Evaluation of a Residential Project in Light Steel Framing According to LEED for Homes

Luiza Morselli
UFPEL: Universidade Federal de Pelotas
Stífany Knop
UCPEL: Universidade Catolica de Pelotas
Osvaldo Luis Vieira Faria
UCPEL: Universidade Catolica de Pelotas
robson andreazza (ROBSONandreazza@yahoo.com.br)
Universidade Federal de Pelotas https://orcid.org/0000-0001-9211-9903

Research Article

Keywords: Environmental Certification, Green Building, Sustainable construction, RTQ-R,PBE Edifica Seal, Prefabricated systems.

Posted Date: August 20th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-777501/v1

Abstract

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.This research aimed to analyze a single-family residential project in the construction system in Light Steel Framing (LSF), to be implemented in southern Brazil, regarding the prerequisites and credits 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. The external sealing system used in the residence was the External Insulated Finish System, and the acoustic and thermal insulation occurred through the use of glass wool on the walls and lining. 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.

1. Introduction

The construction sector, although essential for global economic development, accounts for 38% of carbon dioxide (CO_2) emissions and 35% of energy consumption (UNEP 2020). Brazil is the sixth country in the world ranking for primary energy consumption (IEA 2021). 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 (MME 2021). Most Brazilian buildings have great energy waste due to the lack of consideration of aspects related to the areas of bioclimatic architecture, use of materials and technological equipment that provide better energy efficiency, and of rational use of energy, focused on the environmental comfort of users.

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, and 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 (MME 2021). According to Petrovic et al. (2019), concrete is the building material that most contributes to CO_2 emissions, so the use of alternative and sustainable materials reduces the environmental impact. In addition to the high energy consumption and CO_2 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, besides reducing the generation of solid waste and the consumption of natural resources (Gurgulino et al. 2017, Veljkovic andJohansson 2006).

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 (Hoang et al. 2020). One way to evaluate the environmental management of projects and buildings is through environmental certifications. According to Chi et al. (2020) environmentally certified green buildings have stricter sustainability targets in energy saving and CO_2 emission reduction.

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 CO_2 emissions, energy efficiency, mitigation of the impacts of climate change, protection and restoration 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) (GBC Brasil 2017a, 2017b).

The Brazilian Labeling Program (PBE – *ProgramaBrasileiro de Etiquetagem*) 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 – *Programa Nacional de Conservação de EnergiaElétrica*), a government initiative, awards the most efficient constructions in the Labeling *PBE Edifica* (CB3E 2013). 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 – Regulamento Técnico da Qualidade para o Nível de EficiênciaEnergética*).

Studies on sustainable constructions have grown rapidly in the last 20 years (Li et al. 2021). 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 energy efficiency of a single-family residential project in the construction system in LSFthrough the application of RTQ-R method, to be implemented Bioclimatic Zone 2 (BZ2) of Brazil, and analyze it according to LEED certification requirements for homes last version (v.4). Suggestions for improvements were made to the project.

2. Materials And Methods

To evaluate the residential project according to LEED for Homes certification parameters, guides made available by the Green Building Council Brasil (GBC Brasil 2017a) were used. Thus, the scores for the eight certification topics were analyzed and suggestions were made to increase the level of project 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 condominium has artificial lakes that receive the surplus rainwater, avoiding floods and erosions in the soil. The frames of the residence will be in whitepolyvinyl 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 8m² and storage of 500L of hot water is expected. There will be photovoltaic power generation to supply 100% of the building demand.

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: Standart 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 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 of the project provided the values of thermal transmittance and acoustic insulation of the external and internal walls of LSF, according to Table 1.

Table 1 - Thermal transmittance and sound proofing of walls

Walls	Soundproofing	Thermal insulation/U value
External	40dB	0.32 $W.m^{-2}K^{-1}$
Internal	42dB	0.43 $W.m^{-2}K^{-1}$

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 and spreadsheets of the RTQ-R (INMETRO 2012, 2015) were used.

For the calculations of solar absorbance, thermal transmittance and thermal capacity adapted from RTQ-R to BZ2, the following standards were followed: NBR: 15.220-2 (ABNT 2005a), NBR 15.220-3 (ABNT 2005b), NBR15.575-4 (ABNT2013a) and NBR 15,575-5 (ABNT 2013b).

The areas of the project, necessary for the execution of heat island calculations, requested at LEED for Homes (GBC Brasil 2017a), are found in Table 2.

Table 2 Values of project areas

Area Type	Areas (m²)
Floor area without coverage	70.7
Coverage area	181.43
Green roof area	0
Total floor area without coverage	70.7
Total area with coverage	142.86
Solar panels area	32.47
Upper technical area	6.10

For the calculations of heat islands (Equation 1) data such as floor area without coverage (A), coverage area (B), green roof area (C), total floor area without coverage (D) and total area with coverage disregarding technical areas and photovoltaic plates (E)(GBC Brasil 2017a).

$$\frac{A}{0,5}+\frac{B}{0,5}+\frac{C}{0,5}\geq D+E \qquad (1)$$

3. Results

3.1 Energy efficiency analysis through RTQ-R

In the case of external walls, for BZ2, the established value for thermal transmittance is U ≤ 2.5 $W.m^{-2}K^{-1}$ (INMETRO 2012), and for acoustic performance of external walls away from intense noise, according to the standard the soundproofing should be≥ 20 dB, for blind internal walls between living room or kitchen and eventual traffic areas, as corridors, soundproofing should be ≥ 30 dB (ABNT 2013a). Therefore, the LSF walls (Table 1) 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 met the requirements of the *PBE Edifica* labeling with regard to thermal transmittance, thermal capacity, natural ventilation and natural lighting, according to Table 3.

Table 3 - Final analysis of the classification of the Housing Unit (HU) 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 ifartificiallycooled	5.00	A
Bonuses	1.03	-
Region/Location	-	South
Coefficient a	0.65	-
FinalHU 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, including the use of the two showers at the same time, being complemented by electric heating.

3.2 Sustainable Sites (SS)

In SS all four prerequisites were met, the first requires erosion control, sedimentation and dust in the work, the second requires the use of adequate bioclimatic guidance for the implantation site, the third, the non-use of invasive plants. and the fourth requires that the land has infrastructure with water supply and sewage treatment, already existing in the condominium.

Regarding the prerequisite of Bioclimatic Architecture Guidelines, Brazilian bioclimatic zoning is defined through NBR 15220-3 (ABNT, 2005b), 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 windows of the living room are directed 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. Therefore, this score was not obtained, and it was necessary to analyze credits 2 to 5. 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 and there is a retreat of five meters in front of the lot to the sidewalk, which must not receive any walls or closures. 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. As the lot underwent grounding, the native vegetation would not be transplanted on site.On credit 5 (Proximity to community resources and public transportation), the busstop 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 in this credit.

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) was not analyzed. Nor was analyze credit 8 (Landscaping), due to the landscape design not being finished.

For credit 9 (Heat Island Reduction) the areas listed in Table 2 and the Equation 1 were used. The calculation follows below, according to equation 2. It was possible to reach two points in this credit.

$$\frac{70.7}{0.5}+\frac{181.43}{0.75}+\frac{0}{0.5}\geq 70.7+(181.43-32.47-6.10)=\ 383.27m^2\geq 213.56\mathrm{m}^2 \quad (2)$$

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 with retention time of at least 24h.

3.3 Water Efficiency (WE)

The project is in accordance with all the requirements of 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 hydrosanitary 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.

3.4 Energy and Atmosphere (EA)

In EA, the project met all the prerequisites, as it met the requirements of the *PBE Edifica*labeling with regard to thermal transmittance, thermal capacity, natural ventilation and natural lighting. In addition to the specification that the residence will be delivered with the lamps and luminaires installed, and at least 80% of the points of light will have the *Procel* seal.

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 3).

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 and the use of presence sensors and photocells in external lamps, two points are achieved in this. With the use of at least 80% of appliances with Procel labelwithclassification “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. The surplus produced returns to the local electricity concessionaire and generates credits in the energy bill. However, credit 8 (Commissioning of Installed Systems) does not apply, because the residence did not start construction, and this research turns only to the potential application of LEED for Homes certification. 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.

3.5 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 residuesgenerated are classified according to their characteristics of dangerousness established by the NBR 10,004 standard (ABNT, 2004) in Table 4.

Table 4 Solid waste generated and its classification of dangerousness

Classification (ABNT, 2004)	Waste
Class I D – Dangerous	Inkandsolventsludge.
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) requires the use of legalized wood in the construction of the enterprise, which is acquired from registered timber, and that it can be reused in other works. 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, with a 20-year warranty and anti-termite protection. As for the sidings of the work, these will not be wood, but recycled plastic material, environmentally certified and legalized.

On credit 1 (Construction Waste Management) it would be possible to obtain three points, the Waste Management Plan is in accordance with Brazilian standards (CONAMA 2002) 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 CO_2 emissions and extracting non-renewable natural resources. According to Table 5, 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 5 Classification of materials used in the HU

Classification	% / total cost of materials	% requiredby 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 (Dismountability 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. Because the fixing of the metal structure and the plates are made through screws, which makes the whole structure dismountable.

In the analysis for credit 6.2 (Demontability 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, such as coatings of the internal and external walls, since they are elements screwed to the metal structure. The internal and external seals are composed of reusable and removable partitions. The PVC frames are fixed through screws, and the liners are in plaster, fully removable.

3.6 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 (Lumine Performance) were not met, because it was not possible to perform the software simulation of the energy and luminic 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 bathrooms, with slope of the floor for sewage collectors and moisture resistant gypsum boards. Credit 5 (Protection of Pollutants From the Garage) requires carbon monoxide detectors if the garage is closed, however the garage gate will be leaked aluminum grid, allowing the constant exchange of air from the site, being possible to obtain a point in that credit.

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.

3.7 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, in an explanatory meeting, 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).

3.8 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 air conditioning projects, hydrosanitary installations, electrical and automation installations, integrated projects and planning for the execution of the work, prepared by professional architects or competent engineers.

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, cement and other materials, construction time, noise generated, the amount of material transport trips, influence of truck weight and fuel consumption, reduction of CO_2 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.

3.9 Regional Priorities (RP)

Credit 3 (Regional - South Priorities) for the southern part of the country requires obtaining the following credits, according to Table 6.

Table 6–Topics required by RP Credit 3 and achieved by the survey

Topics required by RP Credit 3	Achieved
SS Credit 5 - Proximity to community resources and public transport	Yes
SS Credit 9 -Heat Island reduction	Yes
SS Credit 10 - Rainwater control and management	Yes
WE Credit 2 - Sectorized measurement of water consumption	No
EA Credit 3 - Improved wrap performance	Yes
EA Credit 4 - Efficient sources of solar heating	Yes
EA Credit 7 - Renewable Energy	Yes
MR Credit 2 - Certified wood	Yes

As seven credits were reached, the residence could obtain a point, if it had reached the credit of Sectorized Measurement of water consumption, the building could receive two points.

3.10 Total score and suggestions for improvements

All the mandatory items of the eight topics evaluated were reached, and the score obtained from the non-mandatory parameters is shown in Table 7.

Table 7 - 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	54.55

The final residency score at LEED for Homes would be 60 points overall, which would classify it as GBC Gold Home. As the project did not go through energy efficiency simulation software, there was a loss of at least 16 points in the evaluation, which demonstrates its importance in the analysis of certification. The classification could be Platinum, if in addition to computer simulation, some modifications were made to the project, such as:

- Implementation in an environmentally certified neighborhood,
- Implementation close to communities with previous development,
- Have a plan to preserve the surrounding vegetation,
- Have landscaping project with regional vegetation,
- Have sectorized measurement of water consumption,
- Possess capture and use of rainwater for non-drinking consumption,
- Have efficient irrigation systems in the gardens,
- Have a water safety plan, which provides an action plan to minimize the health risks of residents,
- The benefits and innovations generated by the construction system in LSF were analyzed.

For the HU evaluated, because it has less than 300m² of built area, the investment required for its certification would be 4,000 reais (GBC Brasil 2017a, 2017b). This, if it were certified through GBC Brazil members, otherwise there would be a 20% increase in values.

The construction method in LSF showed several advantages, such as the use of certified materials, where maximum use was 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 industrialized constructive method need operators trained with courses.

4. Discussion

According to Pai and Elzarka (2021) the two main options to reduce the energy consumption of a building are through operational energy, such as lighting, heating and cooling and incorporated energy, that is, that consumed in the manufacture of construction materials. For Roque et al. (2021), the LSF system is promising in terms of internal thermal comfort of buildings, required by the European energy performance directives. 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.

Lee (2019) analyzed the performance of LEED-certified households based on the differences observed by users, and found that the greatest improvements were temperature, air quality and humidity. 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 CO_2 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.

According to Rosado et al. (2019), municipalities should invest in sorting at construction sites, improving the quality of recovered materials and increasing recycling. 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.

Not only the system in LSF, but other systems can be sustainable, as is the case of steel-bamboo, analyzed by Zhang et al. (2021b), where the results showed that CO_2 emissions during the life cycle of this construction system were lower when compared to emissions from an armed concrete structure in China. The same was analyzed by Du et al. (2019), which stated that prefabricated buildings emitted 18% less CO_2 than conventional buildings.

Wang et al. (2021) states that environmental degradation and the absence of green spaces affects people's mental health and that physically ill people living in places without green spaces are more prone to mental health problems. 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.

However, although widely applied around the world, LEED certification, according to Suzer (2015), still needs more flexible considerations regarding local priorities and system customization possibilities. Another factor is that, in general, the economic benefits of valuing LEED certified properties compared to non-certified properties cannot be confirmed, according to Stanley and Wang (2017). According to Pai and Elzarka (2021), construction professionals still understand the requirements of certification and life cycle evaluation as complex and time-consuming.

However, it is not enough to raise the awareness of professionals and users for the use of more sustainable construction systems, environmental and building legislation has a strong impact on the construction industry. As has been done in the European Union, where building legislation is giving priority to targets for mitigating environmental impacts, saving energy and reducing greenhouse gas emissionsaccording to Zhang et al. (2021a).

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, modular coordination, rationalization and standardization of the system that occurs on the assembly line.

5. Conclusion

The house analyzed has great potential to receive the Seal A of *PBE Edifica* and to be evaluated by LEED for Homes certification, receiving the Gold seal, or from the realization of the suggestions proposed, obtain a better classification. The analysis of the project by energy efficiency simulation software could provide 16 points in the evaluation, which demonstrates its importance in the analysis of certification.

Environmental certifications require more practical applications 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 application of simulation by energy efficiency software, analysis with other material compositions, comparison between construction systems and analysis of residence after construction, evaluating its sustainability and the benefits observed by users.

Declarations

Gratitude to the architects of the project, Alex Sandro Kuhn and Matheus Luz da Costa.

References

1. ABNT.Associação Brasileira De Normas Técnicas (2004)NBR 10.004, Resíduos Sólidos: Classificação.
2. ___ (2005a) NBR 15.220-2, Desempenho térmico de edificações. Métodos de cálculo da transmitância térmica, da capacidade térmica, do atraso térmico e do fator de calor solar de elementos e componentes de edificações.
3. ___ (2005b) NBR 15220-3, Desempenho térmico de edificações. Zoneamento bioclimático brasileiro e diretrizes construtivas para habitações unifamiliares de interesse social.
4. ___ (2013a) NBR 15575-4, Edificações Habitacionais. Desempenho. Sistemas de vedações verticais e externas.
5. ___ (2013b) NBR 15575-5, Edificações Habitacionais. Desempenho. Requisitos para os sistemas de cobertura.
6. CB3E.Centro Brasileiro De Eficiência Energética Em Edificações (2013) Estado da arte em eficiência energética: iluminação e envoltória. Florianópolis.
7. Chi B, Lu W, Ye M, Bao Z, Zhang X (2020) Construction waste minimization in green building: a comparative analysis of Leed-nc 2009 certified projects in the US and China. Journal Of Cleaner Production. 256:120749.http://dx.doi.org/10.1016/j.jclepro.2020.120749.
8. CONAMA. Conselho Nacional Do Meio Ambiente(2002), Resolução nº 307, de 5 de julho de 2002. Estabelece diretrizes, critérios e procedimentospara a gestão dos resíduos da construção civil. DOU. 6:95-96.
9. Du Q, Bao T, Li Y, Huang Y, Shao L (2019)Impact of prefabrication technology on the cradle-to-site CO2 emissions of residential buildings. Clean Technologies And Environmental Policy. 21:1499-1514. http://dx.doi.org/10.1007/s10098-019-01723-y.
10. Fezi BA (2020) Health Engaged Architecture In The Context Of COVID-19. Journal Of Green Building. 15:185-212. http://dx.doi.org/10.3992/1943-4618.15.2.185.

11. Gomes AP, Souza HAD, Tribess A (2013)Impact Of Thermal Bridging On The Performance Of Buildings Using Light Steel Framing In Brazil. Applied Thermal Engineering. 52:84-89. http://dx.doi.org/10.1016/j.applthermaleng.2012.11.015.
12. GBC Brasil. Green Building Council Brasil (2017a) Guia Rápido para a Certificação Green Building Council Brasil Casa®. 119p.
13. ___ (2017b) Guia Prático para a Certificação Green Building Council Brasil Casa®, 15 p.
14. Gurgulino J, Saraiva R, Tatiana M (2017)Light steel framing and structural concrete walls: sustainable perspectives for affordable housing. European Journal Of Sustainable Development.6:1-8. http://dx.doi.org/10.14207/ejsd.2017.v6n3p483.
15. Hoang NH, Ishigaki T, Kubota R, Tong TK, Nguyen TT, Nguyen H G, Yamada M, Kawamoto K (2020)Waste generation, composition, and handling in building-related construction and demolition in Hanoi, Vietnam. Waste Management. 117:32-41. http://dx.doi.org/10.1016/j.wasman.2020.08.006.
16. INMETRO.Instituto Nacional De Metrologia, Normalização E Qualidade Industrial (2012)Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edificações Residenciais, RTQ-R.
17. ___ (2015)Manual A 4.7. Diretrizes para obtenção de classificação nível A para edificações residenciais – Zona bioclimática 2.Versão 1.
18. IEA. International Energy Agency (2021)Energy Atlas.http://energyatlas.iea.org/#!/tellmap/-1002896040Accessed 14 June 2021.
19. Jiang B, Song Y, Li HX, Lau SS, Lei Q (2020) Incorporating biophilic criteria into green building rating tools: case study of green mark and Leed. Environmental Impact Assessment Review. 82:106380.http://dx.doi.org/10.1016/j.eiar.2020.106380
20. Lederer J,Gassner A,Fellner J,Mollay U,Schremmer C (2021) Raw materials consumption and demolition waste generation of the urban building sector 2016–2050: a scenario-based material flow analysis of vienna. Journal Of Cleaner Production. 288:125566. http://dx.doi.org/10.1016/j.jclepro.2020.125566.
21. Lee E (2019) Indoor environmental quality (IEQ) of LEED-certified home: importance-performance analysis (ipa). Building And Environment. 149:571-581.http://dx.doi.org/10.1016/j.buildenv.2018.12.038.
22. Li Y, Rong Y, Ahmad UM, Wang X,Zuo J, Mao G (2021)A comprehensive review on green buildings research: bibliometric analysis during 1998:2018. Environmental Science And Pollution Research.http://dx.doi.org/10.1007/s11356-021-12739-7.
23. Lima L, Trindade E, Alencar L, Alencar M, Silva L (2021)Sustainability in the construction industry: a systematic review of the literature. Journal Of Cleaner Production.http://dx.doi.org/10.1016/j.jclepro.2020.125730.
24. MME. Ministério De Minas E Energia (2021)Balanço Energético Nacional. RelatórioSíntese: Ano base 2020.

25. Pai V,ElzarkaH (2021) Whole building life cycle assessment for buildings: a case study on how to achieve the Leed credit. Journal Of Cleaner Production. 297:126501. http://dx.doi.org/10.1016/j.jclepro.2021.126501.
26. Petrovic B,Myhren JA, Zhang X,Wallhagen M, Eriksson O (2019) Life Cycle Assessment of Building Materials for a Single-family House in Sweden. Energy Procedia.http://dx.doi.org/10.1016/j.egypro.2019.01.913.
27. Roque E, Vicente R, Almeida RMSF (2021)Opportunities of Light Steel Framing towards thermal comfort in southern European climates: long-term monitoring and comparison with the heavyweight construction. Building And Environment. 200:107937. http://dx.doi.org/10.1016/j.buildenv.2021.107937.
28. Rosado LP, Vitale P, Penteado CSG, Arena U (2019) Life cycle assessment of construction and demolition waste management in a large area of São Paulo State, Brazil. Waste Management. 85:477-489. http://dx.doi.org/10.1016/j.wasman.2019.01.011.
29. Song SY, Yeo MS, Koo BK, Lee SJ (2011) Energy Efficiency Analysis of Internally and Externally Insulated Apartment Buildings. Journal Of Asian Architecture And Building Engineering. 10:453-459.http://dx.doi.org/10.3130/jaabe.10.453.
30. Stanley J, Wang Y (2017) An Analysis of LEED Certification and Rent Effects in Existing U.S. Office Buildings. Energy Efficiency And The Future Of Real Estate. http://dx.doi.org/10.1057/978-1-137-57446-6_6.
31. Suzer O (2015) A comparative review of environmental concern prioritization: leed vs other major certification systems. Journal Of Environmental Management.http://dx.doi.org/10.1016/j.jenvman.2015.02.029.
32. Tavares V, Soares N, Raposo N, Marques P, Freire F (2021)Prefabricated versus conventional construction: comparing life-cycle impacts of alternative structural materials. Journal Of Building Engineering. 41:102705. http://dx.doi.org/10.1016/j.jobe.2021.102705.
33. UNEP - United Nations Environment Programme(2020) Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.
34. Veljkovic M, Johansson B (2006) Light steel framing for residential buildings. Thin-Walled Structures. 44:1272-1279. http://dx.doi.org/10.1016/j.tws.2007.01.006.
35. Wang L, Zhou Y, Wang F, Ding L, Love PED, Li S (2021) The Influence of the Built Environment on People's Mental Health: an empirical classification of causal factors. Sustainable Cities And Society. http://dx.doi.org/10.1016/j.scs.2021.103185.
36. Worden K, Hazer M, Pyke, C, Trowbridge, M (2020) Using LEED green rating systems to promote population health. Building And Environment. 172:106550. http://dx.doi.org/10.1016/j.buildenv.2019.106550.
37. Yu S, Liu Y, Wang D,Bahaj AS, Wu Y, Liu, J (2021)Review of thermal and environmental performance of prefabricated buildings: implications to emission reductions in China. Renewable And Sustainable Energy Reviews. 137:110472. http://dx.doi.org/10.1016/j.rser.2020.110472.

38. Zhang C, Hu M,LaclauB,Garnesson T, Yang X,Tukker A (2021a)Energy-carbon-investment payback analysis of prefabricated envelope-cladding system for building energy renovation: cases in Spain, the Netherlands, and Sweden. Renewable And Sustainable Energy Reviews. http://dx.doi.org/10.1016/j.rser.2021.111077.
39. Zhang X, Xu J, Zhang X, Li Y (2021b) Life cycle carbon emission reduction potential of a new steel-bamboo composite frame structure for residential houses. Journal Of Building Engineering. 39:102295. http://dx.doi.org/10.1016/j.jobe.2021.102295.

Figures

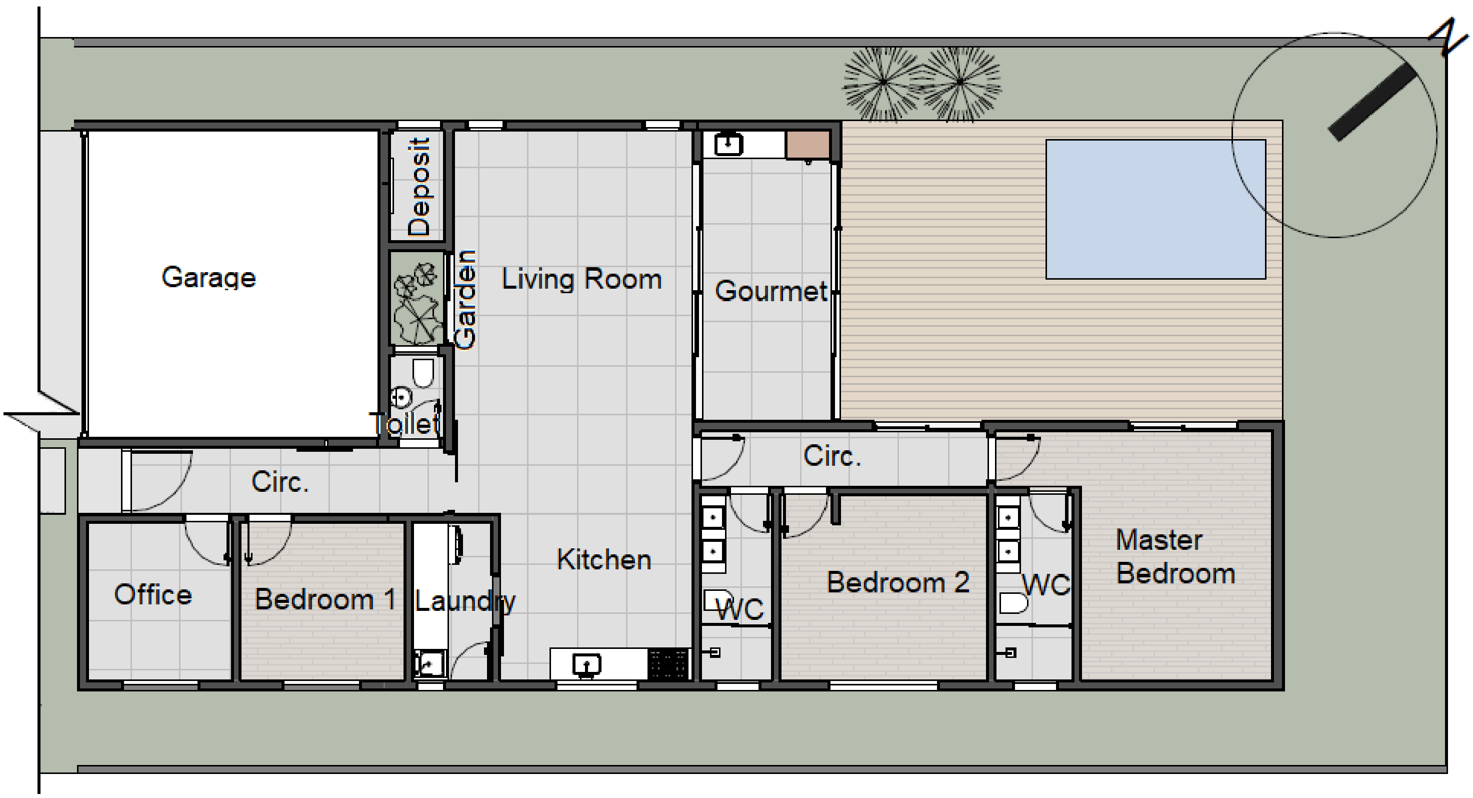

Figure 1

The house floor plan in LSF

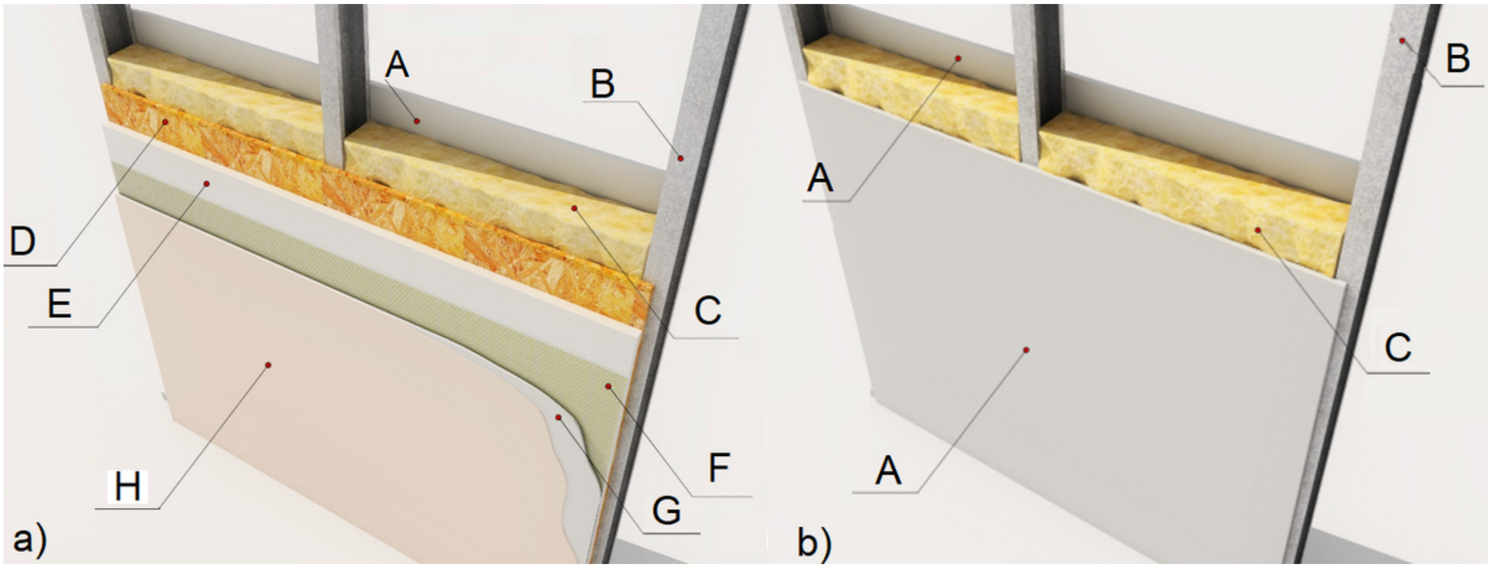

Figure 2

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.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GraphicalAbstract.docx