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Energy Feasibility with Bim of a Multifamily Building in Juliaca-Peru

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Abstract **-** This study investigates the energy feasibility of a multifamily building in Juliaca, Peru, using the Building Information Modeling (BIM) methodology. Given that construction in the year 2020 contributed to 38% of CO2 emissions related to energy, it is crucial to address environmental impacts at all stages of the construction process. This study seeks to offer an accessible and sustainable solution by applying Spanish regulations and BIM methodology in its sixth dimension. Simulation is employed as an operational research technique, following the BIM workflow and parameters of the Method of Energy Certification Managed BIM (MECM-BIM). The results reveal that by defining the characteristics of the sixth BIM dimension for the multifamily building in Juliaca, Peru, a solid foundation for energy assessment is established, allowing for a comprehensive and detailed view of the multidisciplinary aspects of the building. Additionally, the design of the energy model represents a significant advancement towards the implementation of passive construction strategies, facilitating the identification of areas for improvement and optimization. Overall, these results confirm the energy feasibility of the multifamily building in Juliaca, Peru, using BIM methodology. It is concluded that the application of Spanish regulations and BIM methodology in construction projects in Juliaca, Peru, can lead to significant improvements in energy efficiency and sustainability of buildings, thereby contributing to the mitigation of environmental impact associated with the construction industry.

Keywords**:** Energy feasibility, BIM (Building Information Modeling), MECM-BIM (Method of Energy Certification Managed BIM), Energy Efficiency.

1. Introduction

The construction industry faces significant challenges amidst growing concern over climate change and its global impacts. According to [1], construction is one of the main sources of environmental pollution, contributing to 38% of global CO2 emissions. In Peru, studies by [2] highlight that the sector accounts for at least 40% of greenhouse gas (GHG) emissions. Juliaca, located in the Andean region of Peru and characterized by extreme climatic conditions, presents a scenario that demands sustainable solutions in construction.

This study focuses on sustainable construction in Juliaca, proposing an alternative through a passive multifamily building. The objective is to develop a model that combines interior comfort with low energy consumption and care for the envelope and ventilation. Spanish regulations on energy efficiency will be adopted as a reference, aligning with the United Nations Sustainable Development Goals (SDGs) [3] to improve energy efficiency and promote more sustainable development in the region.

2. Metodology

This study adopts a mixed methodological approach to comprehensively address the research questions posed. Following the guidelines proposed by [4], quantitative and qualitative methods are integrated to obtain a complete understanding of the phenomenon studied.

The research design is quasi-experimental, supported by the perspective of [5], [6], which allows examining causal relationships in naturally complex environments. The main simulation is based on the Managed Energy Certification Method

BIM (MECM-BIM) of [7], ensuring a comprehensive evaluation of the variables under study. Shown in Fig.1.

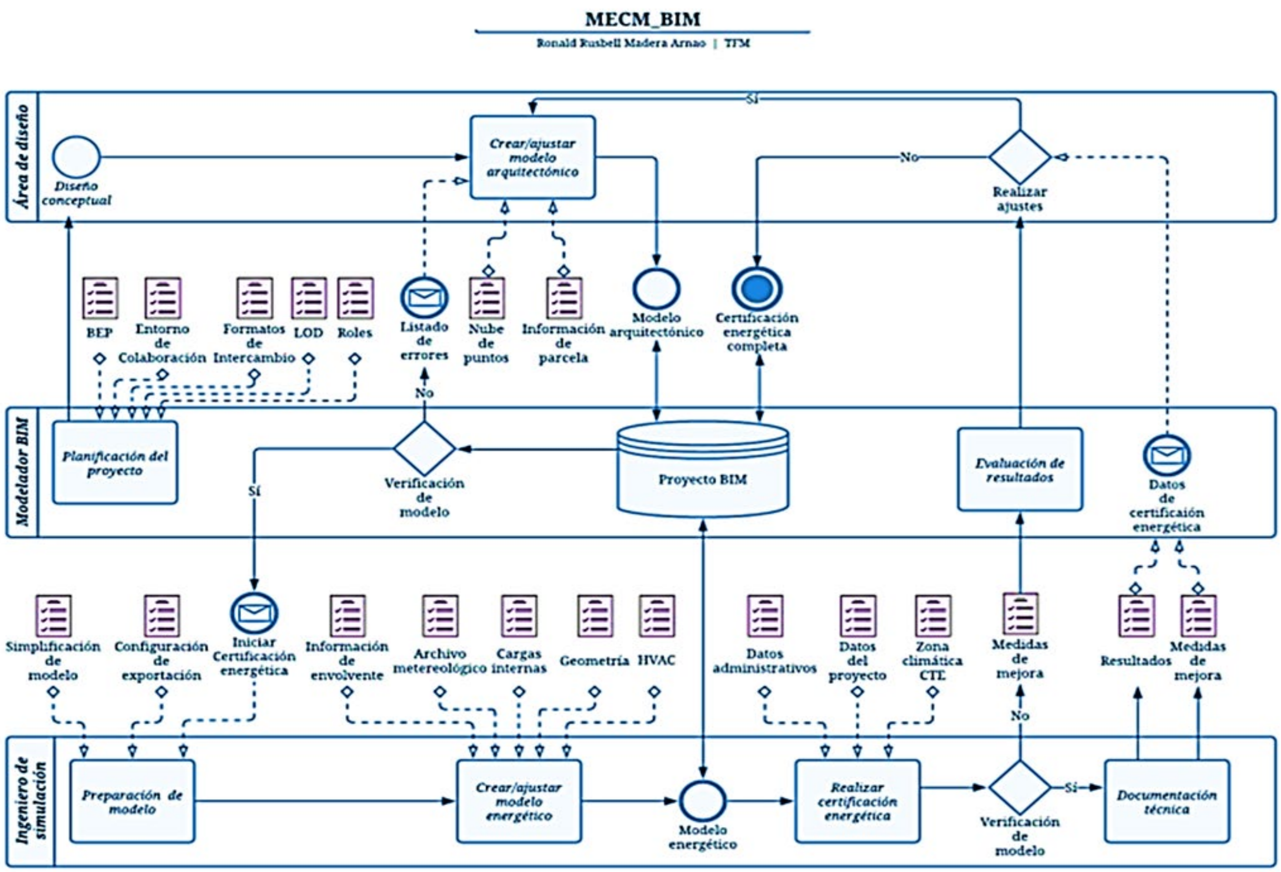

Fig. 1: Managed energy certification method MECM_BIM

The methodological process is developed through a BIM workflow, following the parameters established by [7]. A multifamily building is modeled in a BIM software with IFC scheme to ensure interoperability.

2.1. Testing and Evaluation

The tests are divided into two stages. In the first, the traditional construction process in the buildings of Juliaca is evaluated, identifying condensations in the construction elements and looking for adequate corrections. In the second test, the construction process is considered according to the Spanish CTE standard [8], using insulating materials such as polyurethane (PUR) and verifying that condensations comply with the ISO 13788 standard [9].

2.2. Building Energy Rating

The annual energy consumption and solar control of the thermal envelope are calculated using specific equations. The compliance with CTE HE0 and HE1 regulations [8] is evaluated, allowing the calculation of the building's viability in terms of CO_2 emissions, non-renewable primary energy consumption, heating demand and cooling demand.

3. 3. Results

3.1. Building Characteristics

The multifamily building consists of six floors and a rooftop, with a Level of Necessary Information (LOIN) of 3, according to the BIM Peru Plan [10], defined by the Level of Detail (LOD) and the Level of Information (LOI) according to BIMForum [11]. The aim of the study is to develop a passive building in Juliaca (Peru) that can provide heating and cooling with minimal energy demand, combining interior comfort with low energy consumption and optimal care of the building envelope and a controlled ventilation system. Figure 2 presents the case study.

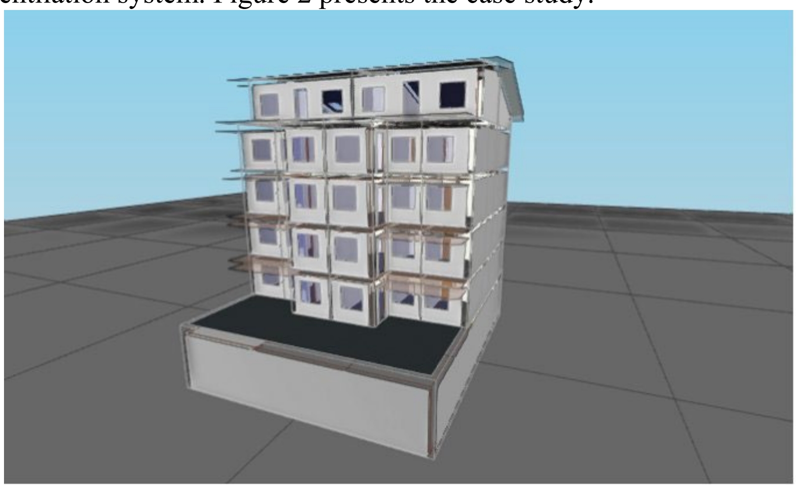

Fig. 2: Case study_BIM server. center

3.2. General Parameters

The building characteristics modeled and the general location parameters, obtained in EPW format from [12], are detailed in Tables 1 and 2, respectively.

Table 1: Modeled building characteristics.

Criterion	Value
Type of building	Multifamily housing
City of location	Juliaca
Level of detail (LOD)	3
Level of Information (LOI)	3
Level of Information (LOI)	3
BIM Softwares	IFC Builder – Cypetherm HE
BIM role to be fulfilled	Energy efficiency as a sustainability criterion (sixth BIM dimension)

Table 2: General parameters

Location	
Municipality	Juliaca
Province	San Román
Altitude	3824.000 m
Longitude	-70.1 grados
Time zone	-5.0

A comparison of the climate data obtained from CYPETHERM HE and SENAMHI was made, showing similarities in maximum and minimum temperatures. Figures 3 and 4 show the temperatures and Figures 5 and 6 show the radiation in Juliaca according to CYPETHERM HE and SENAMHI, respectively. This indicates that the data obtained by CYPETHERM HE are reliable, so we can continue with the study.

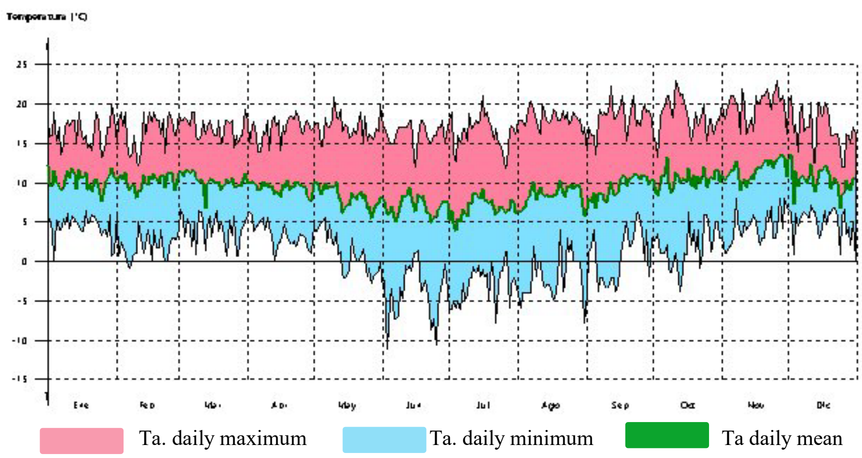

Fig. 3: Temperature in Juliaca, CYPETHERM HE

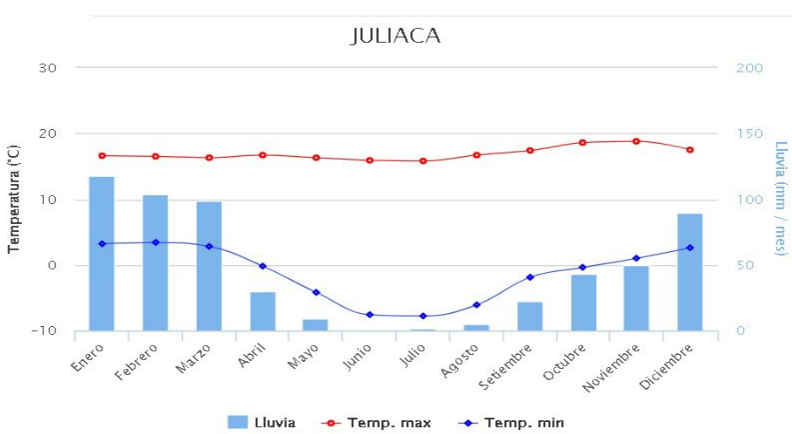

Fig. 4: Temperature in Juliaca, SENAMHI

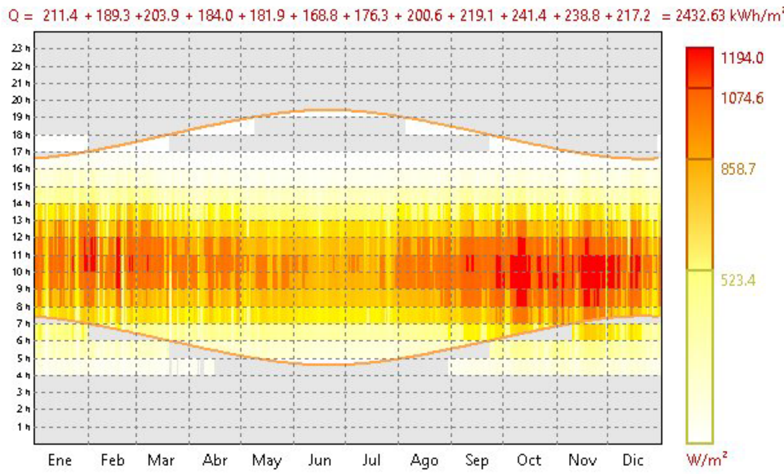

Fig. 5: Radiation in Juliaca, CYPETHERM HE

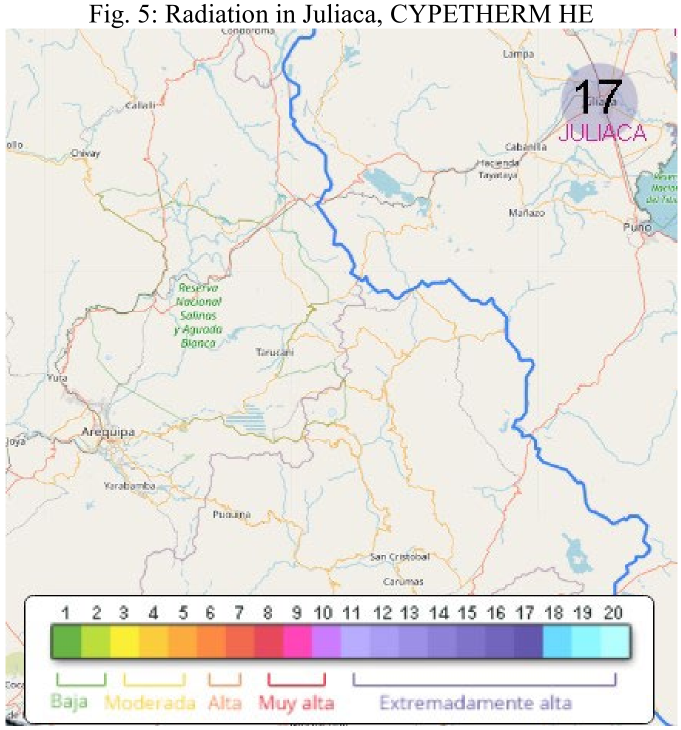

Fig. 6: Radiation in Juliaca, SENAMHI

3.3. Energy efficiency test results

Test 1:

When verifying the model under CTE guidelines, condensation was detected in various construction elements, as shown in Figure 7.

1	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z02_S01_W03)
2	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z02_S04_W06)
3	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z02_S05_W04)
4	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z02_S06_W03)
5	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z02_S06_W04)
6	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z02_S08_W05)
7	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z03_S01_W04)
8	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z03_S04_W03)
9	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z03_S05_W05)
10	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z03_S06_W04)
11	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z03_S06_W05)
12	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z03_S08_W04)
13	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z04_S01_W03)
14	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z04_S04_W06)
15	⊗	Condensaciones	En este elemento constructivo se producen condensaciones (Z04_S05_W04)

Fig. 7: Test 1 results

Using the ISO 13788 standard, the interior surface resistance factors (f_Rsi) were calculated, using Eqs. 1, to determine the presence of surface condensation. The results, presented in Table 5, indicate that the building envelope does not prevent condensation, which affects the energy certification.

Table 5: Surface condensations test 1

BUILDING SURFACE CONDENSATION

Parameter	f_{Rsi}	$f_{Rsi, min}$	Complies (Yes or No)
Dwelling 1A,1B,2A,2B,3A, 3B, 4A	0.433	0.760	No
Rooftop	0.438	0.760	No

Test 2:

It was decided to apply polyurethane rigid foam insulation (PUR) according to the Spanish CTE standard. After simulating the model with this material, it was verified that the condensations comply with the ISO 13788 standard, as shown in Table 6, indicating a significant improvement in the energy efficiency of the building.

Table 6: Surface condensation of the building with (PUR)

BUILDING SURFACE CONDENSATION

Parameter	f_{Rsi}	$f_{Rsi, min}$	Complies (Yes or No)
Dwelling 1A,1B,2A,2B,3A, 3B, 4A	0.788	0.760	Yes
Rooftop	0.935	0.760	Yes

3.4. Energy rating of the building

The test results support the compliance with the requirements of the CTE HE0 and HE1 standards. According to Eqs. (2) - (3), the non-renewable and total primary energy consumption of the building is below the established limits.

$$\boldsymbol{C_{ep,nren} \geq C_{ep,nren,lim} \approx 36.31 \frac{kWh}{m^2}.a\tilde{n}o \geq 38.00 \frac{kWh}{m^2}.a\tilde{n}o} \tag{2}$$

$$\boldsymbol{C_{ep,tot} \geq C_{ep,tot,lim} \approx 75.28 \frac{kWh}{m^2}.a\tilde{n}o \geq 76.00 \frac{kWh}{m^2}.a\tilde{n}o} \tag{3}$$

Furthermore, Eqs. (4) confirms that the solar control of the thermal envelope is within acceptable parameters.

$$\boldsymbol{q_{sol,jul} = 0.96 \frac{kWh}{m^2} \leq q_{sol,jul\_lim} = 2.00 \frac{kWh}{m^2}} \tag{4}$$

Regarding the energy rating of the building, the requirements of the CTE HE0 standard were met in terms of non-renewable and total primary energy consumption. In addition, it complied with the solar control conditions of the thermal envelope as established in the HE1 regulation.

These results indicate that the building complies with the energy efficiency standards established by Spanish regulations, which supports its design as a passive building in the city of Juliaca.

4. Discussion and Conclusions

4.1. Discussion

In the international context, several studies have addressed energy efficiency in passive buildings, highlighting significant reductions in CO2 emissions and energy costs. For instance, [13] and [14] in Spain reported a 40% reduction in CO2 emissions and 35-40% savings in energy costs. Our research demonstrates reliable results of 6.15 kg CO2/m² per year, represented on a color scale: green, indicating an optimal outcome. Additionally, Andersen et al. [15] analyzed energy management systems in commercial buildings, achieving a 25% decrease in total energy consumption. In contrast to these studies, our research evaluated a multifamily dwelling, obtaining an energy consumption of 36.31 kWh/m² per year, also represented on the color scale as an optimal outcome.

At the national level, studies in various regions of Peru have shown the effectiveness of specific strategies to enhance energy efficiency in buildings. For example, in Cusco, Flores et al. [16] prioritized bioclimatic design and renewable energies, while in Arequipa, Gómez et al. [17] focused on efficient air conditioning systems and passive strategies. Compared to these studies, our research highlights the potential efficiency of buildings in Juliaca by applying energy feasibility with BIM.

Some limitations were identified in the study, such as the possible change of regulations and standards over time, as well as the climatic diversity that may require different approaches. However, recognizing these limitations is crucial for an effective application of the findings in the field of energy efficiency in construction.

4.2. Conclusions

The conclusions drawn from this study are fundamental for understanding the impact and relevance of the results achieved in the context of energy efficiency in the construction of multifamily buildings.

Firstly, it is highlighted that defining the characteristics of the sixth BIM dimension for the multifamily building in Juliaca, Peru, has laid a solid foundation for energy evaluation. The integration of relevant data into the BIM model has allowed for a comprehensive and detailed view of the multidisciplinary aspects of the building, thus paving the way for an accurate assessment of its energy performance. This is reflected in the average value of CO2 emissions of 6.15 kg/m² year, which falls within optimal parameters according to international standards.

Furthermore, the design of the energy model represents a significant advancement towards the implementation of passive construction strategies in the region. The use of BIM technology has enabled the simulation and visualization of the building's energy performance in different scenarios, identifying areas for improvement and optimization. As a result, a considerable decrease in energy consumption has been achieved, with an estimate of 36.31 kWh/m² year, demonstrating the potential of the implemented strategies.

Regarding the overall objective of the study, it is positively confirmed that energy viability with BIM has been achieved for a multifamily building in Juliaca, Peru. These results not only have local implications but also contribute to advancing knowledge in the field of energy efficiency in construction at the national and international levels.

In summary, the conclusions drawn from this study support the importance of implementing technologies such as BIM in the evaluation and design of sustainable buildings. These findings provide a solid foundation for future research and professional practices in the field of energy efficiency, promoting the development of more sustainable and environmentally friendly buildings.

4.3. Recommendations

Considering the findings and limitations identified in this study, the following recommendations are proposed for future research and professional practices in the field of energy efficiency in construction:

Future Research: It is suggested that researchers continue to develop studies that expand the knowledge base established in this work. It is essential to further explore the implications of integrating technologies such as BIM in the evaluation and design of sustainable buildings, as well as to identify new opportunities to improve energy efficiency in both local and global contexts.

Promotion of Technologies: Governmental agencies and relevant entities are urged to promote the use of technologies such as MECM - BIM in the simulation and visualization of building energy performance. This promotion should include the dissemination of best practices and training in the proper use of these tools, with the aim of maximizing their impact on energy efficiency and resident well-being.

Practical Application: It is recommended to apply the results obtained in this study to the construction of buildings in Juliaca and other regions with similar climatic conditions. It is crucial that the simulations and analyses conducted are used to increase energy efficiency and housing comfort, contributing to the reduction of environmental impact and the development of more sustainable communities.

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