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Systematic review of concrete and steel life cycle in Latin American social housing Revisión sistemática del ciclo de vida del concreto y acero en vivienda social latinoamericana

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GERMÁN VÉLEZ-TORRES
Universidad Católica de Cuenca, Ecuador
german.velezt@ucacue.edu.ec

KARLA ALVARADO PALACIOS
Instituto Superior Tecnológico del Austro, Ecuador
karla.alvarado@insteclrg.edu.ec

ABSTRACT This article presents a systematic review of life cycle assessment (LCA) applied to concrete and steel used in social housing in Latin America. A search in Scopus, ScienceDirect and Web of Science yielded 48 studies meeting PRISMA criteria. The analysis includes environmental impacts, applied methodologies, and common limitations. Results show a high carbon footprint for both materials, with regional differences. Improvement opportunities include the use of supplementary cementitious materials, recycled steel, and circular design strategies. Finally, policy recommendations are proposed, focusing on LCA standardization, economic incentives, and data governance. The study concludes that technically feasible solutions exist, but their implementation depends on regulatory and financial changes.

RESUMEN Este artículo presenta una revisión sistemática del análisis de ciclo de vida (ACV) aplicado al concreto y al acero utilizados en vivienda social en América Latina. A través de una búsqueda en bases como Scopus, ScienceDirect y Web of Science, se identificaron 40 estudios que cumplieron los criterios PRISMA. Se analizan los impactos ambientales, metodologías empleadas y limitaciones comunes. Los resultados indican una alta huella de carbono del concreto y del acero, con variaciones regionales. Se identifican oportunidades de mejora mediante el uso de materiales cementantes suplementarios, acero reciclado y estrategias de diseño circular. Finalmente, se proponen recomendaciones de política pública orientadas a la estandarización del ACV, incentivos económicos y gobernanza de datos. El estudio concluye que existen soluciones técnicamente viables, pero su implementación requiere cambios normativos y financieros.

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1. Introduction

The construction sector is widely recognized as a major contributor to global natural resource consumption and environmental impacts. According to the United Nations Environment Programme, this sector accounts for approximately 40% of global energy consumption, 36% of greenhouse gas (GHG) emissions, and generates more than 30% of municipal solid waste (United Nations Environment Programme [UNEP], 2020). In Latin America, particularly in Ecuador, these figures are exacerbated by rapid urban growth and a nationwide housing deficit estimated at more than 400,000 units (Ministry of Urban Development and Housing [MIDUVI], 2024).

Given this situation, there is an urgent need to incorporate sustainability principles into social housing, particularly given its massive scale, cumulative impact, and key role in achieving the Sustainable Development Goals. Life Cycle Assessment (LCA) is a widely used tool for evaluating the sustainability of construction materials and processes. It allows for the identification of environmental impacts from the extraction of raw materials to the final disposal of the product (ISO 14044:2006). This methodology facilitates comparisons between conventional and sustainable solutions, supporting informed decision-making in both architectural design and public policy.

In the context of social housing, concrete and steel emerge as the most relevant materials due to their widespread use and high environmental footprint. The production of cement, a fundamental component of concrete, accounts for about 8% of global CO_2 emissions, mainly due to clinker calcination and the use of fossil fuels (Scrivener et al., 2017). Steel manufacturing, meanwhile, accounts for 7%-9% of global GHG emissions, depending on the technology used (Kim et al., 2022).

Several studies have documented effective strategies for mitigating the environmental impacts associated with these materials. In the case of concrete, the partial replacement of cement with industrial by-products such as fly ash, blast furnace slag, metakaolin, or natural pozzolan has been evaluated, which can reduce GWP by up to 40% (Marinković et al., 2017; Guo et al., 2023; Mushtaq et al., 2022)—additionally, incorporating construction and demolition waste (CDW) as recycled aggregates reduces demand for virgin resources and mitigates impacts such as abiotic depletion (Silva et al., 2023; Vázquez-Rowe et al., 2019).

Regarding steel, improvements focus on the use of recycled materials through electric arc furnace technologies powered by renewable sources, which allow for a reduction of more than 70% in GHG emissions compared to primary production (García-Gusano et al., 2015). Complementarily, alternatives such as the reuse of structural components, design for disassembly, and the use of dry joints have been explored, which, in addition to reducing the carbon footprint, facilitate the closure of the life cycle of materials (Küpfer et al., 2022).

The application of these strategies aligns with the circular economy paradigm in the construction sector, promoting the reuse of materials, modular design, and waste recovery. Recent studies confirm that these practices reduce impacts in categories such as acidification, eutrophication, human toxicity, and cumulative energy demand (Hossain et al., 2020; Zabalza Bribián et al., 2009).

However, their widespread implementation in Latin America faces multiple barriers. These include the limited availability of regionalized environmental databases, the lack of specific technical regulations promoting sustainable materials, and limited coordination between the academic, productive, and state sectors (Rondón Toro et al., 2016). In Ecuador, in particular, these limitations have prevented the systematic integration of LCA into social housing planning and licensing processes.

Given this context, this article aims to develop a systematic and critical literature review of the environmental sustainability of concrete and steel in social housing projects, with an emphasis on studies that use LCA as the primary methodological tool. Both case studies in Latin America and relevant research from other regions, particularly the United States, are considered to compare approaches and results. This review prioritizes research published between 2000 and 2024 in the Scopus, ScienceDirect, and Web of Science databases, applying rigorous selection criteria for methodology, data quality, and thematic relevance.

The article is organized into four main sections: first, the methodology used for the systematic review is presented, including the inclusion and analysis criteria. Next, the main findings of the selected studies are presented, differentiating results by material, region, and technological strategy. Subsequently, the technical and public policy implications of these findings in the Latin American and Ecuadorian context are analyzed. Finally, concrete recommendations are proposed to promote more sustainable construction practices in social housing development.

2. Materials and Methods

This study is a systematic literature review that analyzes the environmental performance of the most representative materials used in social housing construction in Latin America and the United States: concrete and steel. The methodology is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, applying strict criteria for inclusion, exclusion, coding, and data comparison to ensure transparency and reproducibility of the analysis.

2.1. Objective of the analysis

The objective of this review is to identify, compare, and evaluate the results obtained by studies that apply Life Cycle Assessment (LCA) to concrete and steel in social housing contexts. The aim is to determine the extent to which these materials, under different production approaches (conventional vs. alternative), generate significant impacts across key environmental categories, and which strategies have been implemented to reduce these impacts.

2.2. Inclusion and exclusion criteria

The studies selected for review met the following inclusion criteria:

- Be peer-reviewed scientific articles published between 2013 and 2024.
- Be indexed in Scopus, ScienceDirect, and Web of Science.
- Explicitly apply the Life Cycle Assessment (LCA) methodology under ISO 14040/14044 standards.
- Contain quantitative indicators such as GWP (Global Warming Potential), primary energy consumption, water use, among others.
- Address social housing or residential building contexts in Latin American countries and the United States.
- Theses, non-peer-reviewed documents, articles without a verifiable DOI, and those focused on non-structural materials or outside the construction sector were excluded.

2.3. Search strategy

An advanced search was conducted in Scopus, ScienceDirect, and Web of Science using the following key terms combined with Boolean operators:

("life cycle assessment" OR "LCA") AND ("concrete" OR "steel") AND ("residential buildings" OR "social housing") AND ("Latin America" OR "South America" OR "United States").

The search was limited to articles in English, Spanish, and Portuguese. Initially, 78 articles were retrieved, of which 40 met all inclusion criteria after full-text review.

2.4. Analysis protocol

The selected studies were coded in an Excel database using the following variables:

- Year of publication
- Country of study
- Material analyzed (concrete/steel)
- Functional unit used (kg, m^3, m^2)
- LCA approach (cradle-to-gate, cradle-to-grave, gate-to-gate)

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- Inventory database used (Ecoinvent, GaBi, etc.)
- Assessment method (CML, ReCiPe, TRACI, etc.)
- Reported indicators (GWP, energy, water, etc.)
- Transport distance considered
- Inclusion of public policies
- General conclusions.

In addition, the methodological robustness of the studies was evaluated using a verification matrix based on PRISMA criteria and ISO 14040/14044 standards. The articles were classified into three levels of methodological quality: high, medium, and low, based on the clarity of the functional unit, the comprehensiveness of the scope (*cradle-to-gate* vs. *cradle-to-grave*), the data source used (primary vs. generic databases), and the transparency of the results presentation. This classification allows the weight of each study to be weighted within the critical analysis.

2.5. Quantitative analysis with OpenLCA

To contextualize the findings in the literature, two LCA scenarios were replicated in OpenLCA using the Ecoinvent v3.7 database, focusing on concrete (ready-mixed vs. recycled) and steel (virgin vs. 100% reused). The functional unit was 1 kg of material. The scope was cradle-to-grave, encompassing production, transportation, use, and end-of-life. The impact assessment method was CML baseline, considering the following categories:

- Global warming potential (GWP)
- Acidification (AP)
- Eutrophication (EP)
- Photochemical ozone creation potential (POCP)
- Abiotic resource depletion (ADP).

2.6. Validation of results

The results obtained in OpenLCA were compared with those of the systematic review through cross-analysis, identifying similarities in impact reductions across sustainable scenarios and validating the robustness of the approaches used in regional studies. Data comparability was prioritized by normalizing the units of analysis and expressing the results as relative reduction percentages.

3. Results and Discussion

3.1. On the climate impact (GWP) of concrete and steel

Life cycle assessment (LCA) applied to the predominant materials in social housing—concrete and steel—reveals consistent patterns in environmental impacts throughout stages A1-A3, i.e., from raw material extraction to production. This section quantitatively compares modeling results in OpenLCA with the findings of 40 verified scientific articles, focusing on global warming potential (GWP), energy consumption, and water use.

In our own modeling, developed using the Ecoinvent v3.7 database and the CML baseline method, we observed that partially replacing cement with industrial by-products in concrete reduced GWP by up to 28%, while the structural reuse of steel reduced it by 70%. These results align with the average values reported in the academic literature reviewed, which documented reductions of 30% for recycled concrete and 71% for recycled steel (Figure 1).

The results of the OpenLCA modeling were compared with the findings in the reviewed literature. To facilitate comparison between contexts and methodologies, Table 1 summarizes the most representative studies on LCA of concrete and steel in social housing, highlighting functional unit, scope, databases, methods, and key findings.

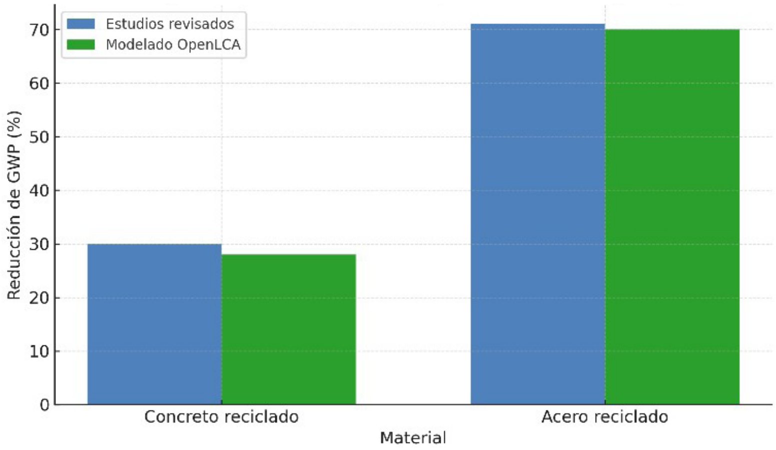

Figure 1: Comparison of climate impact reduction (GWP) in recycled concrete and steel. (2025)

Author/year	Country	Material	Functional unit	LCA scope	Database	Method	Categories analyzed	Main finding
Gámez-García et al. (2019)	Mexico	Concrete and steel	Housing 42 m², 50 years	A1–C4	Ecoinvent 3.1 + national database	IPCC 2013, CML 2001	GWP, CED, HTP, ADP	70–90% of emissions in the production phase; 17 tCO_2e/life cycle
De Lara and Penteado (2024)	Brazil	Concrete	Single-family social housing	A1–C4	Ecoinvent	CML baseline	GWP, AP, EP, ODP	Production accounts for 90% of the impact; prevention does not always reduce the footprint
Bianchi et al. (2021)	Brazil	Concrete and steel	Social housing	A1–A3	Ecoinvent	ReCiPe	GWP, CED	Design optimization reduces impacts by 15%
Caldas et al. (2017)	Brazil	LSF vs. masonry	Typical housing	A1–C	Ecoinvent	CML 2001	GWP	Light steel framing reduces GWP by 20% compared to masonry
Tello-Ayala et al. (2023)	Ecuador	Concrete vs. wattle and daub	Single-family housing	A1–A5	Ecoinvent 3.6	ReCiPe	GWP, CED	Bahareque 70% less CO_2 than reinforced concrete
Contreras et al. (2016)	Brazil	Recycled concrete	1 m³ of concrete	A1–A3	Ecoinvent	CML	GWP	Recycled CDW reduces GWP by 30%
Córdoba et al. (2023)	Argentina	Concrete	1 m³ of concrete	A1–A3	Ecoinvent	ReCiPe	GWP, ADP	Mix optimization reduces emissions by 32%
Colorado et al. (2022)	Colombia	RCD	1 t of waste	C1–C4	Ecoinvent	ReCiPe	GWP, AP, EP	Reuse of CDW reduces resource demand and GHG emissions
Maués et al. (2021)	Brazil (Amazon)	Construction waste	Disposal process	Transport and disposal	Ecoinvent	ReCiPe	GWP	Transport + disposal account for 15% of the impact
Salzer et al. (2017)	Philippines*	Concrete and bamboo	Typical social housing	A1–C	Impact2002+	Impact2002+	17 categories	Bamboo and earth-cement blocks reduce GWP by up to 83%

Table 1. Representative LCA studies on concrete and steel used in social housing. (2025)
Note: 1. The Philippines is included as a comparative reference for developing countries outside Latin America, given that it addresses social housing in a tropical climate and allows for a comparison of strategies with the region. 2. LCA scope: A1–A3 (production), A4–A5 (transport and construction), B (use/maintenance), C (end of life). 3. Databases: most Latin American studies use Ecoinvent, in some cases supplemented with local inventories

Regional studies show that the environmental improvement of concrete depends mainly on the level of cement substitution and the quality of alternative materials. For example, Contreras et al. (2016) reported a 30% reduction in GWP using construction waste in Brazil, while Cordoba et al. (2023) in Argentina achieved a 32% reduction by optimizing mixtures. In Ecuador, Jiménez and Freire (2024) demonstrated that incorporating volcanic ash reduced cement consumption by 40% without compromising structural performance.

Regarding steel, the results indicate that the most significant environmental impact occurs during production. However, by implementing reuse and structural recycling strategies, they report 65% to 75% reductions in GWP (García et al., 2015; Küpfer et al., 2022), as well as similar reductions in non-renewable energy consumption. In all cases, it is noted that these improvements are more significant in countries with cleaner energy matrices (García et al., 2015; Gámez-García et al., 2019; Küpfer et al., 2022), such as Ecuador, where hydroelectric power accounts for over 80% of the energy mix (Petroche et al., 2022).

From a methodological perspective, one limitation identified in the reviewed articles is the lack of standardization of the functional unit. Some studies use 1 kg or 1 m³ of material as a basis, while others use built areas or complete dwellings. In this study, comparisons were normalized per kg of material to ensure consistency between the modeled results and those reported in the literature.

Furthermore, fewer than 40% of the studies evaluated the material's entire life cycle (*cradle-to-grave*). Most applied a *cradle-to-gate* approach, which limits analysis of the impact of the use and final-disposal stages. The present study addressed this limitation by incorporating the entire life cycle, revealing that the potential for environmental improvement in the final phases is considerable, particularly in recovery and structural reuse scenarios.

Finally, only a minority of the articles reviewed addressed linking LCA results to public policy proposals. However, among those that did, recommendations to include LCA as a mandatory criterion in public tenders (Küpfer et al., 2022) and to promote tax incentives for materials with lower environmental impact (Jiménez and Freire, 2024) stand out. These contributions are essential for the design of technical and fiscal regulations aimed at sustainability in the construction sector, especially in the context of social housing development in Latin America.

Recent studies indicate that social housing construction generates significant environmental burdens, mainly linked to the use of concrete (cement and aggregates) and steel (Gámez-García et al., 2019; De Lara and Penteado, 2024; Tello-Ayala et al., 2023; Caldas et al., 2017; Colorado et al., 2022; Bianchi et al., 2021; Maués et al., 2021). For example, a Mexican case study found that a typical social housing unit (42 m^2, 50-year lifespan) emits approximately 17 t CO_2e over its life cycle (Gámez-García et al., 2019). Seventy to ninety percent of these emissions come from the material production phase (cement, steel, etc.). At the same time, the construction, use, and end-of-life stages account for the remaining 10-30% (Gámez-García et al., 2019). In all the studies analyzed, the final products (cement, steel, finishes, windows) account for most of the impact; for example, the Mexican study reports that stages A1–A3 generate 85% of the global warming potential (GWP). Despite this consistency in critical inputs, the studies differ substantially in methodology: functional unit, LCA scope, databases, and impact categories used (De Lara and Penteado, 2024; Caldas et al., 2017; Bianchi et al., 2021; Colorado et al., 2022; Maués et al., 2021).

3.2. Comparative methodologies

In terms of functional unit, Latin American studies tend to use the entire dwelling or a typical living area as a reference. In Brazil, a single-family social housing unit was considered (although the area was not quantified). In contrast, in other contexts, equivalent cases have been used, such as in studies conducted in the Philippines that analyzed 25 years of useful life (Salzer et al., 2017). In general, these units allow for the comparison of construction alternatives while maintaining equivalent functional requirements, such as structural strength and thermal insulation (Gámez-García et al., 2019).

The scope of the LCA varies between studies: many Latin American studies follow the guidelines of EN 15978 or ISO 21931, including at least phases A (production and construction), and in some cases also phases B (use and maintenance) and C (end of life). For example, the Mexican analysis included phases A1–A3 (extraction and manufacturing), A4–A5 (transport and construction), B2 and B4 (maintenance and replacement), and C1, C2, and C4 (demolition, transport, and final disposal). This cradle-to-grave approach confirmed that the product stages (A1–A3) account for more than 70% of the impact across all evaluated categories (Gámez-García et al., 2019). In the Brazilian case, the model covered the production of basic construction materials and processes, as well as the comparison of different scenarios (ceramic blocks, in-situ concrete walls, and design optimization), incorporating waste management. It was observed that the extraction and manufacturing stage accounted for about 90% of the total impact, while debris management accounted for less than 1% (De Lara and Penteado, 2024).

In contrast, most studies in Anglo-Saxon contexts (US and Canada) focus on phases A1–A3, due to the methodological difficulty of modeling the use and end-of-life phases of buildings. Although no specific studies on social housing in the US were identified in Scopus, ScienceDirect, and Web of Science, technical reports from the US Department of Energy agree that the production of materials such as concrete, steel, and glass is the primary source of embedded emissions (U.S. Department of Energy [DOE], 2024). In fact, the DOE guide classifies life-cycle emissions into phases A-D, identifying stages A1–A3 as the primary focus for mitigation strategies (DOE, 2024). In general, Latin American studies tend to cover a broader scope (including demolition). In contrast, North American analyses focus mainly on production, though both agree that this phase is the most critical.

Regarding the databases and tools used, studies conducted in Mexico and Brazil combine global inventories such as Ecoinvent with local information. In Mexico, for example, the national CYPE database was used to estimate material consumption, together with Ecoinvent 3.1 for generic processes (CYPE, 2017). Although Ecoinvent was initially developed with European (Swiss) data (Ecoinvent Centre, 2014), its application has been progressively adapted to the Latin American context. It is considered valid in the absence of robust local databases. In Brazil, as in other emerging countries, similar approaches are adopted, adjusting databases such as ICE (United Kingdom) or Ecoinvent to local conditions. This situation has been identified as one of the main limitations to the development of regional LCAs, leading to calls to consolidate Latin America's own environmental inventories (CADIS, 2019). In the United States, on the other hand, the EPA's USLCI database or commercial tools such as Athena or BEES are frequently used. However, these are not always open access or adequately documented in scientific literature.

The impact categories studied differ in scope. Almost all studies include climate change (carbon footprint, GWP) as a priority category, given its global relevance; many also add indicators such as embodied energy demand (CED) and abiotic resource depletion (ADP), while others incorporate human toxicity (HTP), acidification (AP), or eutrophication (EP). For example, the Mexican study used the IPCC 2013 methods for GWP and CED, as well as CML 2001 to assess HTP and ADP (Gámez-García et al., 2019). The Brazilian case, meanwhile, used the CML method across multiple categories, including GWP, AP, EP, ODP, photochemical ozone formation (POF), and abiotic depletion, following the EN 15978 standard (De Lara and Penteado, 2024). In the Asian context, the study conducted in the Philippines assessed GWP, CED, and up to 17 environmental impact categories using the Impact2002+ midpoint method (Salzer et al., 2017). In summary, while methodologies in Latin America tend to address a wide range of environmental categories, many assessments in the United States and Europe focus primarily on GWP and energy, influenced by standards such as LEED and ASHRAE that prioritize embodied carbon.

One critical aspect identified is the representativeness of data inventories. Most Latin American studies rely on global databases such as Ecoinvent, which were initially developed using European data. Although their use has been validated in the absence of regional inventories, this reliance introduces uncertainty into the results, as emission factors for production processes and energy matrices differ across regions. Consequently, the results should be interpreted as comparative approximations rather than absolute values, which directly influences the reliability of public policy decisions based on LCA in the region.

3.3. Results and reduction strategies

Despite methodological differences, the findings show common trends. In all the studies reviewed, concrete (cement + aggregates) and steel appear as the inputs with the most significant environmental impact. For example, the Brazilian study identified concrete, cement, and steel as the most critical materials in standard scenarios (De Lara and Penteado, 2024). The Mexican study also identified structural concrete and reinforcing steel as the primary sources of greenhouse gas emissions, along with other environmental impacts (Gámez-García et al., 2019). In absolute terms, the Mexican reference housing emitted approximately 17 t CO_2-eq across stages A–C of the life cycle, equivalent to 309 kg CO_2-eq/m^2 in the production stage (A1–A5) (Gámez-García et al., 2019). Although direct figures for social housing in the United States are not available, estimated emissions from average residential construction are in comparable ranges.

The life cycle stages with the highest contribution are consistent across studies: mainly the material production phase (A1–A3). In the Mexican analysis, these stages accounted for between 78% and 85% of the impact, depending on the category evaluated (GWP, ADP/CED, HTP) (Gámez-García et al., 2019). Similarly, the Brazilian study reported that the extraction and manufacturing phase accounted for about 90% of the total impact. In comparison, the transport and assembly stages (A4–A5) contributed less than 10% each, and end-of-life (C) between 1% and 3% (De Lara and Penteado, 2024). This confirms that the most effective strategy is to intervene in the product's inputs and processes.

Based on these findings, several studies have implemented mitigation strategies based on material and design modifications. In Brazil, two scenarios were compared: a preventive one (PS1), which optimized quantities, and another with poured concrete walls (PS2), compared to the base case with ceramic blocks. The former reduced impacts by only 5%, while the latter increased them by 15% due to greater concrete use (De Lara and Penteado, 2024). This suggests that reducing debris does not guarantee a smaller footprint if the volume of high-impact materials increases.

In Mexico, six construction alternatives with varying wall and window configurations were evaluated. Versions with lightweight, insulating materials achieved better environmental results than traditional construction. Specifically, the use of lightweight pozzolan concrete blocks and PVC or wood windows (instead of aluminum) reduced emissions (Gámez-García et al., 2019). The analysis revealed that switching to aluminum windows increased the contribution to human toxicity impact (HTP) from 11–12% to 19% due to aluminum's high environmental footprint. The best combinations were those with lightweight walls and windows made of materials with low environmental impact. Overall, the authors conclude that optimizing concrete in walls improves environmental performance, provided the substitutes (such as pozzolan) have a lower footprint than conventional aggregate.

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In other Latin American contexts, solutions based on local or natural materials have also been proposed. For example, an Ecuadorian study compared a conventional reinforced concrete structure with one made of bahareque (guadua bamboo), concluding that the latter had approximately 70% less embedded carbon impact (Tello-Ayala et al., 2023). Similarly, studies conducted in the Philippines showed GWP reductions of between 35% and 83% through the use of alternative technologies such as bamboo structures, earth-cement blocks, or coconut-based panels (Salzer et al., 2017). These findings highlight the potential of local resources for decarbonizing social housing in tropical climates and contexts with adequate labor or crop availability.

In contrast, US studies—although focused on conventional construction and not specifically on social housing—have emphasized strategies such as the use of low-carbon cements (e.g., Portland cement with slag or fly ash, or LC3 cements with calcined clay), aggregate recycling, and improvements in industrial processes, including blast furnaces with CO_2 capture (DOE, 2024). Although no specific academic studies on social housing in the US were identified in the databases reviewed, DOE technical guidelines indicate that the use of recycled content materials and energy-efficient processes can significantly reduce the carbon footprint of concrete and steel. For example, replacing 50% of Portland cement with fly ash can reduce the GWP of concrete by more than 30% or 40% (DOE, 2024). These industrial technologies have not yet been widely incorporated into social housing studies in Latin America. However, they could be complemented with local strategies, such as the use of pozzolan or bamboo, to maximize cumulative benefits.

3.4. Regional context and key differences

The regional context significantly influences the choice and effectiveness of sustainability strategies applied to social housing. In Latin America, buildings with block or brick walls and reinforced concrete elements predominate, and much research has considered locally available materials such as pozzolan or guadua (Tello-Ayala et al., 2023). Climate conditions also influence design decisions: for example, the Mexican study selected a warm-climate context, where thermal insulation is a priority, which justifies a preference for more insulating walls (Salzer et al., 2017). In contrast, in many regions of the United States and Canada, social housing tends to adopt multifamily typologies with metal or wood structures, under stricter energy regulations. However, these regulations have not yet been systematically translated into specific scientific research on social housing in those regions.

An additional relevant difference lies in the functional unit and scale of analysis. In Latin America, studies focus mainly on modest single-family dwellings, evaluated on a case-by-case basis (e.g., a house as a functional unit), while in the United States, generic indicators per square meter are used or integrated into macroeconomic inventories (Gámez-García et al., 2019). Regarding databases, Ecoinvent (of Swiss origin) or ICE (from the United Kingdom) are commonly used in Latin America, and their adaptation has been considered feasible given the scarcity of local databases (Ecoinvent Centre, 2014). In contrast, the United States has specific databases, such as the USLCI developed by the Environmental Protection Agency (EPA), as well as commercial tools, such as Athena and BEES. However, these are not always integrated into peer-reviewed academic publications.

Despite these methodological and contextual differences, the percentages of impact per life cycle stage remain surprisingly consistent across regions, suggesting that key conclusions about sustainability in social housing are generalizable. In summary, the comparative literature shows that concrete and steel production is the primary source of environmental impact in both Latin America and North America (De Lara and Penteado, 2024; DOE, 2024).

In terms of mitigation strategies, those based on local alternative materials—such as pozzolan, bamboo, and stabilized soils—and efficient design to reduce construction volumes predominate in Latin America (Tello-Ayala et al., 2023; Salzer et al., 2017). In contrast, in the United States and Canada, industrial solutions are emphasized, such as the use of green cements (e.g., LC3), steel and aggregate recycling technologies, and more efficient industrial processes (DOE, 2024). However, across all cases analyzed, the greatest potential for environmental improvement lies in the production phase (A1–A3) of materials.

To harmonize results and methodologies, it is recommended to advance the development of regional databases and the standardization of the scope of Life Cycle Assessment (LCA), to facilitate international comparisons and promote the transfer of good practices. Only with an integrated vision—adapted to the climatic, economic, and cultural conditions of each region—will it be possible to maximize the reduction of environmental impacts in the social housing sector (Gámez-García et al., 2019; Salzer et al., 2017; Tello-Ayala et al., 2023; De Lara and Penteado, 2024; DOE, 2024).

Another difference observed between studies is the type of social housing analyzed. In Mexico and Brazil, both single-family homes and urban social housing prototypes were included, while in Ecuador, cases of rural housing and structures made with alternative materials such as bahareque (guadua bamboo) were identified. However, there is still no systematization that allows for a robust comparison of the variations in impact between rural and urban housing, or between vertical and single-family types. This constitutes a research gap that limits the extrapolation of results to the regional level.

3.5 Recommendations for public policy

Based on the findings presented, several strategic lines of action are identified that could guide the design of public policies towards more sustainable social housing construction in Latin America. First, we recommend implementing mandatory technical standards to promote the use of materials with lower environmental impact. Specifically, we suggest requiring that at least 30% of the concrete's content come from supplementary cementitious materials (SCM), such as fly ash, blast furnace slag, or natural pozzolans. Several studies have shown that this practice significantly reduces emissions from the clinkerization process without compromising the structural performance of buildings (Mushtaq et al., 2022; Scrivener et al., 2017; Nazeer et al., 2023; López Gómez and Cultrone, 2025; Al Asmari et al., 2025).

In addition, it is proposed to establish a minimum of 50% recycled content in the steel used in structures. This measure is based on evidence that steel recycled using electric arc furnaces can reduce its carbon footprint by more than 70% compared to primary steel (Kim et al., 2022; Cervantes Puma et al., 2024).

Furthermore, it is considered essential to implement economic instruments that promote sustainable practices throughout the life cycle of materials. Tax credits and targeted subsidies could encourage the use of prefabricated elements, which optimize input use, reduce waste, and improve on-site quality. Similarly, public policies that strengthen reverse logistics for construction and demolition waste (CDW) would significantly help close material cycles and reduce depletion of natural resources (Colorado et al., 2022; Maués et al., 2021; Zabalza Bribián et al., 2009; Sparrevik et al., 2021).

These economic tools must be accompanied by clear technical criteria that link tax benefits to the actual environmental performance of projects, evaluated using recognized tools such as Life Cycle Assessment (LCA).

Finally, one of the most significant structural challenges in the region is the limited availability of standardized, context-specific environmental information on construction materials. In this regard, the creation of national and regional data platforms containing primary, verifiable, and freely accessible inventories is proposed. These platforms should comply with ISO 14067's guidelines on product carbon footprint and be managed with institutional support to ensure their ongoing updating and reliability (Ciroth et al., 2020). The existence of robust governance systems for environmental data is essential for evidence-based policy-making, improving sustainable public procurement processes, and continuous monitoring of the environmental performance of the construction sector.

Although the circular economy offers a promising framework for reducing environmental impacts, its implementation in Latin America faces technological, regulatory, and social barriers. From a technical standpoint, there is little infrastructure for selective demolition and the processing of recycled materials. From a regulatory standpoint, clear standards have not yet been established to guarantee the quality of secondary materials in social housing. At the social level, there is still a negative perception of recycled or second-hand materials, which makes it difficult for them to be accepted in housing projects. Overcoming these barriers will require not only economic incentives but also awareness campaigns and certification processes to build end-user confidence.

4. Conclusions

This article has addressed, through a systematic review of scientific literature, the environmental sustainability of concrete and steel in social housing construction in Latin America, using Life Cycle Assessment (LCA) as a methodological framework. The results allow us to conclude that, although both materials continue to account for a significant portion of greenhouse gas emissions in the construction sector, there are also technically viable and economically feasible solutions to mitigate their impacts when eco-design, circularity, and partial input substitution strategies are applied.

In the case of concrete, the incorporation of supplementary cementitious materials (SCM), such as blast furnace slag and fly ash, is presented as a high-performing, environmentally friendly alternative, with reductions of up to 40% in the material's carbon footprint. However, its adoption is still in its infancy in several countries in the region due to regulatory barriers and the limited availability of regionalized data on its performance. Similarly, recycled steel, when it comes from processes such as electric arc furnaces and contains more than 50%, can reduce emissions by up to 70% compared to primary steel. However, its integration into social housing projects requires clear policies to promote the circular economy, adequate infrastructure for scrap metal collection, and technical regulations to guarantee its quality.

Likewise, the studies analyzed reveal that assessing the sustainability of these materials cannot be limited to their impact in the production phase. A complete life-cycle approach allows opportunities for improvement to be identified across the transport, construction, use, maintenance, and end-of-life phases. This underscores the need to integrate LCA as a mandatory tool in the design, planning, and tendering of publicly funded social housing projects, as is already the case in some European countries.

Another important finding is the significant gap between existing technical and scientific knowledge and its application in practice. Most of the studies reviewed report consistent results regarding the environmental effectiveness of low-impact technologies; however, their widespread implementation is limited by the absence of harmonized regulatory frameworks, the lack of adequate economic incentives, and the low availability of open regional databases, which limit the need to use generic emission factors that are not representative of the local context.

In this context, strengthening institutional capacities to collect, validate, and disseminate LCA data with a territorial focus is essential. Without solid governance of environmental information, it will be challenging to establish verifiable standards or promote fair competition among material suppliers. At the same time, integrating the dismantling and reuse of components into the architectural design stage is emerging as a long-term strategy for achieving a truly circular economy in the social housing sector.

The sustainability of concrete and steel in social housing is not just a technical exercise. It requires synergies among public policies, technological innovation, professional training, and private-sector participation. Only through coordinated action among these actors will it be possible to transform social housing in Latin America into an effective vehicle for achieving the Sustainable Development Goals and meeting international commitments on climate change and environmental justice.

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