

# Análisis de viabilidad ambiental y de costos al implementar la certificación LEED: estudio de caso aplicado a un proyecto de Viviendas de Interés Social en Bogotá D.C.

## Environmental and cost feasibility analysis when implementing LEED certification: a case study applied to an affordable housing project in Bogota D.C.

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### Abstract

*This article presents the alternatives resulting from the analysis of environmental feasibility and its associated costs, based on the incorporation of the sustainable criteria determined by the LEED certification, for the development of a case study in affordable housing, in the city of Bogotá D.C. The methodology is based on the standards set by LEED BD+C Homes for the Design and Construction of Multifamily Midrise Buildings. A propositional study is developed through financial scenarios, in order to evaluate if these technologies in affordable housing are feasible from the investment perspective of builders in Colombia, considering that to this date the implementation of criteria that will lead to the LEED certification has not been applied to this type of projects. The findings allow us to distinguish barriers and opportunities from the prominent implications of the inclusion of these sustainable technologies in low-income housing.*

**Keywords:** Affordable housing, LEED certification, LEED BD+C Homes, net present value, cost effectiveness

### Resumen

Este artículo presenta las alternativas del análisis de viabilidad ambiental, y sus costos asociados, para el desarrollo de un proyecto de construcción de vivienda de interés social (VIS) ubicado en Bogotá, Colombia, que incorpora los criterios sostenibles determinados por la certificación LEED. La metodología de investigación se soporta en un estudio de caso basado en análisis sobre los estándares dispuestos por la certificación LEED BD+C Homes para el Diseño y Construcción de Viviendas Multifamiliares de Altura Media. Se desarrolla un estudio propositivo mediante escenarios financieros, con el fin de evaluar si estas tecnologías en VIS son factibles desde la óptica de la inversión de los constructores en Colombia, considerando que a la fecha no se han implementado medidas sostenibles con base en esta certificación y en este tipo de proyectos en el país. Las conclusiones permiten distinguir en general barreras y oportunidades de las implicaciones de la inclusión de tecnologías y procedimientos sostenibles en viviendas para personas de bajos ingresos.

**Palabras clave:** Vivienda de Interés Social (VIS), certificación LEED, LEED BD+C Homes, valor presente neto, rentabilidad

## 1. Introduction

The term social housing refers to the initiative implemented by public and private institutions to reduce the social disadvantages of individuals, thereby allowing them access to buy or rent low-cost housing to achieve a satisfactory quality of life and social growth (Boeri et al., 2011). In general, this type of homes are built with a considerably limited budget; consequently, the Colombian construction industry tends to believe that it is impossible to obtain a green seal certification. This research deals with this belief in this kind of projects, and analyzes the possibility of obtaining a certification from one of the main evaluation systems for green buildings, known as LEED (Leadership in Energy and Environmental Design).

The national government, as well as the agencies defining themselves as sustainable in Colombia (for example, the Colombian Green Building Council, CCCS in Spanish), are developing public policies and adopting sustainable aspects that can be applied to social and non-social housing, which are sometimes based on the criteria described in the LEED certification. Thus, this represents a contextual opportunity for this research.

Unlike the Colombian situation, many countries voluntarily apply green construction measures in social housing, especially European countries (Boeri et al., 2011). Therefore, it seems reasonable to establish the environmental and financial viability of including LEED criteria in this type of projects in the country. There are many opportunities for studying green building in this kind of constructions, among which we can highlight the possible development and advancement scenarios that the Colombian government has recently boosted, and the efforts that the CCCS has already made to improve the practices in the green housing environment. Consequently, the objective of the present work

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is to study sustainability parameters; specifically, the variations in environmental and financial issues based on LEED certification criteria, for a social housing project in Bogota, which can help apply these criteria on a wider scale in this city.

## 2. Description of the Case Study

The project considered in this study is a residential complex for relatively low-income persons, consisting in 384 apartments within an area of 7,623.19 m<sup>2</sup>, located in the south of Bogota. The complex has accesses for vehicles, pedestrians and people with disabilities, common areas for social meetings in multi-purpose rooms and open spaces, and parking lots. Figure 1 shows an internal visual of the project object of this study.



Figure 1. Interior view of the project

Considering that the apartment buildings have the same design and construction configuration, one of the external buildings was taken as a unit of analysis, as observed

in Figure 2, whose built area is 1,071.85 m<sup>2</sup>. The choice of the building was based on its greatest exposure to environmental factors, which makes it the most critical.



Figure 2. Location of the analyzed building

### 3. Methodology

Figure 3 illustrates the procedure for the case study analysis.

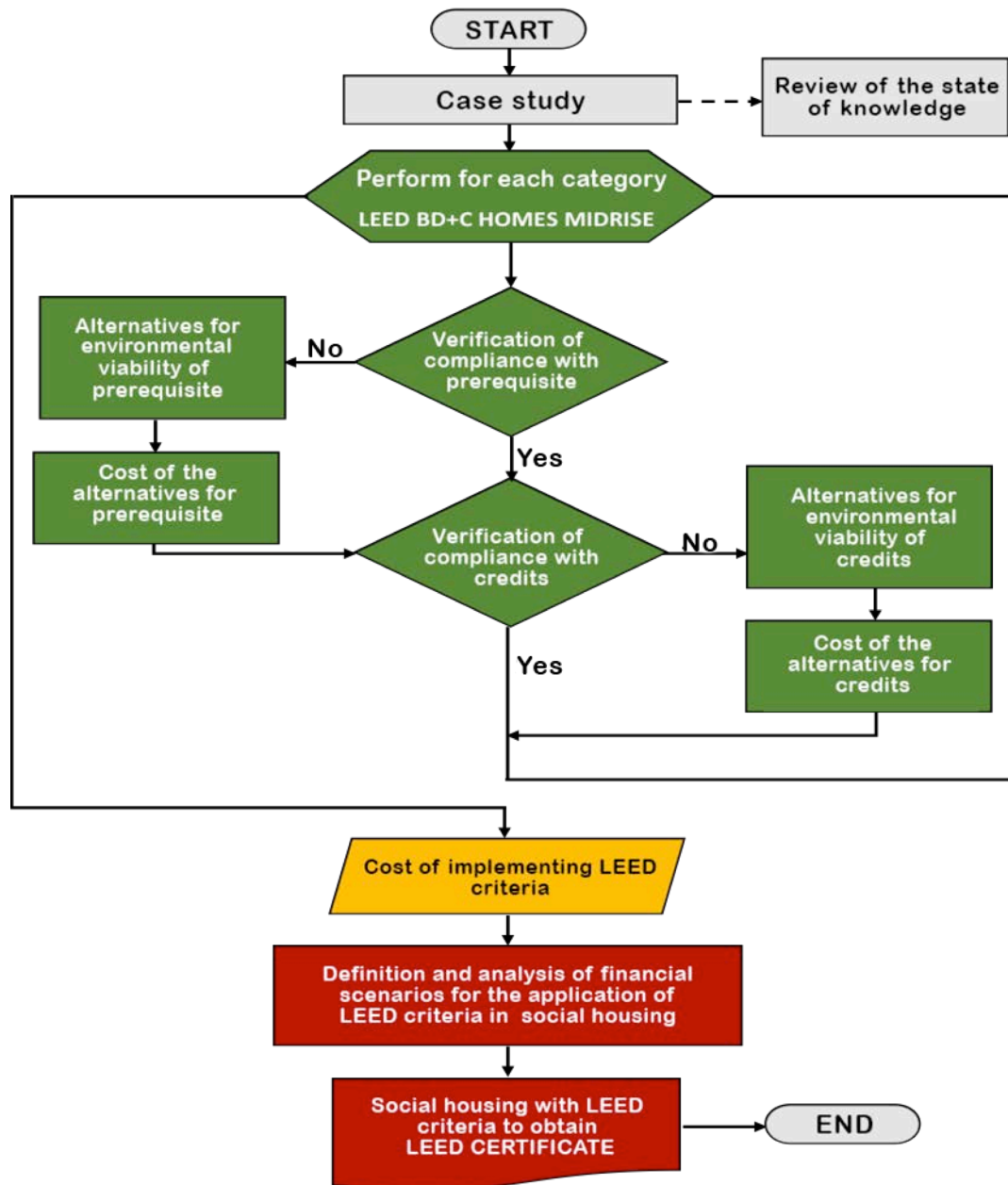


Figure 3. Procedure for the case study analysis

First, we studied the original conditions of the residential project, which was conceived without sustainability criteria, in order to identify these conditions in relation to each LEED certification category described below.

### **3.1 Integrative Process (IP)**

The purpose of the IP category is to integrate green design and construction strategies, with the collaboration of all areas involved in the project. This category awards 2 points.

### **3.2 Location and Transportation (L&T)**

The LT category rewards the project design in different areas that allow reducing the kilometers travelled by vehicle, encouraging the use of public transportation and improving the health of the residents by increasing the physical activity on a daily basis. This category awards 15 points maximum.

### **3.3 Sustainable Sites (SS)**

The purpose of the SS category is to enhance the choice of the sites where the projects seeking certification will be located. The location should emphasize the conservation of the ecosystems, the reduction of CO<sub>2</sub> emissions and the "heat island" effect, as well as the implementation of strategies to protect the environment. This category awards 7 points maximum.

### **3.4 Water Efficiency (WE)**

The WE category allows reducing the project's water demand by using high-efficiency fixtures (e.g., water-saving toilets) and efficient gardening practices (e.g., adequate irrigation methods). This category awards 12 points maximum.

### **3.5 Energy & Atmosphere (E&A)**

The E&A category defines strategies for reducing the energy consumption in the buildings. This category awards 37 points maximum.

### **3.6 Materials and Resources (M&R)**

The objective of the M&R category is to minimize the pollution caused by factors such as the final waste disposal during the construction stage. Likewise, it promotes the reuse

of demolition materials and the use of healthy raw materials. This category awards 9 points maximum.

### **3.7 Indoor Environmental Quality (IEQ)**

The IEQ category rewards the strategies adopted from the design stage, aimed at protecting the health of the residents by increasing their comfort, considering factors such as temperature, air and visibility. This category awards 18 points maximum.

### **3.8 Innovation (IN)**

The compliance with the IN category is not obligatory and its purpose is the implementation of construction techniques and strategies different from those established in the certification, which can improve the performance of the buildings. This category awards 6 points maximum.

### **3.9 Regional Priority (RP)**

The compliance with the RP category is not obligatory and rewards projects using green strategies within areas identified by the USGBC as "environmental priority areas". This category awards 4 points maximum.

In order to evaluate the categories mentioned above, each of the corresponding prerequisites and credits were analyzed, which are applicable for LEED BD+C Homes Design and Construction of Multifamily Midrise Buildings, according to the provisions stipulated in version V4.0, published in 2013 by the US Green Building Council (USGBC) (2017).

The minimum score for pursuing one of the LEED certification levels is the following: 40 points for LEED CERTIFIED, 50 points for LEED SILVER, 60 points for LEED GOLD, 80 points for LEED PLATINUM, where 110 points is the maximum possible score.

Furthermore, in order to calculate the water consumption in the WE category, the daily water use of each fixture installed in the analyzed building was modeled with the "Indoor Water Use Reduction Calculator" (2012) used for LEED V4.0, and the water use in the urban design for the E&A category was modeled with the "Water Budget Tool" of WaterSense (2014). Additionally, for calculating the energy consumptions, it was necessary to model the spaces and materials of the building's walls and floors with the eQUEST software (2016). Figure 4 shows a diagram of inputs and outputs for each modeling indicated above.



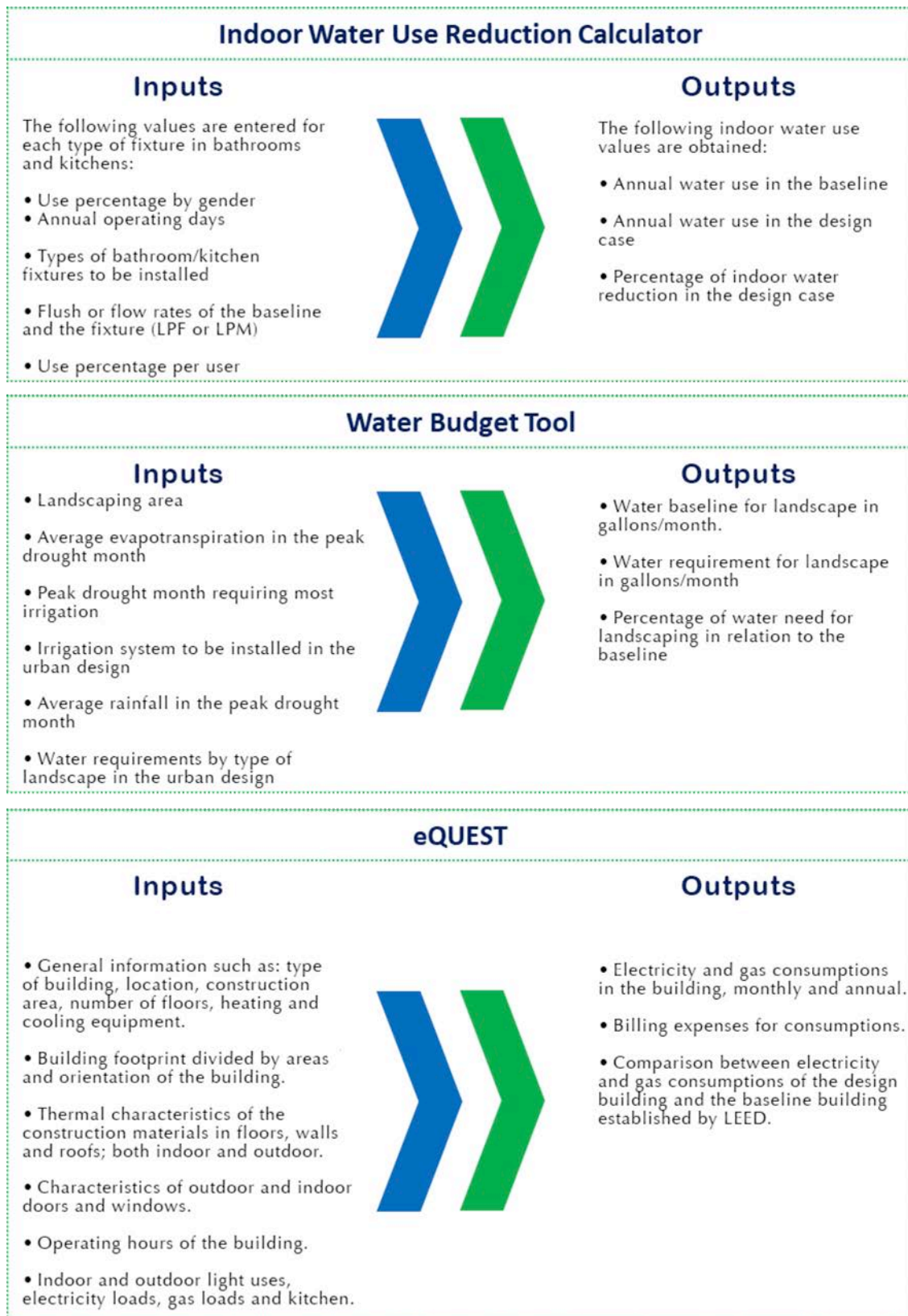


Figure 4. Diagram of inputs and outputs for the modeling of water and electricity consumptions

Then, we established the sustainable alternatives and performed a sensitivity analysis of the costs obtained in the project modified according to the implementation of the certification categories needed to achieve the score required for the LEED CERTIFIED level.

Finally, we envisaged scenarios considering LEED certification parameters that would keep financial return levels similar to those considered by the social housing building association. For each scenario, the return obtained when applying sustainable parameters was calculated and compared with the project's original return. Lastly, the investment cash flow analysis was performed, and the project return was calculated as a result of this flow, through the net present value (NPV) and the internal rate of return (IRR).

#### 4. Sustainability Diagnosis

Once the project's original conditions were analyzed, the baseline was identified based on the compliance with the LEED certification categories, and the points awarded for each category were calculated based on the original conditions involved in the construction of the studied building. First, the compliance with the prerequisites was analyzed and then, the compliance with the credits established for each category. Table 1 shows the number of prerequisites that fulfil the original conditions of the project, and Table 2 indicates the score obtained for the credits.

**Table 1.** Compliance with the prerequisites of the LEED BD+C Homes certification

CATEGORY	NUMBER OF PREREQUISITES IN THE CATEGORY	COMPLIES	DOES NOT COMPLY
L&T	1	1	0
SS	2	2	0
WE	1	1	0
E&A	3	1	2
M&R	2	0	2
IEQ	6	1	5

**Table 2.** Score obtained in the LEED BD+C Homes certification categories

	IP	L&T	SS	WE	E&A	M&R	IEQ	IN	RP
<b>Score obtained</b>	0	9	2	0	17	3,5	3	0	4

It is possible to observe that, among the 15 obligatory prerequisites, 6 comply and 9 do not comply with them. Additionally, the total score obtained as a baseline was 38.5

points, which is below the score required to obtain the LEED CERTIFIED level.

## 5. Study of Sustainable Alternatives and Associated Costs

The information resulting from the baseline was used to establish the construction variables that were liable to modifications and which allowed the compliance with the prerequisites and credits in each certification category to, at least, achieve the certification level. These alternatives

estimated a viable solution in terms of the financial return expected by the builder in the case study, without modifying the building's operating conditions nor the originally planned architectural design.

Table 3 describes the costs per building, associated to the implementation of the sustainable alternatives required to achieve the LEED CERTIFIED level, which were calculated based on the case study works budget and a market analysis in the city of Bogota

**Tabla 3.** Incremento económico por torre asociado a las alternativas para alcanzar el nivel de certificación LEED CERTIFICADO

<b>PREREQUISITE/CREDIT</b>	<b>ALTERNATIVE</b>	<b>COST INCREASE (COP)*</b>	<b>VAT<sup>1</sup> (COP)</b>
<b>IP Credit: Integrative Process</b>	Workshops for the design team and training for skilled occupations	1,377,778	-
<b>WE Credit: Total Water Use</b>	Installation of water-saving toilets, showers, and bathroom and kitchen sinks	5,253,466	1,232,294
<b>E&amp;A Prerequisite: Minimum Energy Efficiency</b>	Installation of occupancy sensors in parking lots and commissioning	4,161,337	7,066
<b>E&amp;A Prerequisite: Training of the Owner, Tenant or Administrator of the Building</b>	Creation of an operation and maintenance manual or CD of the building (includes prohibition of smoking in open spaces)	2,213,151	-
<b>IEQ Prerequisite: Cigarette smoke in the Environment</b>			
<b>M&amp;R Prerequisite: Certified Tropical Wood</b>	Installation of bathroom doors made of certified tropical wood	778,253	182,553
<b>M&amp;R Prerequisite: Durability Management</b>	Installation of floor drain and trap in the kitchen	378,384	88,757
<b>IEQ Prerequisite: Ventilation</b>	Installation of exhaust fan for bathroom and kitchen. Design prescribed for ventilation	11,658,197	1,443,287
<b>IEQ Prerequisite: Ventilation of Combustion</b>	Installation of CO monitor	3,171,059	325,584
<b>IEQ Prerequisite: Radon-resistant Construction</b>	Installation of ventilation skylight, vertical vent pipe and electrical outlet in the roof	241,661	54,039
<b>IEQ Prerequisite: Compartmentation</b>	Installation of door and window weatherstrips	1,217,592	285,608
<b>All categories</b>	Certification by USGBC	4,995,932	-
<b>SUBTOTAL</b>		<b>35,446,810</b>	<b>3,619,188</b>
<b>TOTAL</b>		<b>39,065,998</b>	

\*Costs correspond to constant values of 2017, in Colombian pesos



Considering the implementation of the alternatives proposed in Table 3, the cost increase per building is COP 35,446,810 and a VAT cost per building of COP 3,619,188, which add to a total of COP 39,065,998. This means a 5.5% increase per building in relation to the original cost.

Consequently, considering that the original cost per building is COP 714,994,201 and that of the m<sup>2</sup> of the original construction is COP 667,066, the implementation of the LEED certification would increase the cost per building to COP 754,060,199 and that of the construction m<sup>2</sup> would be COP 703,513, as shown in Figures 4 and 5.

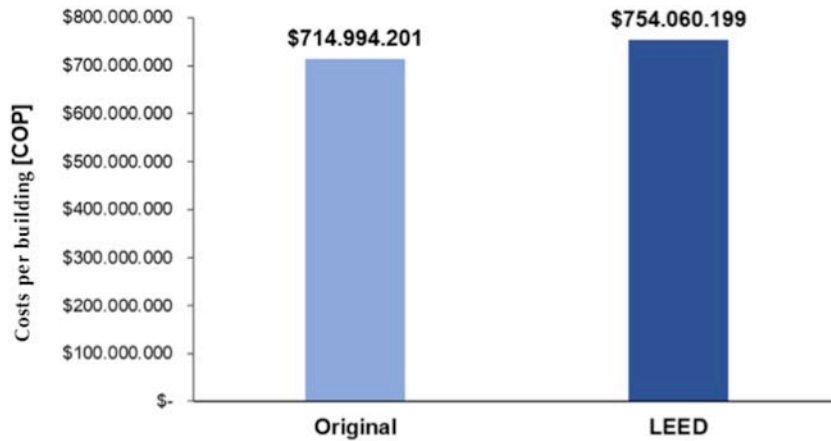


Figure 4. Costs per building obtained for the case study

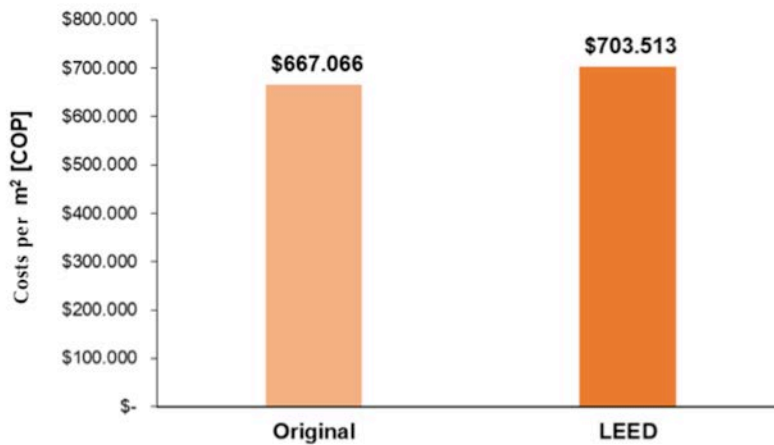


Figure 5. Costs per m<sup>2</sup> obtained for the case study



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### 5.1 Evaluation of the LEED score when implementing alternatives

After implementing the proposed alternatives, the resulting score was evaluated again according to the criteria applicable for LEED BD+C Homes Design and Construction of Multifamily Midrise Buildings V4.0 and, this time, the total score was 44.5 points. Consequently, if the construction of the analyzed building were to implement the proposed sustainable alternatives, the building would achieve the LEED CERTIFIED level.

## 6. Financial Assessment of the Scenarios

The financial analysis allowed identifying the possibilities for the builder to conceive a social housing project that includes green criteria based on the LEED certification. This analysis envisaged two stages: the construction and the use of the homes.

During the construction stage, three financial feasibility scenarios were analyzed: (i) VAT exemption for social housing construction materials; (ii) project development on flat lands; and (iii) the combination of developing the project on flat lands plus a VAT exemption in certain materials indicated below. Moreover, a flow cash analysis of the user was performed during the use stage of the homes, with the aim of calculating the operational cost differences between the original housing and the housing with LEED certification.

### 6.1 Construction Stage

#### 6.1.1 VAT exemption for social housing construction materials

The National Tax Authority of Colombia establishes the parameters for returning credit balances and the Decree 2924 of 2013 regulates the formality and proceeding for requiring a VAT refund related to social housing. The law stipulates that this refund may represent maximum 4% of the value registered in the deed of sale of the homes. Keeping in mind that the studied project originally had a VAT refund for materials such as concrete and steel, the possibility that the government gives a VAT exemption for materials not included in the original refund was analyzed, considering that it is a social housing project whose construction applies sustainable parameters.

Based on this analysis, it was determined that the VAT exemption for the rest of the materials would be COP 39,186,760, which allows covering the cost associated to the implementation of green alternatives stipulated in section 5 above. Consequently, if the rate of return of the original project is 12%, the rate of return would not be affected when implementing the LEED certification if the aforesaid exemption is applied.

#### 6.1.2 Project development on flat lands

This scenario considers the distribution of social housing residential plots in Bogota. Therefore, the information

reported by the UAEC (Special Administrative Unit of District Cadaster, 2017) was used to identify the locations where this type of constructions are concentrated. Additionally, each location was characterized according to the predominant topography, and the lands were parametrized as follows: flat (lands with slopes of less than 4 degrees, which require minimum earthmoving for the construction), undulating (lands with slopes between 5 and 15 degrees that require moderate earthmoving during the construction) and undulating-mountain (lands of locations with undulating characteristics and slopes up to 50 degrees). Furthermore, the earthmoving cost of social housing projects was analyzed by building, location and type of land. The results indicated that social housing projects report approximately COP 9,000,000 in flat lands, COP 13,000,000 in undulating ones, and COP 23,000,000 in undulating-mountain; these costs were obtained from the analysis of several social housing residential projects in the aforementioned locations.

When comparing the average COP 23,000,000 that social housing spent on earthmoving by building in undulating-mountain lands, against the COP 9,000,000 spent on flat lands, we observe a difference of COP 14,000,000 that could be used for the costs incurred in green constructions, considering that the rate of return expected by the builder for both types of land is quite similar in terms of percentage. That said, and considering the need of covering the approximately COP 39,000,000 required to comply with the sustainable parameters in flat lands, there would be around COP 4,000,000 available, which indicates that the builder would have to incur expenses to complete the remaining COP 25,000,000. Thus, the economic goodness-of-fit index analysis for the builder generated a net present value (NPV) of COP 73,107,221 against the NPV of COP 682,561,000 of the original project on an undulating-mountain land, and a reduction of 11.74% in the rate of return, against the original 12% rate of return.

#### 6.1.3 Project development on low-slope lands plus VAT exemption for construction materials

In order to analyze this scenario, we calculated the cost difference between the flat land choice and the land on which the project was built (which has very high slopes). If we chose a flat land to build the housing, we could save approximately COP 13,754,720, and thus cover nearly 35% of the value required to implement the green criteria established by LEED.

Considering the above, and with no intention of affecting the project's rate of return, this measure associated to the land choice can be combined with the VAT exemption for higher cost materials, such as those related to the interior landscaping of the project, the installation of water, electricity and gas piping systems, the metal carpentry, and the fixtures. This exemption would imply a reduction of a total COP 26,115,098, which, added to the saving associated to the land choice, would generate a total of COP 39,869,818, thus exceeding the amount of COP 39,065,998 required to implement the sustainable measures established by the certification. Consequently, this scenario would not have an impact on the rate of return when implementing the LEED certification.



## 6.2 Use Stage of the Homes

This scenario envisaged the costs associated to the use of the building to determine the differences during the operation under the original conditions and the operation of the building with LEED certification. Therefore, the data indicated in Table 4 was considered. Additionally, 2

minimum wages were assumed as the average monthly income of a family living in one of the homes of the studied project, because this is the minimum income required to apply for the purchase of this type of housing, as stipulated by the Decree 428 of 2015

**Table 4.** General considerations of the cash flow for a home operating under the original conditions and a LEED-certified home

<b>DESCRIPTION</b>	<b>ORIGINAL</b>	<b>LEED</b>
<i>Period [years]</i>	10	10
<i>Annual Income [COP]</i>	17,705,208	17,705,208
<i>Administration [COP]</i>	516,000	516,000
<i>Subsidy for aqueduct and sewage system for Socioeconomic Stratum 1 [%]</i>	70	70
<i>Annual water cost<sup>(*)</sup> [COP]</i>	149,397	106,376
<i>Annual water saving by using energy-efficient appliances [m<sup>3</sup>]</i>	-	64,75
<i>Annual sewage cost<sup>(*)</sup> [COP]</i>	203,943	203,943
<i>Electricity subsidy for Socioeconomic Stratum 1 [%]</i>	50	50
<i>Annual gas and electricity cost<sup>(*)(**)</sup> [COP]</i>	370,993	373,148
<i>Annual cleaning cost [COP]</i>	50,297	50,297
<i>Property Tax [COP]</i>	45,000	45,000
<i>Maintenance of equipment installed for LEED compliance [COP]</i>	-	49,375
<i>Annual increase of Property Tax [%]</i>	20	20
<i>Annual cost increase of public services [%]</i>	5	5
<i>Discount Rate [%]</i>	5.32	5.32

\*Includes subsidy for Socioeconomic Stratum 1

\*\*Value obtained from eQUEST software modeling (2016)

\*\*\*Constant values of 2017

A cash flow was considered where the expenditures included the administration costs, taxes, sewage system, cleaning, gas, electricity, and equipment maintenance expenses for the compliance with the LEED criteria, and the aqueduct costs resulting from the subtraction between the

original costs and the saving generated by the implementation of sustainable measures.

According to the information in Table 4, a NPV of COP 168,130,392 was obtained for the cash flow performed under the original operating conditions, and a NPV of COP

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168,435,908 for the cash flow under the operating conditions of a LEED-certified housing. Consequently, although the deviation between both cash flow NPVs is low, it demonstrates that the operation of a LEED-certified housing is more efficient for the user from the economical perspective.

## 7. Discussion

The research question was: How viable is it, in terms of financial return, to use green technologies with LEED criteria in the construction of social housing projects in the city of Bogota? In order to answer this question, we have to bear in mind that the initiative to use green technologies in social housing is still a decision of the private sector, which must rely on funds that affect their financial return, since they do not receive subsidies for implementing these practices. Thus, even if the government guarantees the demand through subsidies for the users and credit terms to buy this type of buildings, the construction of social housing with sustainable criteria is not attractive for the builder. Therefore, it is imperative to consider aspects that encourage the implementation of these criteria.

In relation to the results obtained from the environmental feasibility analysis, it is possible to obtain a LEED certification for social housing in Bogota, as indicated by Pulido et al. (2013). On the other hand, the cost increase of social housing construction, generated by the implementation of the LEED certification, was analyzed. According to Cabas et al. (2014) and Ribeiro et al. (2016) the increase in the additional investment is 6.4% and 3.2%, respectively. Consequently, the results of the present research fit these values, while obtaining a 5.5% increase.

Considering the different financial scenarios set out, it is not very attractive for builders to build social housing with sustainable criteria, because the incorporation of green parameters in the housing construction has an impact on their rate of return.

Therefore, given the conditions of the current legal framework, which does not envisage sustainable construction

incentives for this kind of housing, we reject the hypothesis in which the studied project located in the city of Bogota can obtain the LEED certification by including green technologies while having attractive economic goodness-of-fit indicators for the builder.

## 8. Conclusion

The environmental feasibility analysis verified the compliance with the obligatory prerequisites and the credits of the LEED certification. Likewise, the alternatives liable to be implemented, together with their associated costs, were identified for each category. This implied to select only those alternatives that could be more easily implemented in the social housing project in order to achieve the LEED CERTIFIED level, and disregarding the green alternatives that had a negative impact on the costs. Based on this selection, it was established that the builders can adopt sustainability criteria according to the LEED certification by making adjustments from the design stage of a social housing project and thus achieve the certification without generating high costs associated to the implementation of these criteria. Nevertheless, regarding the case study, it requires an investment increase of 5.5%, in relation to the original cost, in order to develop a social housing project with LEED certification.

Parametrizing location criteria and identifying possible supplies liable to tax exemptions are some alternatives that could encourage both the builder and the industry of social housing to implement sustainability criteria. Moreover, the consumption savings and, therefore, the operating costs reduction during the use stage of the building, may be attractive financial alternatives for the society to demand this kind of projects. Despite this, the case study demonstrated that, to date, applying for the LEED certification is not economically interesting for social housing builders in Bogota D.C.

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