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Review

Clean Technology Transfer and Innovation in Social Housing Production in Brazil and Colombia. A Framework from a Systematic Review

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Abstract: Over recent years in Brazil and Colombia, the social housing programs of these two countries have increasingly become directly related to the concept of green construction and seek to integrate with their respective laws. For example, a series of technological strategies allows bought countries to guarantee a reduction of the environmental impact of traditional construction technologies. Therefore, these actions try to answer the problems in the design of dwellings in Latin America. However, the construction sector reduced productivity and limited innovation in business. Some of the technological management processes in the social housing construction sector only consider the implementation of clean technologies tangentially. This situation is mainly because of general policies since they do not consider different local contexts. It is then worth asking: What impact do the processes of transfer of clean technologies have on social housing in Brazil and Colombia? This systematic review was carried out on scientific papers indexed by the science database from 2013 to 2019. The PRISMA method was applied to this review with an aim to propose a conceptual model for the transfer of clean technology in the production of social housing in Brazil and Colombia. Finally, we identify that the impact of clean technologies transfer on social housing is very low in these two countries.

Keywords: clean technology; innovation; social housing; sustainability; technology transfer

1. Introduction

Over recent years in Brazil and Colombia, the programs oriented towards sustainable development have been driving improvements in quality of life. For example, the social housing programs of these countries are directly related to the concept of green construction and can be implemented in each of their respective countries. Therefore, a series of technological strategies that will ensure the reduction of the environmental impacts produced by traditional construction technologies must respond to a better environment for its inhabitants.

For instance, the process to develop buildings and public spaces are quite complicated and cause impacts on the extraction and transformation of raw materials into building components, the operation and maintenance of buildings, and the final disposal of buildings. From this perspective and in meeting the goals of the sustainable development of CO_2 emissions reduction, energy efficiency, and the rational use of water resources, the construction sector must comply with robust and sustainable legislation [1].

However, some of the processes of technological management in the sector of the construction of the social housing, only considering the partial implementation of the clean technologies and the consequent reduction in the quality of life of its inhabitants, putting in risk the sustainability of their environment. In the case of Brazil, despite efforts to reduce the impact generated by civil construction, especially to adopt green design guidelines to traditional construction technologies. The construction sector must change its responsibility to sustainability [2].

In this context, the action of the various spheres of government through public policies is fundamental for the implementation of the principles of sustainability in decision-making processes in construction [3,4]. Moreover, several studies have shown that social housing units have low environmental performance and low energy efficiency due to the use of bioclimatic materials and strategies that are unsuitable for the local climate and energy consumption reduction systems in the region [5].

The Brazilian civil construction sector is still very conservative regarding the limited range of products offered by companies and the use of traditional construction technologies. The standardization of architectural designs creates a type of identification for each company and allows geographic expansion and commercial viability [6]. Despite that, the companies have produced innovation; however, there have been shortcomings in the management of projects and production processes because general productivity in the sector has remained practically stagnant for the last 50 years [1].

Furthermore, in line with data from the National Confederation of Industry [1], the construction sector is fragmented due to the high number of micro and small businesses, followed by an increase in informality, which reduces the pace of innovation in business. It is then necessary to examine how the impact of the transfer of clean technologies on the social housing sector in these countries has been understood and to understand the relationship between the concepts of technology transfer, accessible housing, social housing, and sustainable buildings. This systematic review was by indexed scientific papers by the science database in the last six years. The PRISMA Method applied to develop the review and analyzed data by VOSviewer software. This article aims to propose a model of understanding the transfer of clean technology in the production of social housing in Brazil and Colombia.

2. Methodology

The method used for this systematic review was PRISMA [7]. This method is an evidence-based set of items for reporting in systematic reviews. It focuses on the reporting of reviews evaluating randomized trials by the indexing database. This review organized in structured and unstructured data. Structured info was by indexed scientific papers by the Scopus database in a timeline from 2013 to 2019. Them, we analyzed data by VOSviewer software. Scopus is a database of bibliographic references with tools for monitoring, analysis, and visualization of research. The database allows different document search options, by author, by affiliation and advanced search for expert users. VOSviewer software tool used for constructing and visualizing bibliometric networks. These networks can be constructed based on citation, bibliographic coupling, co-citation, or co-authorship relations. Furthermore, this software offers to visualize networks of terms extracted from the scientific literature.

Moreover, this review was useful to the conceptual clean technology transfer model building to the production of social housing in Brazil and Colombia. Thus, the algorithm followed the next variables: (1) Technology transfer. (2) Affordable housing. (3) Social Housing. (4) Brazil. (5) Green buildings and (6) Colombia. Finally, it identified 535 documents. The following search connectors were used: "AND" and "OR." The search was carried out by: (Article Title, Abstract, and Keywords; TITLE-ABS-KEY).

The four-phases followed by the PRISMA method were: Identification, Screening, Eligibility, and Included.

- Identification: First, records were identified through database searching (n = 535). Second, additional records were recognized through other sources (n = 15).
- Screening: Third, known records after duplicates were removed (n = 535). Fourth, records were screened (n = 500). Five, acknowledged records were excluded (n = 0).

- Eligibility Sixth, carefully chosen full-text articles were assessed for eligibility (n = 50). Seventh, selected full-text articles were excluded, with reasons (n = 10).
- Finally, designated studies were included in quantitative synthesis (meta-analysis) (n = 45).

Table 1 presented the 11 main keywords. First, the word "technology transfer" occurred 102 times, and it had a total link strength of 66%. Second, the word "Brazil" occurred 51 times, and it showed a total link strength of 36%. On the other hand, the word "Colombia" was only seen six times with a total link strength of 3%. Finally, "climate change" and "sustainability" occurred seven times, and had a link strength of 6% and 4%, respectively.

Table 2 showed the 19 most important countries in the literature review. It can be see that the first four places are Brazil, the United States, the United Kingdom, and Colombia. Figure 1 shows the relationship between the 19 countries. In this way, the term technology transfer has a degree of appearance of 102 times. Figure 2 showed that the terms Brazil was highlighted with a degree of appearance of 11. On the other hand, affordable housing with a degree of appearance of 10 and social housing with a degree of appearance of 6. It means a great interest in these four topics regarding the selected variables. Finally, Figure 3 display links between affordable housing and social housing.

Table 1. Relation of keywords with study variables.

Keyword	Occurrences	Total Link Strength
Technology Transfer	102	66
Brazil	51	36
Innovation	25	22
Developing Countries	21	21
Intellectual Property	15	17
Technology	9	13
Clean Development Mechanism	8	10
Development	7	10
Climate Change	7	6
Sustainability	7	4
Colombia	6	3

Table 2. The network of relationships by country about study variables.

Country	Documents	Citations	Total Link Strength
Brazil	202	1354	52
United States	83	947	46
United Kingdom	25	260	30
Colombia	43	192	19
Australia	7	105	17
France	19	171	17
Canada	17	214	14
Italy	11	32	13
Spain	9	82	12
Netherlands	12	45	11
Germany	12	54	7
Sweden	9	189	6
Belgium	5	12	5
Argentina	5	48	4
China	9	68	4
India	8	37	4
Portugal	5	7	4
Switzerland	7	175	3
South Africa	5	10	2

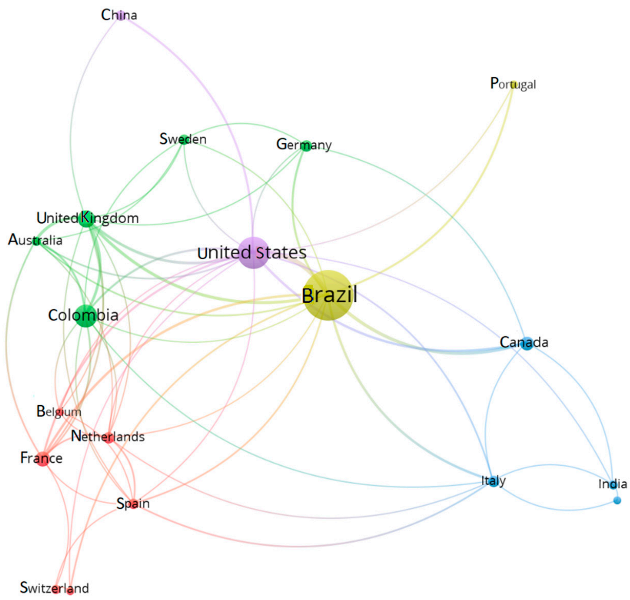

Figure 1. The network of country relations the 19 most prominent countries about the study variables.

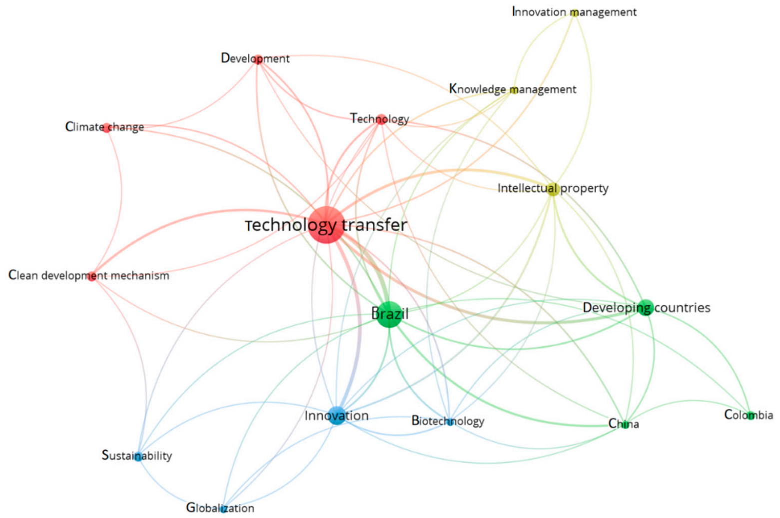

Figure 2. Keywords relationship to the technology transfer concept, Brazil, and Colombia.

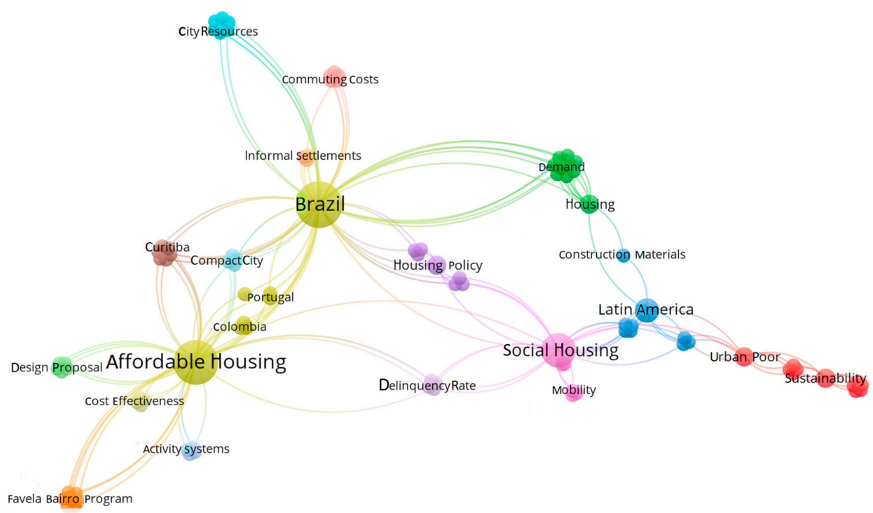

Figure 3. Relation of keywords with affordable housing and social housing in Brazil and Colombia.

3. Green Buildings Concept Approach

For some authors, sustainability can be interpreted by systems theory [8]. On this subject, sustainability is equal to a system. Therefore, green buildings could analyze by the systems theory. Therefore, some studies relate the sustainability concept from evaluating the economic disadvantages that cities around the world can offer, particularly in countries that housing plays a fundamental role [9]. For example, other studies show that the greenhouse is an answer in the German government's sustainability strategy [10].

Authors consulted said that the relationship between interior comfort and the climate context is essential to ensure a superior liable environment for the occupants of the home [11]. About this, the sustainable environment requires the production of both materials and buildings low in CO_2. For example, other authors explain how improvements in the energy performance of homes in the United Kingdom have suggested changes in legislation and the introduction of the sustainable homes code in 2007 [12].

Some authors propose that improvements in the design of energy-efficient houses lead to an increase in environmental impact in the construction and demolition phases [13]. Additional studies explain that people's well-being depends on the use of efficient energy [14]. At the same time, other authors said that there was a sudden and simultaneous expansion of multi-million-dollar housing programs in many emerging and developing economies [15]. Therefore, the effects of such programs in cities should be paid attention to. There are computational framework studies for the analysis and optimization of energy systems in the neighborhoods and districts of cities [16].

Another research study explains how internal energy demands a policy with implications for climate change is, energy vulnerability, and security [17]. Returning to the European context, more authors explain the UK government's adaptation program seeks to improve the energy efficiency of the housing sector [18]. The study of these authors concludes that energy savings in homes are associated with the installation of thermal insulation and heating.

From another point of view, sustainability, internal, or subcontracted projects that affect environmental, social, and environmental performance, the government in urban planning processes [19]. However, the social aspects of sustainability become more complicated [20]. Other authors try to understand how alternative energy activities and policies impact the experiences of communities facing climate change [21].

The authors set out as the mainstream of China's new affordable housing policies, and its integrated sustainability has a powerful effect on the welfare and social stability of low–middle income families. Besides, Europe presents a problem in the renovation of existing social housing. Therefore, it leads to the proposal of renewal strategies based on the life cycle, the social aspects of the aging of society, the preservation of cultural heritage [22].

Finally, some studies identified the performance of sustainability in housing [23]. This analysis illustrates the improvements and sustainable products in the housing design. The authors said that it is not possible to continue evaluating the affordable housing in economic terms today. Durable performance requires different multi-criteria decision methods to support affordable housing [24].

4. Technology Transfer Concept Approach

Authors have identified that although the literature on the social acceptance of new technologies focuses on industrialized societies, concerns about new technologies are more widespread in developing countries [25]. Likewise, other authors explain that the motivation for adopting clean technologies depends on the knowledge structure and the defects of these technologies, since these are the significant factors that affect the behaviors of the adoption of technologies [26].

Studies suggest that construction energy flexibility could play a crucial role in transferring demand to integrate renewable energy into smart grids [27]. Other reviewed authors said that sustainable technology diffusion is full of obstacles and has become an essential area of research [28]. For example, for authors, investment in renewable energy in multi-family residences in the United States has not kept pace with the investment in facilities required to achieve this goal [29].

Other authors related to the state that electricity, heating, and cooling are the three main components that constitute the tripod of energy consumption in residential, commercial, and public buildings worldwide [30]. So, carbon emissions policies reduce is related to technologies type that will accept in the routines of domestic life [31]. On the other hand, climate change mitigation in developing countries is essential for the transition to low-carbon growth pathways [32].

On this subject, the authors argue that the challenge of better understanding the full effect of imperfections and the barriers that can alter the acceleration of such low carbon technologies have implications for energy policy [33]. For example, some authors evaluated the contribution of 75 Clean Development Mechanisms (CDM) projects for technology transfer initiatives and the promotion of the adoption of cleaner technologies [34]. For example, authors have studied the United Kingdom's commitment to reduce CO_2 levels by 80% by 2050 about the 1990 baseline of emissions [35]. In this regard, additional studies analyzed marketing efforts to disseminate sustainable energy technologies (SET) [36].

5. Social Housing Concept Approach

In the study countries context, the projective guidelines for social interest housing in Brazil were defined in the "Energy Efficiency in Social Interest Housing" Notebook, to assist the segments involved with housing programs on the theme of energy efficiency in buildings, and collaborate with the policy of reducing the costs of these types of enterprises [37]. These guidelines propose strategies for environmental comfort and energy efficiency by the Brazilian bioclimatic zoning [38]. Since 2013, Brazil also has the NBR 15,575 standard Housing Buildings Performance [39], which establishes technical parameters for several requirements of a building, such as thermal and acoustic performance, durability, warranty, and useful life, and determines a mandatory minimum level for each of them.

In order to encourage the use of more sustainable technologies and certifications, manuals adapted to the Brazilian reality were created, such as the National Energy Conservation Label (ENCE), of the Procel Edifica program, the hallmark of the High Environmental Quality Process (AQUA-HQE), developed from the French certification Démarche HQE (Haute Qualité Environmental), and adapted to Brazil and applied by the Vanzolini Foundation since 2008, and also the Casa Azul Seal, launched by the Caixa Econômica Federal in 2010 [40].

However, due to the lack of inspection in compliance with the regulations and the fact that certifications are not mandatory, most social housing ventures are not built for sustainability. Besides, architecture typologies reproduction without regional specificities is recurrent. Thus, the same typology is adopted in different Brazilian cities, resulting in low-quality buildings that do not meet the needs of their users [39]. For example, studies analyzed social housing associations that offer a unique opportunity for renewable energy through the implementation and reduction of social costs for tenants [41]. In this sense, the authors explained how old residential buildings dominated by Romania's construction sector, and it must get guidelines imposed by the European Union by the year 2020 [42]. Likewise, authors such as Thøgersen (2017) propose a new instrument to measure the lifestyle of the inhabitants of the house and energy savings.

From another perspective, in the case of Colombia until 2017, the production of sustainable buildings that are related to social housing is not registered [43]. That is that energy inefficiency and the use of technology not adapted to the effects of climate change puts the habitability of large Colombian cities at risk [44]. On the other hand, the cities of Bogotá and Medellín defined local, sustainable construction policies towards 2014 and 2015. For 2015, the guidelines for green construction are set to resolution 0549 by the Colombian government. Finally, in 2018, the Colombian government issued the national sustainable construction policy through document CONPES 3919.

6. Results

Below is shown the synthesis of state of the art presented for understanding the clean technology transfer in social housing.

6.1. Framework Synthesis from a Systematic Review

Three constructs were building like an investigation result. These were: First, Green Buildings concept. This construct has 17 variables, according to the literature review. Furthermore, it is the one that has developed most in its research process. Second, the Technology Transfer notion consists of 12 variables according to the review of the literature. This construct is the second most researched, and social housing concepts identified some variables related to Green Buildings. Finally, Social housing idea. This construct consists of seven variables. About the two last research constructs, this construct is the least studied (see Table 3).

Table 3. Synthesis of constructs of the framework.

Green Buildings (C1) Variables Construct (V1)	**Technology Transfer (C2) Variables Construct (V2)**	**Social Housing (C3) Variables Construct (V3)**
Systemic Sustainability [8]	Technology Acceptance [25]	Renewable Energy Efficiency [41]
Home Comfort [11]	Energy Flexibility [27]	Energetic Certification [37–40]
Management Process [19]	Technological Adoption [26]	Energy Guidelines [42]
Green Affordable Housing [10]	Technological Diffusion [28]	Home Comfort [38]
Economic Disadvantages [9]	Energy consumption [30]	Sustainable Urban Planning [44]
Housing Programs [15]	Renewable Energy Efficiency [29]	Affordable Housing [40]
Affordable Housing [45]	Types of Technology [31]	Constructive Quality [37–40]
Energetic politics [17,21]	Climate Change [32]	
Neighborhood energy analysis [16]	Technology Barriers [33]	
Efficient energy [14]	Clean Development Mechanisms (CDM) [34]	
Social Sustainability [20]	CO_2 Emission Reduction [35]	
Design Improvements [13]	Technological marketing [36]	
Energy Performance [12]		
Lifecycle [22]		
Sustainable Affordability [24]		
Energy-saving of homes [18]		

6.2. Clean Technology Transfer Model Production of Social Housing in Brazil and Colombia

Finally, to identify social housing production, a clean technology transfer model was made. Then, a Venn diagram designed for future studies, and possible visions were detected. Therefore, three lists contained the variables (see Table 4). Relationship similarities were obtained (see Table 5). Finally, a graphic represented these relationships (see Figure 4).

Table 4. Elements identification.

Construct	**Item Number**	**Number of Unique Items**
Green Buildings	17	16
Technology Transfer	12	12
Social Housing	7	7
Total Number of Unique Items		33

Last, the proposed model identifies that there is a first weakness between the similarities of the constructs, which implies a knowledge gap that must be satisfied. Then, it recommends that develop future research that consolidates the innovation processes in the social housing field. Now, from Tables 6–8 shows the relationships from Brazil, Colombia, the European Union, The United States, and the United Kingdom. These tables identify the topics to technology transfer from Industrial Countries to Developing Countries. Table 6 shows the main topics of Green Building construct and reveals that Industrial and Developing countries are active in the Government's Sustainability Strategy and Housing Programs. Nevertheless, Developing Countries need a big drive in the other 13 variables. Furthermore, it means that this kind of country is starting the transfer technologies process.

Table 5. Similarities between variables.

Similarities between Constructs	Total	Number of Unique Items
Green Buildings and Social Housing	1	Affordable Housing
Technology Transfer and Social Housing	1	Renewable Energy Efficiency
Green Buildings	15	Efficient energy; Life cycle Social Sustainability; Housing programs; Economic disadvantages; Energy performance; Management process; Design improvements; Sustainable affordability; Energy savings of homes; Interior comfort of housing; Systematic sustainability; Sustainable housing; Neighborhood energy analysis; Energy policy
Technology Transfer	11	Clean Development Mechanisms (CDM); Technological acceptance; Technological diffusion; Climate change; Energy flexibility; Types of technology; Technological marketing; Technological barriers; Technological adoption; Reduction of CO_2 emissions; Energy consumption
Social Housing	5	Energy certification; Sustainable urban planning; Construction quality Comfort of the house; Energy guidelines

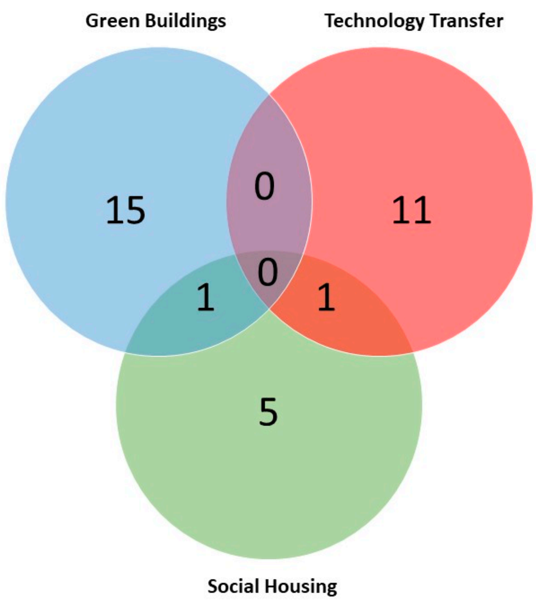

Figure 4. Relationship similarities.

On the other hand, Table 7 illustrates the main topics of the Technology Transfer construct. This table can see that Brazil and Colombia have a critical need for technology Transfer. However, those countries have an advantage that represented in Clean Development Mechanisms (CDM). This tool can help to those countries to do a better Technology Transfer from Industrial Countries. Finally, Table 8 indicated the main topics of the Social Housing construct. The table shows that Brazil and Colombia are currently implement housing legislation in their countries. However, these countries need driving more standards to make possible a good Technology Transfer process.

Table 6. Green Building construct variables results.

Reference	Green Buildings	BRA	COL	EU	US	UK
[10]	Government's Sustainability Strategy	✔	✔	✔	✔	✔
[11]	Interior Comfort			✔	✔	✔
[12]	Materials and Buildings Low in CO_2			✔	✔	✔
[13]	Design Energy-Efficient Houses			✔	✔	✔
[14]	The Use of Efficient Energy			✔	✔	✔
[15]	Housing Programs	✔	✔	✔	✔	✔
[16]	Energy Systems in the Neighborhoods			✔	✔	✔
[17]	Energy Vulnerability and Security Policy			✔	✔	✔
[18]	Housing Energy Efficient Program			✔	✔	✔
[19]	Urban Planning			✔	✔	✔
[20]	The Social Aspects of Sustainability			✔	✔	✔
[21]	Alternative Energy to Climate Change			✔	✔	✔
[22]	Renovation of Existing Social Housing				✔	✔
[23]	Sustainability in Housing			✔	✔	✔
[24]	Decision Methods to Support Affordable Housing			✔	✔	✔

Country: Brazil (BRA); Colombia (COL); European Union (EU); United State (US); United Kingdom (UK).

Table 7. Technology Transfer construct variables results.

Reference	Technology Transfer	BRA	COL	EU	US	UK
[25]	Social Acceptance of New Technologies			✔	✔	✔
[26]	Adoption of Technology Designers			✔	✔	✔
[27]	Construction Energy Flexibility (Smart Grid)			✔	✔	✔
[28]	Sustainable Technology Diffusion			✔	✔	✔
[29]	Renewable Energy in Multi-Family Residences			✔	✔	✔
[30]	Energy Consumption in Residential Buildings			✔	✔	✔
[31,35]	Carbon Emissions Reduction Technologies			✔	✔	✔
[32,33]	Low Carbon Technologies			✔	✔	✔
[34]	Clean Development Mechanisms (CDM)	✔	✔			
[36]	Sustainable Energy Technologies (SET)			✔	✔	✔

Country: Brazil (BRA); Colombia (COL); European Union (EU); United State (US); United Kingdom (UK).

Table 8. Social housing construct variables results.

Reference	Social Housing	BRA	COL	EU	US	UK
[37]	Energy Efficiency in Social Interest Housing	✔	✔	✔	✔	✔
[38]	Bioclimatic Zoning Guidelines	✔	✔	✔	✔	✔
[39,42]	Housing Buildings Standard			✔	✔	✔
[40]	Energy Certification	✔	✔	✔	✔	✔
[41,43]	Social Housing Renewable Energy			✔	✔	✔
[44]	climate change adaptation	✔	✔	✔	✔	✔

Country: Brazil (BRA); Colombia (COL); European Union (EU); United State (US); United Kingdom (UK).

7. Conclusions

This systematic review was by indexed scientific papers by the science database, and the PRISMA Method applied to develop the review. Then, it was analyzing the data by VOSviewer software. The sustainable development programs oriented to social housing programs seeking to relate directly to the green building concept, in recent years, in Brazil and Colombia. However, technological management processes sometimes do not consider the implementation of clean technologies. In this sense, the technology transfer term takes importance to the development concept. For example, in the context of Brazil, where there is extensive research experience about the topic. What does not happen in the Colombian environment where there is a little developed research process concerning Brazil.

On the other hand, technology transfer is of great importance to the concepts of affordable housing and social housing.

So, there is a relationship between these terms and the variables that constitute their relationship.

Regarding the question: What impact do the processes of transfer of clean technologies have on Social housing in Brazil and Colombia? The answer is that clean technology transfer processes have a minimal impact on social housing in Brazil and Colombia. In conclusion, the impact of clean technologies transfer on social housing is very low in these two countries.

Therefore, different relationships study variables that can build to consolidate the clean technologies transfer processes, which guarantee real sustainability in social housing that allows reducing impacts environmental and ensure the balance of the environment of its inhabitants. Finally, it concluded that this research work is the door to the construction of scientific models that guarantee an adequate technological transfer in the social housing sector of Brazil and Colombia.

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