LCA for Brazilians buildings in agreement with LEED v4: overcoming the barriers

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ABSTRACT

This work aims to identify and characterize the main barriers for performing buildings LCA and attendance of the LEED v4 certification in the Brazilian context, indicating ways to overcome these barriers. The method used was a critical literature review following steps: 1 - identify and analyze the LCA requirements from LEED v4; 2 - identify the barriers imposed for the incorporation of buildings LCA into LEED v4 in Brazil by literature review and documentary research; 3 - analyze critically and synthesize the barriers described; 4 - suggest actions and conditions to overcome the barriers. The results were described in 9 barriers, 6 mainly related to LCA and building LCA, 2 for the integration of LCA into LEED v4 and 1 on both strands. For each challenge were indicated overcoming actions and conditions classified according to the degree of complexity to implementation. Most of these, 7, require simpler actions. The other three barriers require more complex actions, highlighting Codes & Public Policies as the main inductor, Market & Demand as influenced by all others. Therefore, it is relevant to concentrate efforts to sensitize the normative and legislative instances for the implementation of actions related to the inducing challenge.

Keywords: *LCA, Life Cycle Assessment, Building, LEED, Certification, Green Building*

1 INTRODUCTION

The Urban Built Environment is considered a voracious natural resources costumer and important environmental impacts generator, consuming 40% of the global resources, 60% of all electrical energy produced, emitting 33% of the greenhouse gases (GHG) (UNEP-SBCI, 2014) and generating large amounts of waste.

Life Cycle Analysis (LCA) is a powerful tool capable of assessing the environmental impacts of a system throughout its lifetime and identifying the critical points (BUXEL; ESENDURAN; GRIFFIN, 2015). The LCA can compare potential environmental impacts resulting from production, use, end-of-life of the different products supplying a framework able to support suitable design decision-making and identify the most environmentally efficient processes and products (ZABALZA BRIBIÁN; VALERO CAPILLA; ARANDA USÓN, 2011). In this context, the use of LCA for Buildings finding the minimization of production, use and end-of-life processes environmental impacts is extremely adequate (RÖCK et al., 2018).

The environmental buildings certification systems are useful and promising means to disseminate the environment sustainability concept, to inform the society about sustainability, to mobilize the production chain to meet established sustainability levels (AL-GHAMDI; BILEC, 2017). Leadership in Energy and Environmental Design (LEED) is an international system of environmental certification and guidance for buildings with the purpose of encouraging adjustments in the design, work and operation of buildings, with a focus on sustainability (GREEN BUILDING COUNCIL BRASIL, 2018). With voluntary adhesion, it is oriented to the market (SILVA, 2003) and the most common building certification used in Brazil. Version 4 of the LEED BD+C incorporates the LCA, which represents a significant improvement over the previous version.

This work is funded on lack of a prepared environment for the dissemination of the application of LCA in the evaluation of Brazilians' buildings. The objective of this work is to identify, characterize and propose a classification addressing the main barriers for the realization of LCA of buildings and to meet the requirements of LEED v4 against the Brazilian context and to point out possible ways to overcome these barriers.

The method used was critical literature review following steps: 1 - identify and analyze the LCA requirements from LEED v4; 2 - identify the barriers imposed for the incorporation of buildings LCA into LEED v4 in Brazil by literature review and documentary research; 3 - analyze critically and synthesize the barriers described; 4 - suggest actions and conditions to overcome the barriers. Scopus, Web of Science, Spring and Scielo databases were utilized for selecting pertinent articles. Brazilian databases were searched, as associations and similar institutions involved in building LCA, universities repositorium and other. There are few papers, 11, with direct approach about building LCA into LEED. However, the subject is secondary and superficially addressed in part of the articles dealing with whole-building LCA, in greater number. The results were described in 9 barriers, 6 mainly related to LCA and building LCA, 2 to the integration of LCA into LEED v4 and 1 to both strands. This paper was organized as follow: 1 - The requirements in the LEED v4 related to the LCA were described and analyzed regarding the procedures, information and results required to meet the corresponding LCA credits; 2 - The discussion about barriers of incorporating buildings LCA into LEED v4 in Brazil were identified using literature review and document search. The information was grouped according to themes and expressed in 9 topics. It was suggested actions and conditions potentially able to promote the overcoming of the identified barriers; 3 - Based on the collated information was performed a critical analysis and synthesis of the barriers described, presented as a conclusion.

The research is limited to the data published in the databases used for the research. Statistics, extensive and in-depth research about use of buildings LCA and certification systems there are not in Brazil until now.

2 REQUIREMENTS LEED V4 FOR BUILDING LCA

The LCA is incorporated into the Version 4 of the LEED in the Materials Resources category, through two credits, Building Life Cycle Impact Reduction and, Optimization and Disclosure of Construction Products - Environmental Product Declaration. In the Building Reduction Impact Reduction credit, there are four options for demonstrating the desired impact reductions, with only one option for LCA. Table 1 provides an indicative summary of the insertion of LCA in LEED v4 points (U.S. GREEN BUILDING COUNCIL, 2018).

Table 1 – LCA into LEED v4 points

Credits	Optimization and Construction Products Disclosure – Environment Product Declaration		
LCA goals	Options	Requirements	Points

Materials and components	Environment Product Declaration (EPD)	Use at least 20 permanent construction materials or components from at least 5 different manufacturers with EPDs compliance with ISO	1
	Multi-attribute Optimization	Use at least 50% of the total value of permanently products that demonstrate impact reduction below industry average in at least 3 of the 6 impact categories* considered at LEED	1

Credits	Reduction of the Building Life Cycle Impacts		
LCA goals	Options	Requirements	Points
Building	Whole Building LCA	A minimum of 10% reduction at least 3 of the 6 impact categories* considered at LEED, being global warming potential (GWP) mandatory and allowed 5% increase in the other 3 impact categories.	3

*global warming potential (greenhouse gases), in CO2e; depletion of the stratospheric ozone layer, in kg CFC-11; acidification of land and water sources, in moles H+ or kg SO2; eutrophication, in kg nitrogen or kg phosphate; formation of tropospheric ozone, in kg NOx, kg O3 eq, or kg ethene; and depletion of nonrenewable energy resources, in MJ

Specially with respect to the whole building, LCA is applicable to new buildings or portions of the new building. Reduction of potential environmental impacts in relation to a baseline building for cradle-to-grave assessment according ISO 14044, considering impacts on the structure and envelope of the building, foundations, structure, walls and fences, structure of floor and ceiling, for life of 60 years. Equipment and electrical controls, sanitary equipment, furniture and elevators should be excluded.

The USGBC declared purpose of that LEED credit is for the project team to use the LCA as an early design decision support tool (U.S. GREEN BUILDIMG COUNCIL, 2013). It is important to note that energy efficiency, environmental comfort and the evaluation of environmental impacts are treated autonomously and disconnected from each other. The LEED life cycle environmental impact assessment is restricted to the impacts incorporated into the building materials used during the life cycle of the building.

3 LEED AND CHALLENGES FOR THE BUILDINGS LCA

Authors indicate that the application of LCA for the evaluation of buildings faces many problems, with greater relevance being those related to the standardization of the limits of the processes analyzed, the degree of detail of the inputs, the relativization of environmental loads, the linking of complementary processes, the determination of a unit of reference measure for the results, among others (ANAND; AMOR, 2017). Differences in these aspects may completely alter the results of the LCA (BASTOS; BATTERMAN; FREIRE, 2014). Due to the flexibility of the method and the complexity and relatively low degree of industrialization of the product building, there is a great variability in the results of the LCA studies, which often results from the lack of methodological homogeneity and prevents the comparison and benchmark establishment (CABEZA et al., 2014).

The delimitation of these dispersed problems and the association of causes is essential to allow the discussion about them in order to find solutions to overcome them. Following, it is concomitantly presented a classification of the issues and respective causes that constitute barriers to the use of LCA for environmental evaluation of buildings and benchmarking for the construction industry and meeting the requirements of LEED v4. This indication results from the process of synthesizing the literature.

Were grouped 9 challenges according to thematic linkage, with barriers from 1 to 6 more aligned to building LCA, barriers 7 and 8 to LEED and challenge 9 to LCA of buildings and LEED. At the end of each subitem, actions and conditions necessary to overcome the challenge are suggested.

3.1 *Knowledge, Research and Development on LCA*

There is growing interest in the use of LCA concepts and methods for evaluating environmental sustainability in construction, as demonstrated by the substantial increase in the number of scientific publications on building LCA, 200% in the last 5 years (ANAND; AMOR, 2017). Such publications are concentrated in developed countries. No Brazilian publications on LCA of whole buildings have been identified (EVANGELISTA; TORRES; GONÇALVES, 2016).

The lack of indexed Brazilian publications on the subject is indicative of the restricted permeability of the LCA of buildings in Brazil. On the other hand, initiatives such as the Brazilian Life Cycle Assessment Program (BRASIL - INSTITUTO BRASILEIRO DE METROLOGIA QUALIDADE E TECNOLOGIA, 2012) and the Life Cycle Assessment Project of the Brazilian Institute of Information in Science and Technology (IBICT) indicate that the LCA has gained relevance in the context of research and production in the Brazilian industry. The number of civil construction LCA research centers has been growing (DE SOUZA; BARBASTEFANO; TEIXEIRA, 2017) while institutions and themes relations complexity indicates the further development trend (ZANGHELINI et al., 2016).

The high degree of knowledge required for the LCA application is pointed out as one of the most relevant barriers to the dissemination of the use of the method for the environmental evaluation of buildings (MALMQVIST et al., 2011). The actions and conditions necessary to overcome this challenge are strengthening of buildings' LCA research centers.

3.2 *Codes and Public Policies*

The establishment of codes and public policies aimed at the dissemination of LCA is one of the main inducers and essential step for the establishment of LCA as a tool for assessing the sustainability of products and processes (GUINÉE et al., 2011).

As already occurs in the case of the Brazilian Quality and Productivity of Housing Program (PBQP-H), which motivated the rapid improvement of the social housing construction sector through voluntary adhesion of the companies into the regulatory program as a condition to accesses public financing, it is possible to indicate that the compulsory conditions created by codes and public policies are excellent to induce improvement in the sector (BENETTI, 2006).

The actions and conditions necessary to overcome this challenge are the elaboration of codes and public policies based on public awareness, with the involvement of stakeholders in the Civil Construction sector, through partnerships with trade unions and professional associations in the sector, the appropriation of accumulated experience and the organizational structure and tools of PBQP-H, and the adoption of a perspective of continuous improvement.

3.3 *Building Design LCA Execution Team*

The almost non-existent demand for LCA from the construction sector, evidenced by the small number of EPDs (Environmental Product Declaration) available and papers related to the subject in the events and periodicals of the area, allows to conclude that the number of professionals of LCA in Brazil is quite small. The issue of the scarcity of specialists in Brazil (EVANGELISTA; TORRES; GONÇALVES, 2016) is inseparable from the small insertion of LCA in the construction market. The lack of specialists in building LCA is an important issue to be solved, since the use of LCA instruments in the area requires a high degree of knowledge (PEUPORTIER; HERFRAY; MALMQVIST, 2011).

The research was not identified training courses and courses on Building LCA in Brazil. Probably the most appropriate way to establish LCA as a subject of wide knowledge among construction professionals is the inclusion of the subject as mandatory content of undergraduate and technical courses in architecture and civil engineering and others.

The actions and conditions necessary to overcome this challenge are the inclusion of the Buildings LCA content in the regular content of the undergraduate and vocational courses of the area, and the offering of courses and training in modules, with increasing depth and complexity, offered in online platforms low cost.

3.4 Information about the Potential of the LCA

The knowledge lack about the potential of the LCA method and the scarcity of environmental parameters related to the production of building materials are important challenges to be overcome (MARTÍNEZ-ROCAMORA; SOLÍS-GUZMÁN; MARRERO, 2016). These challenges are intrinsically related to the scarcity of events, publications of various natures, and dissemination of LCA.

Actions to overcome this challenge began in 2007 with a series of 5 scientific events on Life Cycle Management and culminated in 2016 in the fifth edition of the International Forum of Cooperation of LCA held in March in the capital Brasília, with support (Ibict / MCTI) in conjunction with the United Nations Environment Program (UNEP) (BRAZIL, 2016). The creation of the Latin American Journal of Life Cycle Analysis (LALCA) and Brazilian LCA Congress is part of Ibict's set of actions in support of LCA in Brazil. The participation of the construction sector in these activities should be expanded.

The actions and necessary conditions to overcome this challenge are the increase in the number of articles related to the LCA of Buildings in Brazil, the participation of researchers and the civil construction sector in the events of LCA, support the organization of events, seminars and specific lectures of LCA of Buildings and also, the inclusion of LCA in environmental assessment systems of buildings such as LEED.

3.5 Buildings LCA Tools

The lack of tools that integrate LCA into the planning and design routine of construction industry products, the lack of expertise in LCA in the sector, and the fact that LCA is not part of stakeholder concerns are pointed out as predominant reasons for LCA to be an analytical tool predominantly employed only in the research area (ANAND; AMOR, 2017).

Simplified building-specific LCA tools are offered on the market. These tools have limited application regionally, currently covering only North America. Comparisons between results of simplified tools and complete LCA tools show divergences in results of impacts up to 70% (MITTERPACH et al., 2016). The use of BIM (Building Information Modeling) can automate the assessments and improve the performance and cost building design tools integration making easier the global evaluation of the proposed solutions (PENG, 2016) (RÖCK et al., 2018).

The actions and necessary conditions to overcome this challenge are the development of tools and software that integrate the LCA to the routine of building design, development of methods and software that integrate the evaluations of the impacts resulting from the incorporated and consumed flows and required performances, allowing analysis potential performances of the building.

3.6 Construction Inventory Data and EPDs

The access to regional data to perform the Life Cycle Inventory (LCI) is fundamental for the reduction of errors and uncertainties associated with LCA. These data come from surveys or through EPDs. The acquisition of these data in the LCA of buildings is admittedly complex due to the numerous materials and processes employed, the loss of data, the difficulty of obtaining the data that are considered confidential and the adoption of various calculation methods that imply incompatibility of results (ABD RASHID; YUSOFF, 2015). There is no complete Brazilian inventory available in any full or simplified construction tools for LCA.

The construction of the whole-building LCA inventory phase is largely dependent on components and materials data. Inventory data are also heavily influenced by the time and method of survey. The use of different inventories database and LCA tools can conduct to impacts results up to performance increment required by LEED, changing LEED building score (AL-GHAMDI; BILEC, 2017). ISO procedures to collect data of energy incorporated for the construction industry are insufficient (DIXIT et al., 2012). The lack of a scientifically agreed methodology and of the data from some regions, especially for the design phase, is a problem indicated by several authors (PENG, 2016). LEED v.4 reportedly intends to accelerate the use of tools to support decision-making based on LCA, stimulating market transformation and consequently supporting the improvement of the quality of the database (U.S. GREEN BUILDIMG COUNCIL, 2013).

Ecoinvent, one of the most comprehensive and important inventory database of LCA (PENG, 2016), launched in 2016 a Swiss government-funded action to collect and submit Life Cycle Inventories from major industries and major industries The national data collected will be shared by the National Inventories Bank - SICV Brasil (BRASIL - INSTITUTO BRASILEIRO DE INFORMAÇÃO EM CIÊNCIA E TECNOLOGIA, 2016), so it is expected that this primary barrier will soon be overcome.

3.7 Regionalization of LEED Certification

The regionalization of the requirements of the LEED system is restricted to the adoption of regional standards and codes, and there are no adaptations regarding the distribution of points.

A better adaptation to local specificities through mechanisms such as benchmarking, adjustable weights for evaluation, flexible evaluation processes and customized tools, already employed in systems of evaluation of restricted regional application (SUZER, 2015), can be implemented in future versions of LEED, however the development and success of these will be a direct function of the availability of data and local environmental analyzes.

The actions and conditions necessary to overcome this challenge are the adoption by the LEED system of processes and tools of evaluation flexible and adaptable to local specificities and regionalized benchmarking.

3.8 LCA approach into LEED

LCA is a non-mandatory credit from Material Resources category that encompasses the whole building cradle-to-grave LCA that considers the embodied impacts from building materials and components used in the production and maintenance of the building. Use and operation performance is evaluated through the Energy and Atmosphere category credits.

Authors point to a greater contribution of the operation phase on potential impacts of the life cycle of buildings when analyzing traditional buildings, revealing an inversion in this scenario when analyzing more energy efficient buildings, where the materials and components phase has a greater contribution to the impacts of the life cycle (WITTSTOCK et al., 2012). The materials with incorporated low energy does not necessarily have a low energetic life cycle (ABD RASHID; YUSOFF, 2015). Lessard el al used case studies to evidence the insufficiency of LCA baseline definition from only energy requirements, as it is currently defined, demonstrating the necessity of further investigation to delineate the boundaries defining the baseline scenario and to improve the LEED (LESSARD et al., 2017). The disconnection between the energy performance, environmental comfort and the energy LCA incorporated into LEED may result in inconsistent assessments that may negatively affect the use of the system as a tool to support the building design decision.

Building LCA can conduct a more accurate environmental assessment than LEED through its requirements and credits, buildings that present potentially diverse environmental impacts, have the same level of LEED certification. On the other hand, LEED addresses environmental benefits that LCA does not achieve, such as indoor air pollution, heat islands and light pollution (SUH et al., 2014). The LCA should be the preferred environmental assessment tool in LEED, and the sustainability analysis is complemented by credits that cannot be addressed by LCA.

The actions and conditions necessary to overcome this challenge are the integration of Building LCA, energy efficiency and environmental comfort and the incorporation of cradle-to-grave whole building LCA as the main LEED evaluation procedure.

3.9 Market Demands

The Green Building Council Brazil (GBC Brazil), one of the 21 national councils of the World GBC, has more than 850 Brazilian companies of the construction sector affiliated (GREEN BUILDING COUNCIL BRASIL, 2018).

The expansion of the application of the environmental certifications provokes the growth of more sustainable products for construction market. LEED seeks to encourage transformations in the construction market by creating demand that affects the entire supply chain, fostering the consumption and production of higher efficiency products that provide expected savings of natural resources during the production or operation phase of the building. With the expansion of the market for building LCA, the costs of carrying out the LCA tend to fall, increasing the use of methods and tools and the linked market. The incorporation of the buildings LCA into LEED is a considerable action to establish market and demand in Brazil.

Market and Demand has the greatest interdependence correlation with all other challenges and can be pointed as the aggregating factor of the barriers for the establishment and expansion of the use of Buildings LCA in Brazil. It is worth highlight that the adoption of fiscal incentive or legal requirements settled through public policies have a direct effect to consolidate demand and market for the LCA (GUINÉE et al., 2011).

The actions and conditions necessary to overcome this challenge coincide with the total set of actions and conditions indicated for the other barriers, especially for the actions and conditions necessary for the challenge Codes and Public Policies.

4 DISCUSSION AND CONCLUSIONS

The building certification systems, as LEED, are important instrument to building sustainability concept dissemination. They make essential role in market insertion and demand creation of green buildings and their components.

The LCA building is pointed out as the most complete method for environmental evaluation of the building by its comprehensiveness and flexibility. The integration of LCA into LEED is an extremely appropriate way for the dissemination and constant improvement of the concept, professionals, tools and techniques of building LCA.

Currently, performing LCA is not mandatory in LEED v4, it is an alternative to get few points, about than 3% of the total LEED v4 score for whole building LCA. The disconnection between the energy and comfort performance criteria and LCA in LEED v4 can negatively affect bioclimatic design strategies.

Necessary actions and conditions to overcome the barriers have differentiated nature and several degrees of complexity. The Table 2 presents the summary table of barriers and necessary actions. The necessary actions are classified according to their situation identified by started and not started, are also classified according to their predominant nature in technique and politics, being the technical predominance linked to arrangements dependent preponderantly on the application of knowledge, and political predominance related to arrangements dependents mostly on relations and decisions of society.

Table 2 –Barriers and actions summary

	BARRIERS	OVERCOMING ACTIONS AND CONDICTIONS	PREDOMINANT		STATUS	
			technical	political	started	not started
LCA	Knowledge, research and development on LCA	Creation of research centers	X		X	
		Financial support to research and development		X	X	
		Stimulation of industrial sectors interests		X	X	
	Codes and public policies	Elaboration of codes and public policies		X		X
		Involvement of construction stakeholders		X		X
		Partnerships with trade unions and industry associations		X		X
		Public authorities awareness raising		X		X
	Building design LCA execution team	LCA content in the undergraduate and vocational courses	X			X
		Courses and training in modules for building design professionals	X			X
	Information about the potential of the LCA	Expansion of the number of building LCA papers and news	X			X
		Support to Building LCA events		X		X
		LCA integration into certification systems	X		X	
	Buildings LCA tools	Development of LCA-building design smart tools	X			X
		Integration methods for environmental burdens and building performance assessment	X			X
	Construction inventory data and EPDs	Significant and faster increase in EPDs registration number	X			X
		Availability of national and international databases	X		X	
		Mandatory requirement of EPDs for construction products		X		X
		technical support to companies to make EPDs	X			X
LEED	Regionalization of LEED certification	Flexible and adaptive assessments	X			X
		Regionalized Benchmarking	X			X
	LCA approach into LEED	Integration of building LCA, energy efficiency and environmental comfort into LEED credits	X			X
		Whole Building LCA as the main evaluation procedure	X			X
	Market demands	Total actions and conditions indicated		X	X	

The political arrangements involve changes in paradigms and habits, requiring greater human and financial investment and long-term return, that is, they are more difficult to implement than technical-predominant arrangements. The implementation of actions and conditions linked to the predominantly technical barriers are easier and faster to be implemented. Most of the actions required to overcome the barriers are technical nature and with easier implementation and short-term results. However, actions of predominantly political nature, despite the smallest recurrence, are related to one of the main inducers of the dissemination of the Building LCA, the challenge of Public Codes and Policies, and they must be initiated.

Notwithstanding the efforts of public research institutions and centers, the interest of a few large exporter construction companies, and the promotion of LCA by its implementation as an option to achieve few points in LEED v4 certification, the barriers pointed out still fall on the buildings LCA, broadly, in the absence of requirements for potential environmental impacts of components and civil construction products in Brazil. This allows us to understand that the focus of effective efforts, able to promote and improve the installation of the necessary conditions to induce significant changes on all other barriers, should be the Public Codes and Policies.

Efforts should be made by the sector to raise awareness of legislative and normative institutions and seek the implementation of the necessary actions and conditions to overcome the challenge of Codes and Public Policies in order to access the benefits of the widespread use of LCA in construction.

This research intends to make an important contribution to promote new works and to the planning of actions in favor of the application of LCA to evaluate the environmental sustainability of buildings in Brazil. Future works based on this work should produce quantitative and qualitative data on the insertion of LCA building in the construction market through surveys.

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