

Evaluation of a residential project in light steel framing according to leed for homes

The construction industry is responsible for high energy consumption, high carbon dioxide emissions, high extraction of non-renewable materials, and large generation of solid waste in the world. The use of prefabricated, industrialized, and technological construction methods can reduce environmental impacts generated. Aiming to confirm its environmental benefits, the research proposal was to analyze the sustainability of a residential project in Light Steel Framing (LSF), according to the requirements of the environmental certification Leadership in Energy and Environmental Design (LEED) for Homes of the Green Building Council (GBC) Brazil Homes. For this, it was necessary to apply the Technical Quality Regulation for the Energy Efficiency Level for Homes, achieving the A-level classification in this analysis, with 5.06 final points. Therefore, it was considered the constitution of the building wrap in LSF, the energy efficiency of the materials used, the water heating and lighting systems. In order to obtain the highest level of LEED certification, the project has received suggestions for improvements. The project obtained 60 final points in the analysis, which would allow the achievement of the gold certification seal. The total score in the Materials and Resources topic demonstrates the great benefit of the system in LSF in environmental preservation.

Palavras-chave: Environmental certification; Sustainable construction; RTQ-R; PBE Edifica Seal.

Avaliação de um projeto residencial em light steel framing de acordo com o leed for homes

A indústria da construção civil é responsável pelo alto consumo de energia, alta emissão de dióxido de carbono, alta extração de materiais não renováveis e grande geração de resíduos sólidos no mundo. O uso de métodos de construção pré-fabricados, industrializados e tecnológicos pode reduzir os impactos ambientais gerados. Com o objetivo de confirmar seus benefícios ambientais, a proposta da pesquisa foi analisar a sustentabilidade de um projeto residencial no sistema Light Steel Framing (LSF), de acordo com as exigências da certificação ambiental Leadership in Energy and Environmental Design (LEED) para Casas do Green Building Council (GBC) Brasil Casa. Para isso, foi necessário aplicar o Regulamento de Qualidade Técnica para o Nível de Eficiência Energética para Residências, alcançando a classificação de nível A nesta análise, com 5,06 pontos finais. Para isso, foi considerada a constituição do envoltório predial em LSF, a eficiência energética dos materiais utilizados, os sistemas de aquecimento e iluminação da água. Para obter o mais alto nível de certificação LEED, o projeto recebeu sugestões de melhorias. O projeto obteve 60 pontos finais na análise, o que permite a obtenção do selo de certificação ouro. A pontuação total no tópico de Materiais e Recursos demonstra o grande benefício do sistema na LSF na preservação ambiental.


Keywords: Certificação ambiental; Construção sustentável; RTQ-R; Selo PBE edifica.

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INTRODUCTION

The construction sector, although essential for global economic development, accounts for 38% of carbon dioxide (CO₂) emissions and 35% of energy consumption¹. Brazil is the sixth country in the world ranking for primary energy consumption². With the coronavirus pandemic in 2020, Brazilian energy consumption decreased by 1.0%, in contrast, residential buildings increased 4.0% in energy consumption compared to 2019 (BRASIL, 2021). Most Brazilian buildings have great energy waste due to the lack of consideration of aspects related to user comfort, bioclimatic architecture areas, and use of materials and technological equipment that provide better energy efficiency.

The use of conventional construction methods, with a waste of time, material and resources, is more common in Brazilian civil construction, compared to technological, and advanced construction methods (GOMES et al., 2013). The use of prefabricated systems can reduce environmental impacts, consumption of materials, waste generation (TAVARES et al., 2021). In Brazil, precast concrete panels are the most common in industrialized, and prefabricated systems, however, they have high cost and weight disadvantages (Gomes et al., 2013).

In 2020, the cement industry was responsible for the 9.4% increase in energy consumption and 11.0% in clinker production compared to 2019 (BRASIL, 2021). According to Petrovic et al. (2019), concrete is the building material that most contributes to CO₂ emissions, so the use of alternative and sustainable materials reduces the environmental impact. In addition to the high energy consumption and CO₂ emissions, the construction industry has a high consumption of natural resources. The environmental impact caused by civil construction is notorious, therefore, sustainable practices are needed throughout the sector chain (LIMA et al., 2021).

The Light Steel Framing (LSF) construction system, consisting of galvanized steel profiles and industrialized plates screwed into them, is a prefabricated and industrialized method, which can be designed to meet high functional and energy requirements (GURGULINO et al., 2017). Compared to conventional concrete constructions, LSF uses less water throughout its process, makes use of recyclable technological materials and its production interferes less with air pollution, especially compared to the manufacture of Portland cement (GURGULINO et al., 2017). Sustainable management strategies in the construction sector should be more intense and consider the use of recyclable materials (HOANGET al., 2020). One way to evaluate the environmental management of projects and buildings is through environmental certifications.

According to Lima et al. (2021), the Leadership in Energy and Environmental Design (LEED) certification, is the most recurrent in research on sustainability in construction. Created in 2000 by the United States Green Building Council (USGBC), LEED analyzes the performance of sustainable buildings, with mandatory practices and supporting credits of social, environmental, and economic benefits. The reduction of CO₂ emissions, energy efficiency, mitigation of the impacts of climate change, protection and restoration

¹ <https://wedocs.unep.org/handle/20.500.11822/34572;jsessionid=A270AE28A596EC073AE1041C25A320F7>

² <https://www.iea.org/>

of water resources are the most relevant points in the evaluation of projects and constructions. The certification is voluntary and has four seal levels: Green (40 to 49 points), Silver (50 to 59 points), Gold (60 to 79 points), and Platinum (80 to 110 points)³.

The Brazilian Labeling Program (*PBE*) is a broad energy conservation program used to inform the energy efficiency of various products. The National Program for The Conservation of Electric Energy (*PROCEL*), a government initiative, awards the most efficient constructions in the Labeling *PBE Edifica* (GBC Brasil, 2017a; 2017b). The LEED certification accepts this Brazilian seal, which can be obtained through the application of the Technical Quality Regulation for the Energy Efficiency Level for Homes (*RTQ-R*).

According to Fezi (2020) after the beginning of the pandemic by COVID-19, society is even more concerned with the health of buildings and especially with the internal air quality of buildings. Green and certified buildings do not only bring benefits to the environment and to the physical comfort of the inhabitants, but positively affect the well-being and mental health of building users. To Wang et al. (2021) the presence of green spaces in homes and work environments influences people's mental health, so housing developments need to be planned with emphasis on green areas and environmental management strategies.

The aim of this research was to analyze the sustainability of a residential project in LSF through the application of RTQ-R method, and according to LEED certification requirements for homes last version (v.4). Suggestions for improvements were made to the project.

MATERIALS AND METHODS

To evaluate the residential project according to LEED for Homes parameters, guides made available by the Green Building Council Brasil¹ were used. Thus, the scores for the eight topics were analyzed and suggestions were made to improve the classification.

The residence project (Figure 1), executed in Revit software from Autodesk, has a total area of 181.43 m² and was designed to be implemented in BZ2, in a condominium of houses, in the city of Pelotas. The frames of the residence will be in white polyvinyl chloride (PVC) with double glass and insulated with 9mm of air chamber, the walls and the lining will have internal thermoacoustic insulation with glass wool. Solar water heating system with an energy catchment area of approximately 8 m² and storage of 500 L of hot water is expected. There will be photovoltaic power generation to supply 100% of the building demand and solar panels area is 32.47 m². The total floor area without coverage is 70.7 m², the total area with coverage is 142.86 m², and the upper technical area is 6.10m².

The constitution of the building walls was kindly made available by the company responsible for the project. Represented in Figure 2 are the compositions of the external and internal walls: Standard plasterboard, for dry areas and moisture resistant plasterboard for wet areas, both 12.5mm thick (A); galvanized steel structural profile with a thickness of 100mm (B); insulation with glass wool with 50mm thickness (C); reforested and pressed wood boards of the kind Oriented Strand Board (OSB) with 11.1mm

³ <https://www.gbcbrazil.org.br/wp-content/uploads/2019/08/Guia-Ra%CC%81pido-GBC-Brasil-Casa.pdf>

thick (D); medium density expanded polystyrene plate (EPS) with a thickness of 45mm (E); reinforcement screen in fiberglass (F), elastomeric mortar (G) and paint (H). An external sealing system will be used in the residence, External Insulated Finish System (EIFS) with the use of EPS, providing a thermal bridge seal.

One of the criteria adopted for evaluating the thermal performance of construction systems is through thermal transmittance (U) of external walls or descending thermal flow in roofs. The company responsible for the project and future execution provided the values: 40dB and 42dB for soundproofing and $0.32 \text{ W.m}^{-2} \text{ K}^{-1}$ and $0.43 \text{ W.m}^{-2} \text{ K}^{-1}$ for thermal insulation of the external and internal walls, respectively.



Figure 1: The house floor plan in LSF

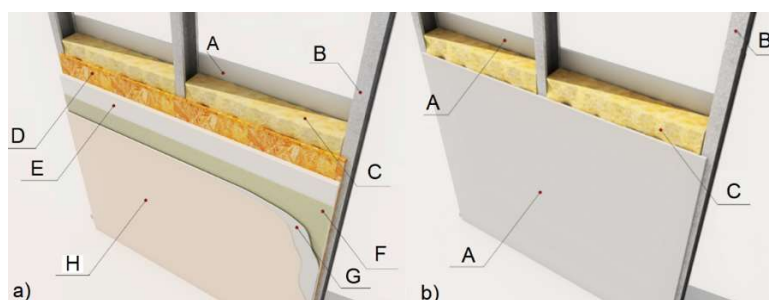


Figure 2: Constitution of the external (a) and internal (b) walls of the LSF system used. A: gypsum board; B: structural profile of galvanized steel; C: Glass wool; D: OSB board; E: EPS plate; F: fiberglass reinforcement screen; G: elastomeric mortar; H: Painting.

The materials used in the construction evaluated were analyzed for their energy efficiency and parameters necessary for the proposed environmental certification, according to information provided by the company responsible for the project and future execution, information from material manufacturers, and Brazilian standards. To calculate the efficiency level of the Housing Unit of BZ2, methods of the RTQ-R (BRASIL, 2012; 2015) were used.

RESULTS

Energy efficiency analysis through RTQ-R

In the case of external walls, for BZ2, the established value for thermal transmittance is $U \leq 2.5 \text{ W.m}^{-2} \text{ K}^{-1}$ (BRASIL, 2012), and for acoustic performance of external walls away from intense noise, according to the standard the soundproofing should be $\geq 20 \text{ dB}$, for blind internal walls between living room or kitchen and

eventual traffic areas, as corridors, soundproofing should be ≥ 30 dB (BRASIL, 2013). Therefore, the LSF walls established in the project are in accordance with the requirements of Brazilian standards. In the evaluation of the topic of Minimum Wrap Performance, the analyzed project with the RTQ-R, met the requirements of the *PBE Edifica* labeling with regard to thermal transmittance, thermal capacity, natural ventilation and natural lighting, according to Table 1.

Table 1: Final analysis of the classification of the Housing Unit (HU) with RTQ-R

Components analyzed	Score	Classification
Summer Wrap	4.35	B
Winter wrap	4.77	A
Water heating	3.00	C
Numerical equivalent of the wrap	4.58	A
Wrap if artificially cooled	5.00	A
Bonuses	1.03	-
Region/Location	-	South
Coefficient a	0.65	-
Final HU Score	5.06	A

The project has the potential to obtain scores of 5.06 and classification A on the *PBE Edifica* seal, although the efficiency value for wrap in the summer was "B", due to the positioning of the first bedroom and office windows facing southwest, and the classification "C" for the water heating system. This was due to the fact that the solar water heating system was designed to supply between 60 and 69% of the hot water demand.

Sustainable sites (SS)

In SS all four prerequisites were met. Regarding the prerequisite of Bioclimatic Architecture Guidelines, Brazilian bioclimatic zoning is defined through NBR 15220-3 (BRASIL, 2005), which establishes that for projects in BZ2 it is necessary to direct openings, from the environments of greater permanence of users, to the north, east, northeast, west or northwest, being these last two the last options. The project has reached this prerequisite, because the residence master bedroom and corridor are directed to the northwest, the living room to the northeast and northwest, except for an area of light, which directs the opening to the southwest. However, the incidence of sun in this window is limited by the garage wall, not being harmful in summer. The other bedrooms, office, kitchen and laundry, for limitations of the land, have their openings directed to the southeast.

Credit 1 (Certified Urban Development) cannot be applied, because the neighborhood where the project is inserted is not environmentally certified. With regard to credit 2 (Urbanization of the surroundings and walking streets) it was possible to get two points, because there are sidewalks in the condominium with width of 1.5m, the entrance of vehicles does not obstruct the sidewalk. The project includes walls of two meters on the sides of the land and a canvas in the background covered by native vegetation. As around the condominium the land was not previously developed, it could not obtain the credit 3 (Location preferably developed).

In credit 4 (Preservation or restoration of habitat) it was possible to obtain two points. Because the building construction coefficients were approved by the Municipality of Pelotas and the vegetation area of

the land will be composed of at least 80% of native vegetation acquired from local floriculture. On credit 5 (Proximity to community resources and public transportation), the bus stop closest to the condominium is approximately 210 meters walk, and its daily routes are 179 total for both directions, totaling the achievement of 2 points.

On credit 6 (Access to open space) it was possible to obtain a point, because the condominium has 64.353 m² of green area, 28.416 m² of social space area with gym, walking track and bike path in the external area. The project land has a total area of 400.20 m², and as the total built area of the residence will be 181.43 m², there will be 54.67% of green area, with low, medium and high vegetation. However, as a plan for the preservation of trees and vegetation on the ground was not elaborated, the credit 7 (Reduction of the impact of the work on the ground) and credit 8 (Landscaping) were not analyzed due to the landscape of the garden design is not finished. For credit 9 (Heat Island Reduction), it was possible to reach two points in this credit. For credit 10 (Rainwater Control and Management), a point was reached, because the permeability coefficient of the land is 37%, adequate according to the legislation of the municipality and the condominium has rainwater retention for artificial lakes.

Water efficiency (WE)

The project is in accordance with all the prerequisites of this topic. For credit 1 (Efficient use of water - Optimized), three points were obtained, as there is the prediction of the installation of mixers for washbasin and showers with maximum flow of 6L.min⁻¹ and the faucets of general use have restricted drive. Because there is no sectorized measurement of water consumption, only at the water inlet of the local concessionaire, nor the forecast of the use of water that is not potable for the hydro sanitary system, and because there is no forecast for irrigation system for the garden, it was not possible to obtain scores on credits 2, 3 and 4.

Energy and atmosphere (EA)

In EA, the project met all the prerequisites. Credit 1 (Enhanced Energy Performance) cannot be analyzed because the project was not submitted to energy efficiency software simulation. For credit 2 (Obtaining the *PBE Edifica* label), it was possible to obtain two points, and for credit 3 (Enhanced Performance of the Wrap) two points, because the residence would reach level A of the *PBE Edifica* (Table 1). For credit 4 (Efficient Sources of Solar Heating) it would be possible, with the choices for heating water between solar and electric, to obtain two points in this item. For credit 5 (Optimized Lighting), with the addition of installing lamps and luminaires with *Procel* seal throughout the residence, two points are achieved in this. With the use of at least 80% of appliances with *Procel* label with classification "A", it would be possible to obtain a point in credit 6 (Efficient Appliances).

It would be possible to obtain four points in credit 7 (Renewable Energy), considering that the photovoltaic energy production project includes the use of 20 photovoltaic panel boards in the residence, which will provide all the energy demand of the building. However, credit 8 (Commissioning of Installed Systems) does not apply, because the residence did not start construction. As for credit 9 (Basic Energy

Measurement), with the future sharing of photovoltaic energy production data with GBC Brazil, it would be possible to obtain a point.

Materials and resources (MR)

Prerequisite 1 requires a Construction and Operation Waste Management Plan, which was made by the company responsible for the design and execution. The residues generated are classified according to their characteristics of dangerousness established by the NBR 10,004 standard (BRASIL, 2004) in Table 2.

Table 2: Solid waste generated and its classification of dangerousness

Classification (BRASIL, 2004)	Waste
Class I D – Dangerous	Ink and solvent sludge.
Class II A	OSB boards, plaster, wood, paper and cardboard.
Class II B	Profiles in steel, cementitious plates, sheet metal, electro ducts, electrical wiring, pipes and connectors in PVC, EPS, concrete and gravel.

Prerequisite 2 (Legalized Wood) has been fulfilled, because the wood used in the sealing of the walls will be of the type OSB boards, of certified company, with the use of reforestation wood in manufacturing. On credit 1 (Construction Waste Management) it would be possible to obtain three points, the Waste Management Plan is in accordance with Brazilian standards and more than 80% of the waste generated will be recycled and/or reused.

The residence could obtain two points in credit 2 (Certified Wood), one point in credit 3 (Environmental Labeling Type I - Certified Woods) and three points in credit 5 (Environmental Labeling Type III - Environmental Product Declaration - EPD), because the OSB boards and the wood used will be acquired from a company that uses 100% reforested wood, with EPD, with green seal as established by ISO 14.024 and forest stewardship council (FSC) certified, that is timber from properly managed forests. In addition, more than five products that will be used and permanently used in the residence are certified, such as: plaster lining, plasterboard, mass for plasterboard joints, paper tapes and mass for cementitious board joints.

Credit 4 (Environmental Labeling Type II - Environmentally Preferable Materials) requires the use of materials that come from reuse, with recyclable content, rapid renewal and recyclable, aiming at reducing CO₂ emissions and extracting non-renewable natural resources. According to Table 3, based on the total materials to be used, the company responsible for the design and execution states that 4.4% of the total cost of materials is with reuse materials, 62.72% with recyclable materials and 14.69% with materials of rapid renewal, meeting the percentages established by LEED certification. It is possible to obtain three points in this credit.

Table 3: Classification of materials used in the HU

Classification	% / total cost of materials	% required by LEED
Reuse materials	4.40	2.5
Recyclable materials	62.72	20.0
Fast-renewal materials	14.69	1.0
Total	81.81	-

In credit 6.1 (Dismount ability and Waste Reduction – Structural Systems), it would be possible to obtain a point, because the LSF system is prefabricated, industrialized and can be assembled and

disassembled in a practical, easy and fast way. Its waste generation is low, due to the modulation of the system and the use of industrialized materials. An LSF building can be dismantled if it needs, without losing its properties, and reassembled elsewhere, maintaining the same shape and structural strength. In the analysis for credit 6.2 (Dismount ability and Waste Reduction – Non-structural elements) it would be possible to obtain a point, because more than 60% of the non-structural materials are completely demountable.

Indoor environmental quality (IEQ)

All the prerequisites of the item were reached, because in the project there is no prediction of the installation of equipment with combustion process within the internal spaces of the residence, and the openings met the requirements of Brazilian standards, including cross ventilation, ensuring a minimum air quality. Unfortunately, credits 1 (Thermal Performance) and 2 (Luminescence Performance) were not met, because it was not possible to perform the software simulation of the energy and luminous efficiency of the building. However, in credit 3 (Acoustic performance) it would be possible to obtain two points, considering that the minimum acoustic performance was reached according to Brazilian specifications.

On credit 4 (Local humidity control) it could obtain a point, because the projects are equipped with waterproofing of boxes of bathroom and moisture resistant gypsum boards. On credit 5 (Protection of Pollutants from the Garage) it could be possible to obtain a point, because the garage gate will allow the constant exchange of air from the site.

To obtain three points in credit 6 (Contaminant Particle Control), the residence must have all ducts and openings sealed and opened after the end of all phases of construction. At the construction site there should be a demarcation for smokers, eight meters from the cafeteria, dressing room and work area. After the work is finished, contaminant control should be made in indoor environments with cleaning and cleaning of all rooms by a specialized company.

It would be possible to obtain two points for credit 7 (Low Emission Materials), with the use of materials of low urea emission, formaldehyde, levels of volatile organic compounds equal to zero. For credit 8 (Health and Well-Being) a point could be obtained because the requirements of the Implementation credit 6 were reached, about space for physical activities, and because the residence will be delivered with a User Manual, with an explanatory guide to the operation, maintenance and cleaning of the enterprise and its materials. The residence also has ventilation control with easily operable frames, keeping carbon dioxide levels below 800 ppm.

Social requirements (SR)

The prerequisite would be achieved because the company responsible for the future execution of the work is with its regular legal obligations. Credit 1 (Universal Accessibility) requires that the enterprise be accessible to users with accessibility limitations. Because it is a single-site residence and a modular construction system that is easy to dismount, the necessary adaptations would be quick to accomplish, so the building would gain a point.

It would be possible to obtain a point in credit 1 (Good Practices for Design and Work) considering that all employees of the company are literate and have a course to implement the LSF system. The professional training courses for assembly of LSF are taught by the company itself and covers 100% of employees. This training is carried out during the execution of the work and the methodology includes the following stages: knowledge transmission, skills development, supervised experience and professional evaluation.

In credit 3 (Good Social Practices for Operation and Maintenance) a point can be obtained, because the owners receive a User Manual, with all the information necessary for maintenance and use of the building. However, because the company responsible does not have a member of GBC Brazil, it is not possible to obtain a score in credit 4 (Leadership in Action).

Innovation in design process (IDP)

Prerequisite 1 (Operation Manual Use and Maintenance) was reached, because the owners of the building receive a User Manual, with all the projects and explanations necessary to understand the operation of the residence. Credit 1 (Integrated and Planned Project) grants three points with the existence of integrated projects and planning for the execution of the work.

In credit 2 (Education and Disclosure), to obtain two points, it is necessary to publish information, characteristics and benefits of the sustainable house and maintain the certification board of *GBC Brasil Casa* outside the residence, near the entrance. As for credit 3 (Innovation and Design) it is necessary to minimize the environmental impacts caused by the residence through the incorporation of sustainable techniques and constructive measures that bring benefits, in addition to those existing in LEED for homes certification.

Some benefits of LSF could be analyzed and compared to other construction systems, such as: use of water, materials, construction time, noise generated, the amount of material transport trips, influence of truck weight and fuel consumption, reduction of CO₂ emissions during the construction period and use of the building, or the low impact on land movement and damage to buildings, justified by the use of surface foundation in the LSF system.

Regional priorities (RP)

Credit 3 (Regional - South Priorities) for the southern part of the country requires obtaining the credits: SS Credit 5; SS Credit 9; SS Credit 10; WE Credit 2; EA Credit 3; EA Credit 4; EA Credit 7; MR Credit 2. The only credit not obtained was of Sectorized Measurement of water consumption (WE – Credit 2), so the residence could obtain a point in this credit.

Total score and suggestions for improvements

All the mandatory items of the eight topics evaluated were reached, and the final score would be 60 points overall (Table 4), which would classify the project as GBC Gold Home. The classification could be Platinum, if in addition to computer simulation, some modifications were made to the project, such as: a)

implementation in an environmentally certified neighborhood and close to communities with previous development; b) have a plan to preserve the surrounding vegetation, and landscaping project with regional vegetation; c) have sectorized measurement of water consumption and efficient irrigation systems; d) possess capture and use of rainwater for non-drinking consumption and have a water safety plan; e) the benefits and innovations generated by the construction were analyzed. The investment required for its certification would be 4,000 Reais¹. This, if it were certified through GBC Brazil members, otherwise there would be an increase of 20%.

Table 4: Application of the Check List LEED for Homes - *GBC Brasil Casa*

Topics	Total	Obtained	Percentage Achieved (%)
Sustainable Sites (SS)	21	11	52.38
Water Efficiency (WE)	12	3	25.0
Energy and Atmosphere (EA)	28	14	50.0
Materials and Resources (MR)	14	14	100.0
Indoor Environmental Quality (IEQ)	18	10	55.55
Social Requirements (SR)	5	3	60.0
Innovation in Design Process (IDP)	10	4	40.0
Regional Priorities (RP)	2	1	50.0
Total	110	60	-

The construction method in LSF showed several advantages, such as the use of certified materials, where maximum points were obtained in the topic Materials and Resources, in the energy efficiency provided by the composition of thermal and acoustic insulation used, in Social Requirements, while the system in LSF allows rapid reforms for adaptations of accessibility in the residence, and by the benefits of the industrialized constructive method.

DISCUSSION

In addition to being within Brazilian standards for energy efficiency, the system LSF presented lower U value, with $0.32 \text{ W.m}^{-2} \text{ K}^{-2}$ compared to $4.4 \text{ W.m}^{-2} \text{ K}^{-2}$ of the concrete wall with 10 cm thickness and $2.48 \text{ W.m}^{-2} \text{ K}^{-2}$, of the brick wall with 14 cm thickness, both walls widely used in Brazil (BRASIL, 2015). According to Song et al. (2011), the EIFS system significantly reduces building heating and cooling, improving heating efficiency. Therefore, the use of efficient construction systems with recycled and recyclable materials, clean energy generation and economical electrical equipment is of fundamental importance.

According to Gomes et al. (2013), the use of EPS with 25 mm thickness in the outer layer of the LSF system proved to be efficient, almost completely eliminating the effect of thermal bridges in energy efficiency analysis caused mainly by metal structures. A way to mitigate the effects of thermal bridges in LSF, according to Yu et al. (2021), is the use of foam profiles and additional external insulation. Therefore, the use of glass wool and EPS plates with 45mm thickness confirms the energy efficiency of the system used in this research.

The choice of the construction system and material compositions directly influences energy efficiency and sustainability. To Lederer et al. (2021), in order for cities to achieve their sustainable development strategies, there must be a reduction in the consumption of raw materials, incentives for recycling and renovation of old buildings, without their demolition. Some measurements can be made, such as the replacement of high-density building materials such as concrete, by materials with lower CO₂ emissions.

On emission reduction, waste generation minimization, and material recycling, prefabricated buildings have proven better performances compared to conventional buildings in general in China (YU et al. 2021). According to a life cycle analysis comparing several construction systems for a single-family residence, in addition to impacts, waste, costs and production time, carried out by Tavares et al. (2021), the LSF system was only behind the wood frame system, this by the use of recycled and recyclable materials. To Hoang et al. (2020), the rate of recycling of metals is more significant than for bricks, concrete and soil. It is, therefore, an incentive to the use of metal systems in civil construction.

Jiang et al. (2020) state that, in addition to energy efficiency, LEED certification has biophilic strategies in several evaluation criteria, providing well-being and strengthening the connection with nature. To Worder et al. (2020) most LEED strategies have a potential impact on human health and well-being, without sacrificing environmental considerations. According to Gomes et al. (2013) the greater acceptance of sustainable systems and the LSF system itself, in Brazil, will happen while the professionals and users of the buildings verify the success of the thermal performance of the system, and benefits of the process such as efficiency of industrialized construction, more accurate and rapid completion of the project, rationalization and use of sustainable materials.

CONCLUSION

The house analyzed has great potential to receive the Seal A of *PBE Edifica* and the Gold seal by LEED for Homes, or from the realization of the suggestions proposed, obtain a better classification. The total possible points obtained in the topic of Materials and Resources demonstrates the sustainability of the construction system in LSF, in addition to its energy efficiency, low material consumption and low waste generation.

Environmental certifications require more practical applications and so that their real long-term and short-term benefits are demonstrated. As long as residential certifications are voluntary there will be many inefficient buildings that, in addition to wasting energy, will cause numerous damages to the environment, users, throughout the life cycle of the building. The continuity of this research can be done through the analysis with other material compositions, comparison between construction systems and analysis of residence after construction and evaluating its sustainability and the benefits observed by users.

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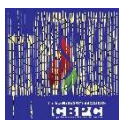
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