energy demand and greenhouse gas emissions in the Faculty of Agricultural Sciences. This can be achieved by implementing energy efficiency measures, using renewable energy and raising awareness of the importance of environmental sustainability.

As electrical energy consumption continues to increase, the ability to forecast the maximum energy consumption of UAEM buildings is critical to effectively manage the energy system. The selection of an appropriate model is crucial to accurately predict such consumption, given that consumption trends and characteristics vary substantially.

Public Universities, such as the Autonomous University of Morelos State, play a crucial role in leading the transition to more sustainable practices. They should promote environmental education and adopt green and renewable technologies to reduce their environmental impact.

LCA provides valuable information on the environmental impact of buildings during their operational lifetime. This approach should be widely applied to guide more sustainable design and management decisions.

It is recommended to continue to regularly monitor and evaluate energy consumption and emissions in the Faculty of Agricultural Sciences. Continuous improvement in environmental and energy practices is essential to achieve long-term sustainability goals according to Sustainable Development Goals, SDG.

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

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Author contribution

Brito-R Julio: Contributed to the project idea and to the research of the information.

Hernández-Luna, Gabriela: Contributed to the methodology use.

Availability of data and materials

Data are available from the corresponding author.

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Abbreviations

ADP	Abiotic Depletion Potential
AP	Acidification Potential
C_2H_4eq	Ethylene
CFC-^{11}eq	Equivalent Trichlorofluoro Methane
CFE	Federal Electricity Comission
CH_4	Methane
CO_2	Carbon Dioxide
CO_2eq	Equivalent Carbon Dioxide
DBeq	Equivalent Dichlorobenzene
DGDS	General Directorate of Sustainable Development
EP	Eutrophication Potential
FAETP	Freshwater Ecotoxicity Potential
FDP	Fossil Fuel Depletion Potential
GCA	Global Carbon Atlas
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
HTP	Human Toxicity Potential
ISO	International Organization for Standardization
kg	Kilogram
LCA	Life Cycle Assessment
MJ	Mega-Joules
$MtCO_2$	Mega ton of Carbon Dioxide
N2O	Nitrous Oxide
ODP	Ozone Depletion Potential
PFCs	Perfluorocarbons
PIDE	Plan Institucional de Desarrollo
PO_4eq	Equivalent Phosphate
POCP	Photochemical Ozone Creation Potential
PROGAU	University Environmental Management Program
Sbeq	Equivalent Antimony
SDGs	Sustainable Development Goals
SF_6	Sulphur Hexafluoride
SICOM	Commercial System
SO_2eq	Equivalent Sulfure Dioxide
TETP	Terrestrial Ecotoxicity Potential
UAEM	Autonomous University of the State of Morelos
UN	United Nations
UNFCCC	The United Nations Framework Convention on Climate Change
WEF	World Economic Forum

References

Background

IEA. (2022). International Agency of Energy.

La Roche, P. (2010). Cálculo de emisiones de gases de efecto invernadero en edificios: análisis del funcionamiento de varias herramientas en diferentes climas. *Informes de la Construcción, 62*(517), 61-80.

UNFCCC (The United Nations Framework Convention on Climate Change). Paris agreement. (2019).

GCA. (2022). Global Carbon Atlas.

WEF. (2022). World Economic Forum.

UAEM. (2024). Universidad Autónoma del Estado de Morelos.

PIDE. (2018). Plan Institucional de Desarrollo.

ECORFAN® All rights reserved.

Basics

Larrey-Lassalle, P., Catel, L., Roux, P., Rosenbaum, RK, López-Ferber, M., Junqua, G. y Loiseau, E. (2017). An innovative implementation of LCA within the EIA procedure: Lessons learned from two Wastewater Treatment Plant case studies. *Environmental Impact Assessment Review, 63*, 95–106.

Guerin-Schneider, L., Tsanga-Tabi, M., Roux, P., Catel, L. and Biard, Y. (2018). How to better include environmental assessment in public decision-making: Lessons from the use of an LCA-calculator for wastewater systems. *Journal of Cleaner Production*, *187,* 1057-1068.

ISO. (2006). International Organization for Standardization.

Leda, P., Kruszelnicka, W. Leda, A., Piasecka, I., Klos, Z., Tomporoswki, A. and Opielak, M. (2023). Life Cycle Analysis of Photovoltaic Power Plant Using the CED Method. *Energies, 16*(4), 2-19.

Hernández-Moreno, S. (2010). Integration of service life in the process of management and design of buildings. *Management Research and Practice,* 2(4), 397-400.

Hernández-Moreno, S. (2011). Aplicación de la información de la vida útil en la planeación y diseño de proyectos de edificación. Acta Universitaria, 21(2), 37-42.

Macías-Bernal, J. M., Calama-Rodríguez, J. M., Chávez-de Diego, M. J. (2014). Modelo de predicción de la vida útil de la edificación patrimonial a partir de la lógica difusa. *Informes de la Construcción*, 66 (533).

Aguirre C., F., Treviño M., F., Hoyos C., C. A., y García A., M. E. (2024). Efectos del envejecimiento estructural durante la vida útil de Edificios: caso de estudio de un edificio educativo. *Memoria Investigaciones En Ingeniería*, (26), 125–142.

Green Delta. (2022). Open LCA.

Mutel, C. and Hellweg, S. (2009). Regionalized Life Cycle Assessment: Computational Methodology and Application to Inventory Databases. *Environmental science & Technology*, 43(15), 5797–5803.

Rodríguez, C., Moller, F. y Ciroth, A. (2016). ecoinvent v. 3.2 en OpenLCA. *OpenLCA, Berlín.*

McCarl, B. A., Yang, Y., Srinivasan, R., Pistikopoulos, E. N. and Mohtar, R. H. (2017). Data for WEF nexus analysis: A Review of Issues. *Current Sustainable/Renewable Energy Reports*, 4(3), 137-143.

Atmaca, A. and Atmaca, N. (2015). Life cycle energy (LCEA) and carbon dioxide emissions ($LCCO_2A$) assessment of two residential buildings in Gaziantep, Turkey. *Energy and Buildings*, 102, 417-431.

Support

Saavedra, F. E. (2020). Huella de carbono-emisiones de GEI por uso del sistema de iluminación de la Facultad de Ingeniería Ambiental de la Universidad Nacional de Ingeniería, Lima-Perú. *Tecnia*, 30(1), 121-138.

Bautista, J., Sierra, Y. y Bermeo, J. F. (2022). Emisiones de Gases de Efecto Invernadero en las Instituciones de Educación Superior. *Producción + Limpia*, 17(1), 169-186.

Molina-Moreno, F., Martí, J. V., Yepes, V. and Ciroth, A. (2017). Environmental impact shares of a reinforced concrete earth-retaining wall with buttresses. *Resilient Structures and Sustainable Construction*, 1-6.

Nydahl, H., Andersson, S., Astrand, A. and Olofsson, T. (2019). Environmental Performance Measures to Assess Building Refurbishment from a Life Cycle Perspective. *Energies*, 12 (2), 299.

CML-IA Baseline. (2016). Universiteit Leiden.

Discussions

Ortiz, J. A., Edo, B., M. D. y Gonzalo, B. M. (2022). Análisis de ciclo de vida en el sector de la edificación residencial: estado del arte. 407-419.

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Brito-R., Julio Cesar & Hernández-Luna, Gabriela. [2024]. Environmental impact of energy consumption in academic buildings: Case study of the faculty of agricultural sciences at UAEM, Life Cycle Analysis approach. ECORFAN Journal Republic of Guatemala. 10[18]1-8: e21018108.
https://doi.org/10.35429/EJRG.2024.10.18.1.8