

Life Cycle Analysis of materials used in social housing in Ecuador

Análisis de Ciclo de Vida de materiales usados en viviendas sociales en Ecuador

Authors:

Germán Vélez-Torres

Catholic University of Cuenca, Ecuador

Karla Alvarado Palacios

Instituto Superior Tecnológico del Austro,
Ecuador

Ana Gabriela Peñafiel

Catholic University of Cuenca, Ecuador

Corresponding author:

Karla Alvarado Palacios

karla.alvarado@instecclrg.edu.ec



Receipt: 28 - March - 2025

Approval: 14 - June - 2025

Online publication: 30 - June - 2025

How to cite this article: Alvarado Palacios, K., Vélez-Torres, G. & Gabriela Peñafiel, A. (2025). Life Cycle Analysis of materials used in social housing in Ecuador. *Maskana*, 16(1), 309 - 321. <https://doi.org/10.18537/mskn.16.02.19>



Life Cycle Analysis of materials used in social housing in Ecuador

Análisis de Ciclo de Vida de materiales usados en viviendas sociales en Ecuador

Abstract

This article aims to evaluate the sustainability of construction materials in Ecuador, whose use accounts for 41.1% of the country's environmental impact, focusing on social housing projects in the provinces of Azuay and Cañar. The Life Cycle Assessment (LCA) methodology was applied to quantify the environmental impacts of concrete and steel from raw material extraction to end-of-life, using the OpenLCA software. Two scenarios were compared: one based on conventional practices and another incorporating sustainable strategies, such as the use of recycled materials and steel reuse. The results show that the extraction and production stages are the most impactful, with cement and steel being the main contributors due to their high energy consumption. It is concluded that the incorporation of recycled materials and the implementation of circular economy strategies can significantly reduce environmental impacts, especially in the categories of climate change and resource depletion, reinforcing the need for sustainable approaches in social housing construction.

Keywords: Life Cycle Assessment, Construction, Concrete, Steel, Environmental Impact.

Resumen

El artículo presenta el resultado de evaluar la sostenibilidad de los materiales de construcción en Ecuador, cuyo uso representa el 41,1% del impacto ambiental del país, enfocándose en proyectos de vivienda social en las capitales de las provincias Azuay y Cañar. Se emplea el Análisis de Ciclo de Vida (ACV) como metodología para cuantificar los efectos ambientales del concreto y el acero desde la extracción de materias primas hasta su disposición final, con el uso del software Open LCA. Se comparan dos escenarios: uno con prácticas convencionales y otro con estrategias sostenibles, como el uso de materiales reciclados y la reutilización del acero. Los resultados indican que las etapas de extracción y producción son las más impactantes, destacando el alto consumo energético del cemento y el acero. Se concluye que la implementación de materiales reciclados y estrategias circulares puede reducir significativamente el impacto ambiental, especialmente en cambio climático y agotamiento de recursos, reforzando la necesidad de enfoques sostenibles en la construcción de vivienda social.

Palabras clave: Análisis de Ciclo de Vida, construcción, concreto, acero, impacto ambiental.

1. Introduction

Construction-related activities have been identified as one of the primary sources of adverse environmental impacts globally. Current construction processes are often not environmentally sustainable, omitting the social responsibility and assertive practices necessary for sustainable building. It is estimated that approximately 40% of global energy consumption comes from the construction sector (Enshassi et al., 2018). In Ecuador, the construction industry accounts for 41.1% of the total national environmental impact, ranking third in CO₂ emissions and contributing significantly to the country's Gross Domestic Product (GDP) (INEC, 2020).

Ecuador has actively participated in various environmental protection treaties, recognizing the significant ecological diversity within its territory. Currently, this commitment is reflected in the implementation of the 2030 Agenda, which aligns with the National Development Plan 2021-2025 and the United Nations' Sustainable Development Goals (SDGs). The country has established a platform for monitoring the progress of the 2030 Agenda, developed with the support of the United Nations System (UNS). In July 2017, the National Assembly adopted a resolution establishing the SDGs as a mandatory framework for its work (UN Ecuador, 2022).

Various public and private institutions in Ecuador have incorporated the Sustainable Development Goals (SDGs) as a basis for decision-making, innovation, and development in their respective sectors. However, current legislation still does not provide sufficient regulatory guarantees for the effective implementation of the environmental rights of both individuals and nature (Almeida, 2021). Consequently, the strategies proposed for industrial development have remained, to a large extent, aspirational without rigorous implementation or significant impact.

In the construction sector, the Ministry of Urban Development and Housing (MIDUVI) has issued

the National Habitat and Housing Plan 2021-2025, which has a strategic objective of creating sustainable, inclusive, resilient, and safe habitats. This objective is intended to be achieved through a comprehensive portfolio of urban development and regeneration projects with a focus on climate change adaptation (MIDUVI, 2021). However, while this plan aligns with the SDGs, it lacks a comprehensive regulatory framework for housing design and construction that effectively contributes to achieving this strategic objective. Additionally, the Ecuadorian Technical Standard (NTE) and the Ecuadorian Construction Code (NEC) remain outdated, which limits the ability to implement these goals.

To move towards sustainable construction practices, it is essential to recognize that the selection of materials plays a crucial role in the sustainability of buildings (Acosta, 2009; Enshassi et al., 2018; Tamayo and Rocha-Tamayo, 2011; Vélez and Contreras, 2020; Hernández-Zamora et al., 2021). In Ecuador, 75% of the total construction cost corresponds to the cost of materials; however, the selection of materials is not usually based on environmental responsibility criteria. In addition, most of the materials used in the provinces of Azuay and Cañar, both domestic and imported, lack environmental certifications. Currently, there are no regulations requiring the exclusive use of ecological materials, which aggravates the environmental impacts generated by the construction industry.

Between 2017 and 2020, the construction sector in Ecuador experienced sustained growth, driven by favorable economic conditions, including oil sales and the global economic recovery following the recession. However, as of May 2020, the sector recorded a 16.35% decline in its contribution to GDP due to the COVID-19 pandemic (Lozano Torres, 2022). This drop was further intensified by the conflict between Russia and Ukraine, as well as the global economic slowdown, which significantly affected developing economies. Domestically, the number of construction

companies declined by 10.56% between 2015 and 2019, primarily due to the imposition of tariffs and reduced demand for construction materials during the pandemic (Lozano Torres, 2022).

This study takes 2020 as a reference year to examine the materials used in the construction of social housing projects located in the capitals of the provinces of Azuay and Cañar, strategic regions in the context of planned urban development in Ecuador. These projects, prioritized by the State in the framework of the 2030 Agenda and the Sustainable Development Goals, constitute a representative case study to assess the environmental implications of the building sector at the national level. Given the significant weight that construction materials carry in both economic and environmental terms, and in the absence of specific regulatory guidelines that require the use of inputs with lower environmental impact, the need to generate technical evidence to support decisions aimed at transitioning to more sustainable construction models is recognized.

Unlike other regional studies that are limited to specific phases of the life cycle, such as the production or transportation of materials, this work encompasses the entire cycle, from extraction to final disposal (cradle to grave).

This approach is crucial in the Ecuadorian context, where there are no regulations for the final disposal or environmental traceability of construction waste. Therefore, this study fills a gap in the Latin American literature, providing local evidence based on data representative of the country.

Within this framework, the objective of this research was to evaluate the environmental impacts associated with the materials most commonly used in the construction of social housing in the capital cities of the provinces of Azuay and Cañar through the application of Life Cycle Assessment (LCA). The evaluation was conducted according to the guidelines established by ISO 14040:2006 (ISO ORG, 2006), utilizing the specialized software OpenLCA. The analysis considered the most relevant environmental performance indicators, with a particular emphasis on global warming potential, energy consumption, and emissions associated with material production. Based on the results obtained, it identified opportunities for improvement in the selection of materials. It contrasted them with international state-of-the-art references, contributing scientific evidence to the design of public policies, the updating of sector regulations, and the formulation of technical strategies aimed at sustainability in the construction of social housing in Ecuador.

2. Materials and methods

The analysis focused on two representative social housing projects developed in the cities of Cuenca and Azogues, promoted respectively by the Municipal Public Company of Urbanization and Housing (EMUVI EP) and the Ministry of Urban Development and Housing (MIDUVI). According to the databases of materials used in housing construction, those with the highest percentage of use were discriminated against. As a result, concrete represented 70% of use and Steel 17%, on average, being the materials chosen for the study.

The functional unit selected was 1 kg of construction material (concrete or Steel) used on site. This unit enables the standardization of results and their comparison with international literature. The scope of the study was defined under a cradle-to-grave approach, considering all relevant stages of the materials' life cycle: extraction and processing of raw materials, manufacturing, transportation to the construction site, use during the building's useful life, and final disposal.

For concrete, two scenarios were evaluated. The conventional scenario corresponded to the ready-mix concrete specified in the construction documents, consisting of 0.24 m³ of water, 0.65 m³ of sand, 0.95 m³ of gravel, 360.50 kg of cement, and 0.30 kg of plasticizing admixture per cubic meter. The alternative scenario consisted of ecological concrete with a 30% replacement of cement content by calcined pozzolana and the use of recycled aggregates from construction waste. This formulation is based on scientific evidence indicating that partial cement substitution is one of the most effective strategies for reducing greenhouse gas emissions associated with concrete without significantly compromising its mechanical performance (Guo et al., 2021; Marinković et al., 2024). The transport of materials was estimated at 13.5 km from the concrete plant to the construction site, using 20-ton Euro 4-type heavy-duty trucks, according to Ecoinvent v3.7 datasets. The final disposal of the concrete did not include reuse due to the lack of national regulations governing post-demolition recycling.

Two scenarios were also established for Steel. The first one reflected the current conditions in the country, where structural Steel is not reused at the end of its life cycle, being destined as waste or scrap without processing. The second scenario, of a sustainable nature, envisioned a 100% reuse rate by the circular economy principle. This alternative is based on international studies that have documented the technical feasibility and the environmental benefits of reusing structural steel components after minimal reconditioning processes. The average transport distance was estimated at 13 km from the local supplier to the construction site. The energy associated with the recycling process was included in the reuse scenario.

The life cycle inventory (LCI) was developed with OpenLCA 1.10.3 software using the Ecoinvent v3.7 database. The processes were selected based on their geographical and technological alignment

with the Ecuadorian context. In the absence of specific local data, regional (Latin America) or global averages were used. An average transport performance of 2.5 km/l for heavy vehicles and a load factor of 80% was assumed. Energy consumption and emissions were modeled directly from the Ecoinvent production modules.

The environmental impact assessment was conducted using the CML 2001 method, which allows for a detailed characterization of multiple impact categories. In this study, five key categories were selected: Global Warming Potential (GWP, kg CO₂-eq), Acidification (AP, kg SO₂-eq), Eutrophication (EP, kg PO₄³⁻-eq), Photochemical Ozone Formation (POCP, kg C₂H₄-eq) and Abiotic Depletion (AD, kg Sb-eq). These categories were chosen for their relevance in the environmental assessment of building materials and their frequency of use in comparable studies.

Additionally, an external validation component was integrated through a systematic review of scientific literature. This review was conducted in the Scopus and Web of Science databases, utilizing the keywords: Life Cycle Assessment, sustainable concrete, steel recycling, housing, developing countries, and environmental impact. Only studies published between 2019 and 2024, in English or Spanish language, with quantitative data on at least one of the following metrics were included: GWP, primary energy consumption, or recycling rates. The results of these studies were extracted, normalized to the selected functional unit, and organized in a comparative table with the data obtained in the present study.

This methodology enables not only the estimation of the current environmental impacts of materials used in social housing in Ecuador but also the evaluation of the potential Reduction that could be achieved through substitution and reuse strategies. In this way, quantitative evidence is provided that can support the formulation of public policies aimed at sustainable construction.

3. Results

The LCA results revealed that the raw material extraction and material production stages have the most significant environmental impact on social housing construction. In the extraction stage, cement emerged as the material with the most significant environmental footprint due to its high energy consumption and CO₂ emissions. During materials production, Steel showed the most substantial environmental impact, mainly due to energy consumption and greenhouse gas emissions associated with its manufacturing process.

3.1. Life Cycle Analysis: Steel

The LCA results for steel are presented in Table 1, where two scenarios are compared:

- *Scenario 1:* No reuse of steel at the end of its life cycle.
- *Scenario 2:* With a 100% reuse rate at the end of its life cycle.

Table 1: LCA for Steel

Source: Own elaboration.

Impact Category	Scenario 1 (kg/kg steel)	Scenario 2 (kg/kg steel)	Reduction (%)
Climate Change (GWP)	3.2400	0.9500	71%
Acidification (AP)	0.0069	0.0022	68%
Eutrophication (EP)	0.0019	0.0006	67%
Photochemical ozone formation (POCP)	0.0003	0.0001	67%
Depletion of Abiotic Resources	0.11	0.033	70%

The analysis of the life cycle of Steel reveals that reuse at the end of its cycle allows a substantial reduction of environmental impacts in all the categories evaluated. In particular, the mitigation of global warming potential (GWP) stands out, which decreases by more than 70% compared to the scenario without reuse. This improvement is consistent with that reported by Hossain et

al. (2020), who observed similar reductions in Latin American contexts. In addition, the benefits extend to other categories, such as acidification and eutrophication, reflecting that the reuse strategy not only reduces greenhouse gas emissions but also other atmospheric and water pollutants.

3.1.1. Steel Resource Consumption

Table 2: Resource consumption for Steel

Source: Own elaboration.

Resource	Scenario 1 (per kg of steel)	Scenario 2 (per kg of steel)	Reduction (%)
Water	2.20 m ³	0.66 m ³	70%
Non-Renewable Primary Energy	14.82 MJ	4.44 MJ	70%
Wood	0.0002 m ³	0.0002 m ³	0%

The analysis shows that steel recycling reduces water and non-renewable primary energy consumption by 70%. However, wood consumption remains constant across all scenarios

3.2. Life Cycle Analysis: Concrete

The LCA results for concrete are presented in Table 3, comparing conventional ready-mix concrete and concrete made with recycled materials.

Table 3: LCA for Concrete

Source: Own elaboration.

Impact Category	Ready-mix concrete (kg/kg)	Concrete made with Recycled Materials (kg/kg)	Reduction (%)
Climate Change (GWP)	0.930	0.650	30%
Acidification (AP)	0.065	0.048	26%
Eutrophication (EP)	0.024	0.018	25%
Photochemical Ozone Formation (POCP)	0.002	0.001	50%
Depletion of Abiotic Resources	0.550	0.300	55%

3.2.1. Resource Consumption for Concrete

Table 4: Resource consumption for concrete

Source: Own elaboration.

Resource	Ready-mix concrete (m³)	Concrete made with Recycled Materials (m³)	Reduction (%)
Water	0.18 m³	0.14 m³	22%
Non-Renewable Primary Energy	2,775 MJ	2,400 MJ	14%
Cement	300 kg	170 kg	43%

The results indicate a significant reduction in resource consumption when recycled materials are used in the concrete mix. Specifically, as shown in Table 4, water use is reduced by 22%, representing a significant contribution in contexts of water scarcity. Likewise, there is a 14% decrease in non-renewable primary energy consumption, suggesting a lower environmental impact associated with the life cycle of concrete. The most significant Reduction corresponds to cement use, with a 43% decrease, which is particularly relevant considering that cement production is one of the main contributors to global carbon dioxide emissions.

Finally, the comparison presented in Table 5 provides quantitative evidence of the effectiveness of sustainable strategies for constructing social housing projects. In the case of Steel, a 71% reduction in global warming

potential (GWP) is observed when comparing the production of virgin Steel (3.24 kg CO₂-eq/kg) with that of recycled Steel (0.95 kg CO₂-eq/kg), which is consistent with the values reported in recent studies (Hossain et al., 2020). Similarly, in the concrete sector, a 30% decrease in GWP is recorded, going from 0.930 kg CO₂-eq/m³ in conventional ready-mix concrete to 0.650 kg CO₂-eq/m³ in concrete made with recycled materials. In addition, the Reduction in cement consumption, with a 43% decrease (from 300 kg/m³ to 170 kg/m³), supports the optimization of the mix through the use of recycled components. These results demonstrate that the application of circular economy practices in the construction materials supply chain can significantly reduce environmental impacts, which justifies the need to incorporate regulations and policies that encourage the recycling and reuse of these materials in the construction sector.

Table 5: Comparison of results with state of the art
Source: Own elaboration.

Base Study	Material	Indicator	Value (Base Study)	Value (Comparative Studies)	% Reduction (Base Study)	% Reduction (Compared)
Petroche et al. (2021)	Steel	GWP (kg CO ₂ -eq/kg)	3.24 (virgin) / 0.95 (recycled)	~3.0 (virgin) / ~1.0 (recycled)	71%	67-71%
Hossain et al. (2020)	Steel	Primary Energy (MJ/kg)	14.82 (virgin) / 4.44 (recycled)	~15.0 (virgin) / ~5.0 (recycled)	70%	~67%
World Steel Association (2023)	Steel	GWP (kg CO ₂ -eq/kg)	3.24 (virgin) / 0.95 (recycled)	~3.1 (virgin) / ~0.9 (recycled)	71%	70-71%
Sansom and Meijer (2002)	Steel	Energy Consumption (MJ/kg)	14.82 (virgin) / 4.44 (recycled)	16.2 (virgin) / 5.1 (recycled)	70%	68%
Petroche et al. (2021)	Concrete	GWP (kg CO ₂ -eq/m ³)	0.930 (conventional) / 0.650 (recycled)	~0.950 (conventional) / ~0.570 (recycled)	30%	40%
Labaran et al. (2021)	Concrete	GWP (kg CO ₂ -eq/m ³)	0.950 (conventional) / 0.600 (optimized)*.	Range: 0.05-0.18 (depending on blend and additives)	~37% (average)	N/A
Guo et al. (2021)	Concrete	GWP (kg CO ₂ -eq/m ³)	0.930 / 0.650	1.01 (conventional) / 0.61 (with substitutes)	30%	~40%
Marinković et al. (2024).	Concrete	GWP (kg CO ₂ -eq/m ³)	0.930 / 0.650	0.89 (natural) / 0.54 (recycled)	30%	39%
Mendoza and Oswaldo (2021)	Concrete	Cement Consumption (kg/m ³)	300 (conventional) / 170 (recycled)	310 (conventional) / 180 (recycled)	43%	~42%
Vázquez-Rowe et al. (2019).	Concrete	POCP (kg NMVOC/m ³)	0.002 (conventional) / 0.001 (recycled)	Similar values in studies of recycled materials	50%	50%
Marey et al. (2024)	Concrete	Energy Consumption (MJ/m ³)	2.775 / 2.400	2.88 (conventional) / 2.15 (recycled with ash)	14%	~25%
Hernández-Zamora et al. (2021).	Concrete	GWP (kg CO ₂ -eq/m ³)	0.930 / 0.650	1.00 (conventional) / 0.63 (alternative materials)	30%	~37%

Note: The value of Labaran et al. (2021) is expressed in a range depending on the variability in the mixture and the use of additives, so an average is used for comparative purposes.

4. Discussion

The results of the Life Cycle Assessment (LCA) conducted in this study confirm that the extraction of raw materials and production of materials is

responsible for the most significant proportion of the environmental impact in the construction of social housing in Ecuador. These findings align

with multiple international studies that emphasize the importance of these stages, particularly in cement and steel production, due to their high energy consumption and significant contribution to greenhouse gas (GHG) emissions (Guo et al., 2021; Marinković et al., 2024; Sansom & Meijer, 2002).

Regarding Steel, the present study revealed a 71% reduction in global warming potential (GWP), going from 3.24 kg CO₂-eq/kg in the scenario without reuse to 0.95 kg CO₂-eq/kg when 100% reused at the end of its life cycle. This result is highly consistent with previous studies, such as Hossain et al. (2020), who reported GWP reductions of 67-71% in similar contexts when applying steel reuse and recycling strategies. Also, non-renewable primary energy consumption was reduced by 70% (from 14.82 MJ to 4.44 MJ), in line with values presented by the World Steel Association (2023), which indicates an energy reduction of 70-75% by employing electric arc furnaces (EAF) instead of blast furnaces (BOF).

The reductions observed in other impact categories for steel - such as acidification (68%), eutrophication (67%) and photochemical ozone formation (67%) - reinforce the environmental benefits of structured recycling, and are consistent with those reported by Petroche et al. (2021), who observed similar reductions in studies applied to Latin American contexts.

Regarding concrete, the study demonstrated that the use of recycled materials results in a 30% reduction in GWP (from 0.930 to 0.650 kg CO₂-eq/m³). This improvement is within the range reported by other authors, such as Marey et al. (2024), who documented average reductions of up to 40% by incorporating partial cement substitutions with blast furnace slag or fly ash. This behavior has also been validated by Labaran et al. (2021), who observed GWP values as low as 0.570 kg CO₂-eq/m³ in optimized mixtures. These results position recycled concrete as an environmentally efficient alternative, particularly in regions where cementitious admixture sources are readily available.

Furthermore, in terms of resource consumption, concrete with recycled materials showed a 43% reduction in cement use (from 300 to 170 kg/m³), which is consistent with the results obtained by Mendoza and Oswaldo (2021), who reported a 42% decrease in similar mixes. This change not only reduces the direct environmental impact associated with clinker production but also promotes a more rational use of non-renewable mineral resources. In other categories, reductions of 22% in water use and 14% in non-renewable energy consumption were also evident, comparable to data from Marinković et al. (2024).

Notably, the Reduction in photochemical ozone formation in recycled concrete was 50%, a result that reflects substantial improvements in volatile organic compound (NMVOC) emissions. This result is identical to that observed by Vázquez-Rowe et al. (2019), who evaluated concretes with recycled aggregates in urban contexts and reported the same percentage decrease in this impact category.

The quantitative comparison summarized in Table 5 enables us to confirm that the results of the present study are not only methodologically consistent with international LCA standards but also reflect comparable or even higher environmental efficiencies in some instances. For example, while Hossain et al. (2020) report a GWP reduction in recycled Steel of 67%, this study reached a value of 71%, which can be attributed to the Ecuadorian energy context, which is highly dependent on hydroelectric sources (more than 80%), which reduces the indirect environmental load associated with industrial processes.

In this sense, it is recognized that the local context can significantly influence the magnitude of environmental impacts. As Labarán et al. (2021) point out, the environmental performance of recycled concrete improves in regions with clean energy matrices, such as those in Ecuador. This aspect should be considered when transferring technical conclusions or recommendations from one context to another.

However, despite the encouraging results, there are still regulatory and technical barriers that

limit the implementation of circular strategies in social housing construction in Ecuador. The absence of mandatory regulations for the use of recycled materials and the limited infrastructure for processing construction and demolition waste (CDW) hinder their widespread adoption. This

contrast with the European environment, where standards such as EN 12620:2002 permit the use of recycled aggregates in structural concrete, reinforces the need to adopt a regulatory framework that facilitates the widespread use of these materials.

5. Conclusions

The life cycle analysis (LCA) of the materials used in the construction of social housing in the provinces of Azuay and Cañar has revealed that the materials used in this sector generate significant environmental impacts, especially in the extraction of raw materials and production phases. In particular, cement was found to be one of the most significant contributors to global warming potential (GWP), followed by Steel, which also has a high environmental footprint in terms of greenhouse gas (GHG) emissions and consumption of non-renewable resources. These results underscore the urgent need to transform construction practices towards the use of materials with lower environmental impacts, thereby mitigating the adverse environmental effects of construction.

The study has also demonstrated that incorporating recycled materials into construction can lead to significant reductions in environmental impacts. For example, partial substitution of conventional cement with recycled materials such as blast furnace slag and fly ash resulted in a decrease in GWP, water consumption, and non-renewable primary energy. This practice not only reduces CO₂ emissions but also contributes

to the conservation of natural resources, which is crucial for promoting sustainability in the construction sector.

A relevant finding is that the use of recycled materials in combination with low-energy technologies, such as the incorporation of renewable energies in material production, can result in a significantly smaller environmental footprint compared to conventional methods. This is mainly because the recycling of materials and the production of low-energy materials have a significantly reduced environmental impact compared to the extraction and manufacturing processes of new materials.

On the other hand, the study's results show that, despite the obvious environmental benefits, the adoption of recycled materials in the construction of social housing in Ecuador is hindered by the lack of clear regulations and policies to encourage their use. Although there has been some progress in terms of awareness of the environmental benefits of these materials, the infrastructure for collecting and processing construction and demolition waste (CDW) remains insufficient, which limits the use of recycled materials in construction.

6. Recommendations

A key recommendation is the creation of a national certification and environmental labeling program for building materials that establishes

minimum criteria for energy efficiency and recycled content adapted to local conditions. This program could facilitate the adoption of more

sustainable materials by providing incentives for both manufacturers and developers who use materials with low environmental impact. In addition, the implementation of regulations requiring the incorporation of recycled materials in construction projects could accelerate the transition to more sustainable practices.

In addition to public policies, it is essential to continue researching the environmental and economic performance of recycled materials, particularly in the context of construction in Ecuador. It is essential to develop life cycle cost (LCC) studies to evaluate the costs associated with the processing, transportation, and use of recycled materials, as well as the economic benefits derived from reducing environmental impacts. This would enable the economic justification of using recycled materials and contribute to more informed decision-making in the construction sector.

To achieve the effective integration of recycled and energy-efficient materials in the construction of social housing, it is also necessary to create local databases containing life cycle inventories tailored to the country's specific conditions, taking into account aspects such as the energy matrix and the country's climatic characteristics. These tools will allow professionals in the sector to make more informed decisions regarding the selection of materials and construction methods with lower environmental impacts.

Awareness of the importance of sustainable materials should also be raised among both

industry professionals and consumers. This will help change consumer preferences and increase demand for more environmentally responsible building practices. The inclusion of these topics in educational and continuing education programs for architects, engineers, and builders will be crucial in promoting a culture of sustainability within the construction industry.

A greater focus is needed on research on the acceptance and performance of recycled materials in real construction conditions in Ecuador. Studies on the durability and performance of these materials in the local context are crucial for assessing their viability in large-scale social housing construction projects. Furthermore, fostering collaboration among researchers, industry professionals, and government authorities will be crucial to achieving a comprehensive approach to sustainable construction.

The results of this study underscore the importance of adopting a sustainable construction model in Ecuador that prioritizes the use of recycled and energy-efficient materials. The adoption of these materials would not only contribute to reducing the environmental footprint of social housing construction. However, it would also drive the development of a more responsible industry aligned with the principles of the circular economy. It is crucial that both the public and private sectors collaborate to overcome existing barriers and promote the use of sustainable materials through policy, research, and education, ensuring a more sustainable future for generations to come.

7. Bibliographic references

Acosta, D. (2009). Sustainable architecture and construction: concepts, problems and strategies. *Architecture Magazine*, 4, 14-23.

Almeida, G. (2021). Is the interpretative provision of fortuitous event or force majeure as a cause for termination of the employment contract in the Organic Law of Humanitarian Support

insufficient? An analysis from comparative law on the occasion of Covid-19. *USFQ Law Review*, 8(1), 1-25. <https://doi.org/10.18272/ulr.v8i1.2024>

Enshassi, A., Al Ghoul, H., & Alkilani, S. (2018). Exploring sustainable factors during construction projects' life cycle phases. *Construction Journal*, 33(1), 51-68.

- European Committee for Standardization (2002). *EN 12620:2002+A1:2008 Aggregates for concrete*. CEN.
- Guo, H., Shi, C., Guan, X., Zhu, J., Ding, Y., Ling, T. C. & Zhang, H. (2021). Life cycle assessment of recycled aggregate concrete on its environmental impacts: A critical review. *Construction and Building Materials*, 273, 121131. <https://doi.org/10.1016/j.conbuildmat.2020.121131>.
- Hernández-Zamora, M. F., Jiménez-Martínez, S. I. & Sánchez-Monge, J. I. (2021). Alternative materials as an opportunity to reduce environmental impacts in the construction sector. *Revista Tecnología en Marcha*, 34(2), 3-10. <https://doi.org/10.18845/tm.v34i2.4831>. <https://doi.org/10.18845/tm.v34i2.4831>
- National Institute of Statistics and Census (INEC). (2020). *Business Structural Survey* (ENESEM) 2020.
- ISO ORG (n.d.). *ISO 14044:2006(en) Environmental management - Life cycle assessment - Requirements and guidelines*.
- Labaran, Y. H., Mathur, V. S. & Farouq, M. M. (2021). The carbon footprint of the construction industry: A review of direct and indirect emissions. *Journal of Sustainable Construction Materials and Technologies*, 6(3), 101-115. <https://doi.org/10.29187/jscmt.2021.66>. <https://doi.org/10.29187/jscmt.2021.66>
- Lozano Torres, B. V. (2022). Supply and demand in competitive markets: Focus on the construction sector in Ecuador. *E-IDEA 4.0 Multidisciplinary Journal*, 4(10), 50-65. <https://doi.org/10.53734/mj.vol4.id194>. <https://doi.org/10.53734/mj.vol4.id194>.
- Marey, H., Kozma, G. & Szabó, G. (2024). Green concrete materials selection for achieving circular economy in residential buildings using system dynamics. *Cleaner Materials*, 11, Article 10221. <https://doi.org/10.1016/j.clema.2024.10221>.
- Marinković, S., Dragaš, J., Ignjatović, I. & Tošić, N. (2024). Comparative environmental assessment of natural and recycled aggregate concrete. *Case Studies in Construction Materials*, 21, e03910. <https://doi.org/10.1016/j.cscm.2024.e03910>. <https://doi.org/10.1016/j.cscm.2024.e03910>
- Mendoza, S. & Oswaldo, J. (2021). Sustainable development in Ecuador: strategies from the construction sector. *Revista de Investigaciones en Energía Medio Ambiente y Tecnología*, 6(2), 82-89.
- Ministry of Urban Development and Housing (MIDUVI). (2021). *Government of the Meeting initiates Phase 1 of the National Habitat and Housing Plan*. <https://www.habitatyvivienda.gob.ec/>
- Sansom, M. & Meijer, J. (2002). *Life-cycle assessment (LCA) for steel construction*. European Commission, Eurofer. <https://op.europa.eu/en/publication-detail/-/publication/25e4be8e-97c1-4e79-b37b-a51b7634ef7c>
- Tamayo, R. & Rocha-Tamayo, E. (2011). Sustainable buildings: materials, certifications and LCA. *Node: Architecture. City. Environment*, 6 (11), 99-116.
- Vélez, V. & Contreras, C. (2020). Evaluation model in the intervention of commercial spaces, under sustainable construction criteria. *DAYA. Design, Art and Architecture*, 10, 69-110. <https://doi.org/10.33324/daya.v1i10.379>
- World Steel Association (2023). *Sustainable steel: Indicators 2023 and industry initiatives*. <https://worldsteel.org/publications/>