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ANALYSIS OF THE IMPACT OF EDGE CERTIFICATION ON BUILDINGS: THE CASE OF PERU

UN ANÁLISIS DEL IMPACTO DE LA CERTIFICACIÓN EDGE EN EDIFICACIONES: EL CASO DE PERÚ

ANÁLISE DO IMPACTO DA CERTIFICAÇÃO EDGE EM EDIFÍCIOS: O CASO DO PERU

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RESUMEN

Las certificaciones ambientales, se han implementado en el sector de la construcción por los beneficios de reducción del impacto ambiental, mejora de la eficiencia energética, uso de agua, entre otros. En ese sentido, en los últimos años se ha adoptado en más de ciento cuarenta países la certificación EDGE (Excellence in Design for Greater Efficiencies). Sin embargo, pese a su popularidad; la literatura sobre los impactos en el medio ambiente, es escasa a nivel mundial y latinoamericano. Por ello, el siguiente artículo analizará el uso de EDGE en proyectos de vivienda en el Perú y mostrará las estrategias empleadas en los casos de estudio para disminuir el impacto ambiental. Para ello, se realiza una revisión literaria de EDGE y un análisis de dieciocho proyectos de edificaciones peruanos, los principales ahorros promedio obtenidos, son: 27.6% en Energía, 41.2% en Agua y 51.81% en Carbono Incorporado en Materiales. El siguiente estudio significa un aporte a los profesionales del sector construcción interesados en implementar la certificación EDGE en sus proyectos, ya que se evidencian los impactos ambientales que genera este tipo de certificación.

Palabras clave
EDGE, edificaciones verdes, eficiencia energética, sustentabilidad

ABSTRACT

Environmental certifications have been implemented in the construction sector because of the benefits of reduced environmental impact, improved energy efficiency, and water use, among others. In recent years, the EDGE (Excellence in Design for Greater Efficiencies) certification has been adopted in more than 140 countries. However, despite its popularity, the literature on its environmental impacts worldwide and in Latin America is scarce. Therefore, the following article will analyze the use of EDGE in housing projects in Peru and show the strategies employed in the case studies to reduce the environmental impact. The main average savings obtained were 27.6% in energy, 41.2% in water, and 51.81% in embodied carbon in materials. The following study aids professionals in the construction sector interested in implementing EDGE certification in their projects, as it will show the environmental impacts generated by this certification.

Keywords
EDGE, green buildings, energy efficiency, sustainability

RESUMO

As certificações ambientais foram implementadas no setor de construção pelos benefícios da redução do impacto ambiental, da melhoria da eficiência energética e do uso da água, entre outros. Nesse sentido, a certificação EDGE (Excellence in Design for Greater Efficiencies) foi adotada em mais de 140 países nos últimos anos. Entretanto, apesar de sua popularidade, a literatura sobre os impactos no meio ambiente é escassa em nível global e latino-americano. Portanto, o artigo a seguir analisará o uso do EDGE em projetos habitacionais no Peru e mostrará as estratégias empregadas nos estudos de caso para reduzir o impacto ambiental. Para isso, é realizada uma revisão da literatura sobre EDGE e uma análise de dezoito projetos de construção peruanos, sendo que as principais economias médias obtidas são: 27,6% em energia, 41,2% em água e 51,81% em carbono incorporado em materiais. O estudo a seguir é uma contribuição para os profissionais do setor de construção interessados em implementar a certificação EDGE em seus projetos, pois mostra os impactos ambientais gerados por esse tipo de certificação.

Palavras-chave:
EDGE, edifícios verdes, eficiência energética, sustentabilidade

INTRODUCTION

The construction industry is one of the primary sources of energy consumption (Aini & Taringa, 2023) and air pollution in most countries (Li et al., 2019), and contributes to 38% of global carbon dioxide emissions (CO_2) (UNIDO, 2021). Diverse certification systems have been developed to control the impact of construction projects. The first certification system developed was BREEAM (Building Research Establishment Environmental Assessment Methodology) in the United Kingdom. It is now widely used in different parts of the world, although 80% of its certified projects are in Europe. BREEAM evaluates the sustainability of buildings throughout their life cycle, and the environmental factor is predominant in the certification (Doan et al., 2017). BREEAM has also influenced the development of other certification systems, such as LEED (Leadership in Energy and Environmental Design), which is a certification system developed by the USGBC (US Green Building Council) and is considered the most widely adopted certification system since it has been implemented in more than 160 countries and like BREEAM is mainly focused on environmental factors (Doan et al., 2017). LEED is a certification system based on scores and categories, leading to four building certification levels (Certified, Silver, Gold, and Platinum) (Marzouk, 2023). LEED also has environmental, human health, and economic benefits (Chavez-Finol et al., 2021; Elkhapery et al., 2021). Another of the certifications used is DGNB, which consists of a system developed by the GSBC (German Sustainable Building Council) in 2007 and has more than 5900 projects in more than 30 countries. This certification seeks to evaluate and certify the sustainability of buildings in Germany and internationally since it has the ability to adapt to climate, structural, legal, and cultural variations and has four types of certifications: platinum, gold, silver, and bronze (Samamé-Zegarra, 2021).

In Latin America, LEED and EDGE have been shown as the certifications with the highest acceptance. However, countries have adopted other local certifications such as CASA (Colombia), Punto Verde (Ecuador), EcoCasa (Mexico), and the Sustainable Mivivienda Program (Peru), among others (Villaseñor, 2021). According to the Colombian Council of Sustainable Construction (CCCS, 2024), in the latest LEED analysis for Latin America, 75% of projects are concentrated in the following countries: Brazil, Mexico, Colombia, and Chile, and more than 50% of projects are rated gold and platinum. LEED has presented benefits such as improved occupant health and well-being and lower building operating costs. Although LEED is a rigorous and demanding certification system, it has limited acceptance in developing countries due to its cost and complexity (Beltrán-Méndez & Nik-Bakht, 2018). The World Bank's International Finance Corporation (IFC) has responded to this need with the development of EDGE (Excellence in Design for Greater Efficiencies), an environmental certification tool for buildings available in more than 140 emerging markets (Isimbi & Park, 2022). EDGE also provides technical solutions to reduce operating expenses, reduce carbon emissions, and mitigate environmental impacts in new and existing buildings (Villaseñor, 2021).

To comply with the EDGE certification, a building must achieve a minimum of 20% savings in its three categories: energy, water, and embodied carbon in materials compared to usual local practices (Aini & Tarigan, 2023). EDGE covers different types of buildings, such as houses, apartments, hotels, stores, industries, offices, health centers, warehouses, hospitals, airports, and mixed-use (Kapoor et al., 2019; Marzouk, 2023). It can also be applied at any stage of the building life cycle, from the conceptual design to new constructions, existing buildings, and renovations.

The EDGE v3 guide (IFC, 2021) mentions that the measures being evaluated to achieve these 20% savings depend on the type of project. In the case of this research for the energy category, 34 measures proposed by the EDGE guide and software can be evaluated. Six are mandatory, and the rest are optional. This will depend on whether the energy simulation results in the EDGE software are greater than 20%. For the water category, 17 measures can be assessed, of which six are mandatory and the rest are optional. This will depend on the energy simulation results in the EDGE software. Finally, in the case of materials, 11 measures are evaluated, all mandatory.

The evaluation under the Houses and Apartments typology, on which this study focuses, is based mainly on energy and water efficiency at a residential level, emphasizing domestic systems such as lighting, heating, and appliances, as well as on water consumption in bathrooms and kitchens. Using sustainable materials and efficiency in thermal insulation is also considered to improve energy efficiency in the housing unit. On the other hand, the evaluation for the other typologies, such as industries, focuses on the efficiency of machinery and production processes, optimization of water use in industrial processes, and selection of low-embodied energy materials with efficient waste management. Meanwhile, stores focus on the energy efficiency of lighting, HVAC, and refrigeration, the reduction of water consumption in common areas, and the use of sustainable and recycled materials (IFC, 2021).

Marzouk (2023) mentions that the advantage of EDGE over LEED is the free EDGE web application that

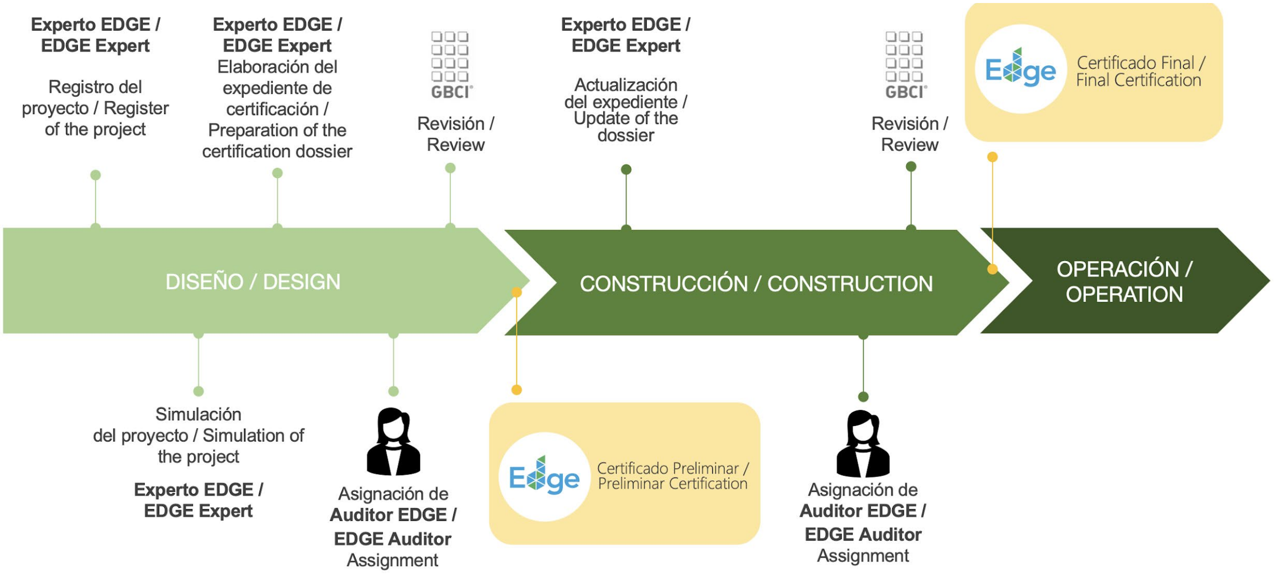


Figure 1. Timeline of the EDGE Certification. Source: Preparation by the authors.

allows a self-assessment of the building to be certified informally before the initial certification process without incurring any cost. A second advantage is its ease of understanding and achieving the certification criteria. Thirdly, EDGE has a database that allows it to adapt to the location set by the user for the project that will be designed and built. With this, collecting additional data, such as prices and weather information for the design, is unnecessary. The last advantage is the fast, interactive response that can be obtained by using the EDGE online software during the design, in addition to quickly showing the changes in water or energy or optimizing the use of construction materials. Likewise, Samamé-Zegarra (2021) mentions that the EDGE water calculation web tool makes the water analysis process simpler than other certifications such as LEED, BREEAM, or DGNB.

EDGE has been adopted in many countries. However, research on its benefits and impacts is limited, especially in Latin America, which has over 400 certified projects. Colombia has 200 certifications and the highest number of certified projects (Villaseñor, 2021), with 81% residential (Rodríguez et al., 2021). Peru is the second Latin American country for EDGE-certified projects (Villaseñor, 2021). In Peru, environmental certifications are increasingly being adopted in the market, where LEED-certified constructions lead the way, with the office building typology representing about 50% of the certified projects (Villaseñor, 2021). However, adopting LEED has certain limitations, such as using materials unavailable in the country, the reuse of construction materials, renewable energy on-site, and few certified wood suppliers (Regalado-Espinoza et al., 2021).

Another certification with rapid growth in the Peruvian market has been EDGE, which has become quite popular among real estate developers due to the municipal incentives they receive for obtaining the certification, such as the height bonus, which allows them to build more apartments (Samamé-Zegarra, 2021). The Mivivienda Sostenible Program certification promoted by the Peruvian state is used at a local level. It is optional and has been implemented since 2016. It is focused on social housing and ranges from $17,262 to $122,901. This certification evaluates six criteria: water, energy, bioclimatic, materials, waste, and urban sustainability (Samamé-Zegarra, 2021).

Given Peru's housing deficit, sustainable housing is presented as a critical solution, and EDGE is a potentially transformative tool for addressing energy efficiency and housing shortages. That is why this research aims to analyze the adoption of EDGE certification in buildings in Peru.

EDGE CERTIFICATION PROCESS

The EDGE certification process of a new building is divided into the design and construction stages and can be summarized in Figure 1.

According to the EDGE V3 guide (IFC, 2021), the process begins with the project's registration on the EDGE platform, where simulations are then carried out applying different sustainable strategies, looking to achieve the minimum required savings of 20% in the three categories contemplated by EDGE. Then, in the design stage, the certification file is made

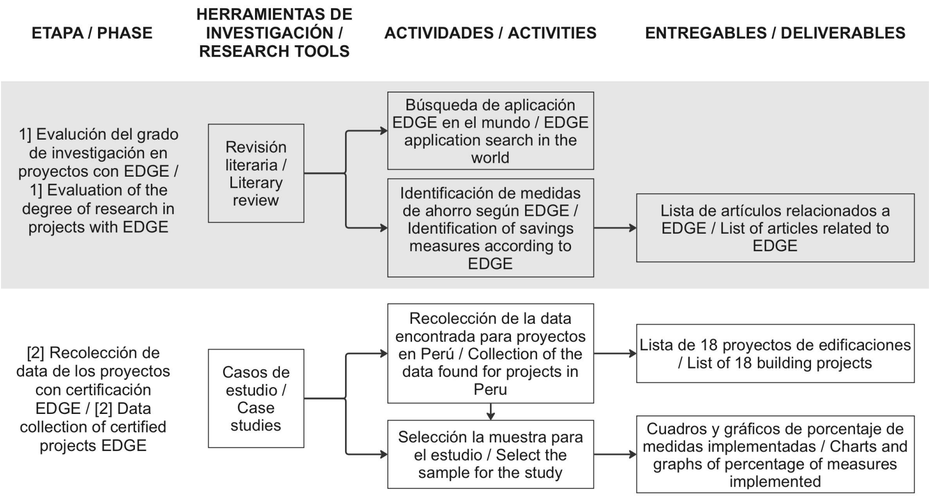


Figure 2. Methodology of the research. Source: Preparation by the authors.

and submitted for review by the EDGE Auditor and the GBCI certifying entity. After the first round of review, the observations are identified and communicated to the project team. Subsequently, the team has the opportunity to address and correct the observations before a second round of review to finally obtain the Preliminary Certification.

During the construction stage, the same process is repeated. It begins by updating the file based on the changes experienced by the project, if any. Subsequently, the EDGE Auditor is assigned, who conducts an on-site audit and, in collaboration with the GBCI, verifies compliance with all the measures adopted and implemented in the project. This process concludes with obtaining the Final EDGE Certification.

According to the EDGE V3 guide (IFC, 2021), the EDGE certification includes 3 levels based on the savings achieved:

- EDGE Certified. This is the basic level at which this recognition can be obtained: it is awarded by meeting a minimum saving of 20% in the energy, water, and embodied carbon in the building materials categories. These are the "base savings" on which the EDGE assessment is based.
- EDGE Advanced. This level rewards projects that demonstrate a minimum 40% reduction in energy, while the minimum savings in water and materials' embodied carbon are maintained at 20% as in EDGE Certified.
- Zero Carbon. This level of certification seeks the maximum reduction and compensation of the building's energy consumption. To achieve this, at least 40% of the energy must be reduced at the design stage through the implementation of strategies in the building (such as EDGE Advanced), and the missing savings to complete 100% of the energy consumption will be offset through on-site renewable sources or the purchase of carbon credits. Likewise, the minimum savings of water and embodied carbon are maintained at 20% as in the EDGE Certified level.

METHODOLOGY

Figure 2 details the research methodology. In the first stage, a literary review of EDGE was conducted using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). In the second stage, 18 EDGE projects were analyzed.

FIRST STAGE: LITERATURE REVIEW

A literature review on EDGE was conducted using the PRISMA methodology, previously used for reviews on sustainability issues (Cao et al., 2022a; Cao et al., 2022b). The Scopus and Web of Science databases were used, with the keywords "Excellence in design for greater efficiencies." Twelve results were obtained in Scopus, 5 in Web of Science, and 50 in Google Scholar. Twenty were repeated, and 27 articles were discarded, leaving a list of 20 articles related to EDGE.

SECOND STAGE: ANALYSIS OF EDGE BUILDING PROJECTS

To select the projects to be analyzed, the EDGE web database was searched for files of project studies and new project studies (Edge Buildings, 2024). The search and exclusion criteria are detailed in Figure 3.

In the initial phase, 163 projects were identified, of which 81 lacked a specific designation and were called "housing." Another 28 projects had incomplete information, leaving 54 revised projects.

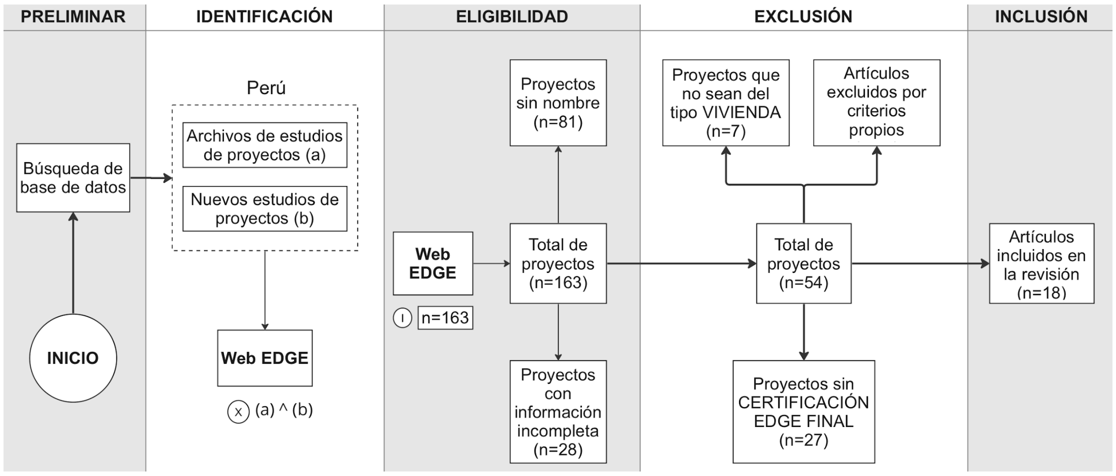


Figure 3. Selection process of projects under study. Source: Preparation by the authors.

Table 1. Eighteen residential complexes with EDGE certification. Source: Preparation by the authors.

Building code	Building's name	Surface area (m2)	Date of certification
P1	Edificio Alborada II	963.66	November 1, 2021
P2	Alcanfores 1262	4024.04	February 1, 2022
P3	Parque Verde Sur	5556.00	February 1, 2022
P4	Soleada	4825.04	November 1, 2021
P5	Parque Club	4509.69	September 1, 2021
P6	Madrid Amistoso	3208.62	September 1, 2021
P7	Madrid en Vivo	5274.93	October 1, 2020
P8	Conde de la vega	2834.00	December 1, 2020
P9	Hermano Lobo 188	2770.00	September 1, 2019
P10	Golf Los Incas	5188.00	November 1, 2017
P11	Edificio Manco Cápac 860	3675.75	May 19, 2023
P12	Multifamiliar Farah	3140.75	April 21, 2023
P13	Lumiere 7 - Llosa Edificaciones	5814.82	March 8, 2023
P14	Casimiro Ulloa 227	3608.12	August 22, 2023
P15	Edificio Multifamiliar Laureles	8367.14	January 29, 2024
P16	Edificio Multifamiliar Today	6725.39	January 17, 2023
P17	Edificio Multifamiliar Túnez 448	1643.72	June 13, 2023
P18	Edificio Helsinki	1848.3	January 29, 2024

In the next phase, nine projects were excluded, seven structures were not of the building type, and two were eliminated due to inconsistent information. Twenty-seven projects without final EDGE certification were also discarded, as the savings data are more reliable in the final certification. As a result, 18 residential buildings with Final EDGE Certification were obtained, as detailed in Table 1.

RESULTS

LITERATURE REVIEW

After the literature review, 20 articles were identified, as detailed in Table 2.

Table 2 shows 20 articles developed in the five continents, mostly in developing countries. Of the 20

Table 2. Articles related to EDGE. Source: Preparation by the Authors.

No.	Author	Country	EDGE Measurement	EDGE concept implemented
1	Azouz & Elariane (2023)	Egypt	Energy Efficiency	EDGE calculator to calculate energy efficiency.
2	Ayanrinde & Mahachi (2023)	Nigeria	Energy efficiency, water, and materials	CO2 footprint measurement.
3	Velázquez Robles et al. (2022)	Mexico, Puerto Rico, and Indonesia	Energy Efficiency	Use of EDGE software to calculate energy savings.
4	Bochare & Bagora (2022)	India	Energy efficiency, water, and materials	EDGE to evaluate energy, water, and material efficiency in sustainable construction.
5	Kapoor et al. (2019)	Does not specify	EDGE for urban developments	Proposal of an EDGE GUD tool for Urban Green Developments.
6	Kartikasari et al. (2018)	Indonesia	Energy Efficiency	Use of EDGE software to simulate energy efficiency measures.
7	Saberi & Kapoor, (2016)	United Kingdom	Energy Efficiency	Evaluation of the new EDGE measurement and its impact on energy savings.
8	Isimbi & Park (2022)	South Africa	Energy efficiency, water, and materials	EDGE software to calculate energy savings, water, embodied energy in materials and annual CO2 emissions.
9	Marzouk (2023)	Oman	Energy efficiency, water, and materials	EDGE software to calculate the energy, water, and material savings of a base case vs. a modified design case.
10	Dlamini & Yessoufou (2022)	South Africa	User evaluation on energy and water	Evaluates the barriers, opportunities, and users' perceptions about using energy and water in a residential complex.
11	Ibrahim et al.(2023)	Egypt	Energy efficiency, water, and materials	Analysis of the EDGE application to calculate the energy, water, and materials' embodied carbon savings.
12	Beltran-Mendez & Nik-Bakht (2018)	Colombia	Feasibility of implementation in the Colombian market	Evaluation of the characteristics of EDGE compared to other certifications regarding cost, operability, and penetrability.
13	Indriyati & Izzah (2022)	Indonesia	Water	To measure the efficiency of water use in a university building.
14	Tarigan & Kartikasari (2016)	Indonesia	Energy Efficiency	The EDGE calculator was used, and an energy saving of 28% was generated
15	Aini & Tarigan (2023)	Indonesia	Energy efficiency, water, and materials	EDGE software to calculate the energy, water, and material savings of a base case vs. a modified design case.
16	Rodríguez et al.(2021)	Colombia	Analysis of EDGE Projects (Energy Efficiency and Water)	Lists the EDGE and LEED energy and water savings in Colombia
17	Setyowati et al. (2020)	Indonesia	Water efficiency	Use of EDGE software and manual measurement to calculate water efficiency in a water treatment scenario
18	Atolagbe et al. (2023)	Nigeria	Energy efficiency, water, and materials	EDGE software for estimating energy consumption reduction in a university building
19	Agyekum et al., (2023)	Ghana	User evaluation of indoor air quality	Indoor environmental quality assessment (IEQ) in EDGE buildings,
20	Samamé-Zegarra (2021)	Peru	Water efficiency	Comparison of water efficiency between EDGE, LEED, BREEAM, HQE, DGNB, and Mivivienda Sostenible Program

studies, four are focused on Latin America, two on Colombia (Beltrán-Méndez & Nik-Bakht, 2018; Rodríguez et al., 2021), one in Peru (Samamé-Zegarra, 2021), and one in Mexico and Puerto Rico (Velázquez Robles et al., 2022), which represents a low amount compared to the certified projects in Latin America.

Regarding the energy category, nine articles in Table 2 address this topic (1, 3, 6, 8, 9, 14, 15, 17, and 18). These focus on using the energy analysis software provided by the EDGE online tool, which allows designing a project efficiently and freely, authorizing the choice of different ecological measures that generate more significant energy savings. A stand-out advantage of EDGE is its free online self-assessment tool, which facilitates pre-assessing a building's design before starting the official certification process (Marzouk, 2023). The EDGE software simulated energy efficiency measures in Indonesia, identifying nine measures that could achieve 18.9% savings (Kartikasari et al., 2018). In Egypt, the EDGE software was applied to calculate energy savings (Azouz & Elariane, 2023). In Mexico, Puerto Rico, Indonesia, and the United Kingdom, the EDGE software was also used to calculate energy savings (Velázquez Robles et al., 2022).

Regarding water use efficiency (13,17, 20), Table 2 has three articles that explore and analyze water efficiency with the help of EDGE software for simulations of proposed scenarios. The application was mainly used due to its ease, speed, and affordability (Samamé-Zegarra, 2021; Setyowati et al., 2020). In the case of articles 12 and 16, a comparison is made between the EDGE certification and others, which allows assessing the feasibility of its application in projects according to costs or operability. According to Beltrán-Méndez and Nik-Bakht (2018), EDGE has a lower cost and greater operability than other certifications, such as LEED, which may be behind its insertion in the Colombian market.

In articles 10 and 19, user perspectives are evaluated, where a lack of knowledge about the concepts of environment and sustainability was evidenced, in addition to the low awareness of the benefit of implementing energy and saving measures in buildings, suggesting a greater diffusion of these. On the other hand, there is only one article related to indoor air quality (EIQ) in EDGE buildings. Although this is not a concept analyzed by EDGE, Agyekum et al. (2023) evaluate the comfort parameters that should be considered based on an EDGE certification.

At a Latin American level, the implementation of EDGE certification in Colombia and Peru has common points. In Colombia, Rodríguez et al. (2021) mention that a concerted effort by companies and the government to promote sustainable construction has been observed, in line with Resolution 0549 of 2015. The EDGE certification stands out for its ease of use and low cost, facilitating its adoption in the country. Government strategies and collaboration with the private sector have been vital for EDGE to aspire to capture 20% of the construction market in the coming years. In the case of Peru, Samamé-Zegarra (2021) mentions that real estate developers have adopted EDGE due to local incentives, such as increasing the building's height on having the certification. In both countries, residential projects have the highest number of certified projects; in the case of Colombia, it is close to 80% (Rodríguez et al., 2021) and 50% in the case of Peru (Samamé-Zegarra, 2021). Another common point is that the authors of both countries have mentioned the importance of the EDGE online tool, highlighting its importance and ease of use for water and energy (Beltrán-Méndez & Nik-Bakht, 2018; Rodríguez et al., 2021; Samamé-Zegarra, 2021).

SUSTAINABILITY ANALYSIS OF THE PROJECTS UNDER STUDY

The technical solutions in energy, water, and materials embodied carbon of the 18 projects are detailed in the corresponding tables. It is highlighted that the Farah and Today buildings lead in implementing strategies in all categories of the EDGE standard, while the Golf Los Incas building has fewer implemented strategies. Buildings certified under the EDGE standard are crucial in mitigating environmental impact, significantly contributing to the fight against climate change. None of the 18 buildings achieved the EDGE Advanced Certification in the Zero Carbon Certification.

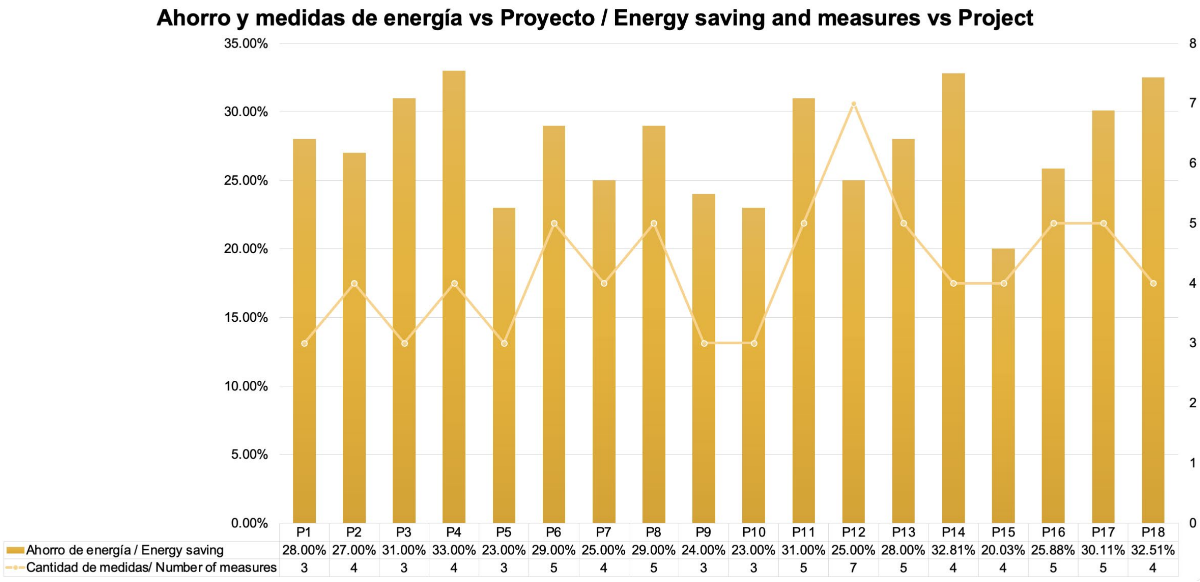
ENERGY AND ENERGY-SAVING MEASURES

Table 3 shows the application percentage of the EDGE v3 Energy measures in the studied buildings, classified into energy saving (78.4%), energy generation (13.5%), and energy measurement (8.1%). The design of the buildings focused on efficiency and reduction of consumption and also included strategies implemented during the design and construction stage, such as lighting controls, reflective paint on ceilings and walls, LED lighting, reduction of the window-wall ratio, low thermal transmittance glazing, exterior shading devices, roof insulation, and the adoption of photovoltaic solar energy. Seeking to avoid thermal bridges, energy efficiency was optimized by reducing the window-wall ratio, low thermal transmittance glazing, and insulation on ceilings and walls, which generated clear savings in the electricity bills of the end owners.

Table 3. Summary of technical solutions related to the Energy category. Source: Preparation by the authors.

Technical solutions	Percentage of buildings with solutions
E01*: Lower proportion of glass on the exterior facade	100.00%
E02: External solar control devices	44.44%
E03: Reflective paint/roof tiles	22.22%
E04: Reflective paint for external walls	5.56%
E05*: Ceiling insulation	50.00%
E06*: Thermal insulation of external walls	44.44%
E07: Glass with a low-emissivity coating	33.33%
E12*: Air conditioning system	5.56%
E33: Energy-saving light bulbs	66.67%
E34: Lighting controls	33.33%
E42: Photovoltaic solar energy	16.67%

* Mandatory measure



	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
Ahorro de energía / Energy saving	28.00%	27.00%	31.00%	33.00%	23.00%	29.00%	25.00%	29.00%	24.00%	23.00%	31.00%	25.00%	28.00%	32.81%	20.03%	25.88%	30.11%	32.51%
Cantidad de medidas/ Number of measures	3	4	3	4	3	5	4	5	3	3	5	7	5	4	4	5	5	4

Figure 4. Energy savings against project measures. Source: Preparation by the authors.

According to local regulations, the evaluated projects achieved an average energy savings of 27.6% compared to the base case; between 2017 and 2024, energy savings fluctuated between 20% and 33%. Soleada led with 33%, followed by Casimiro Ulloa with 32.81%. Laureles had the lowest energy savings, with 20.03%, followed by Parque Club and Golf Los Incas, with 23%.

Most buildings reduced the glazed area proportion on the facade, minimizing thermal gains and maintaining interior comfort. However, Madrid en Vivo opted for efficient HVAC equipment in the housing units, which did not significantly affect energy savings. In addition, Camfores, Manco Cápac, and Lumiere implemented photovoltaic panels to cover the energy demand in common areas. Figure 4 shows the number of measures adopted by each project under study. However, it shows that the energy savings achieved are not necessarily related to the number of measures implemented. This is because each project has unique characteristics, such as the architecture of the project, the glazing proportion on the facade, and elements on which the evaluation of the measures will depend.

WATER AND WATER-SAVING MEASURES

Of the three EDGE categories, the Water category had the fewest strategies. The water-related strategies focus on controlling the consumption of bathroom

Table 4. Summary of technical solutions related to the Water category. Source: Preparation by the authors.

Technical solutions	Percentage of buildings with solutions
W01*: Water-saving shower heads	94.44%
W02*: Efficient water-saving faucets for all bathrooms	100.00%
W04*: Efficient water-saving toilets for all bathrooms	83.33%
W08*: Water-saving kitchen faucets	100.00%
W15: Wastewater treatment and recycling system	5.56%

* Mandatory measure

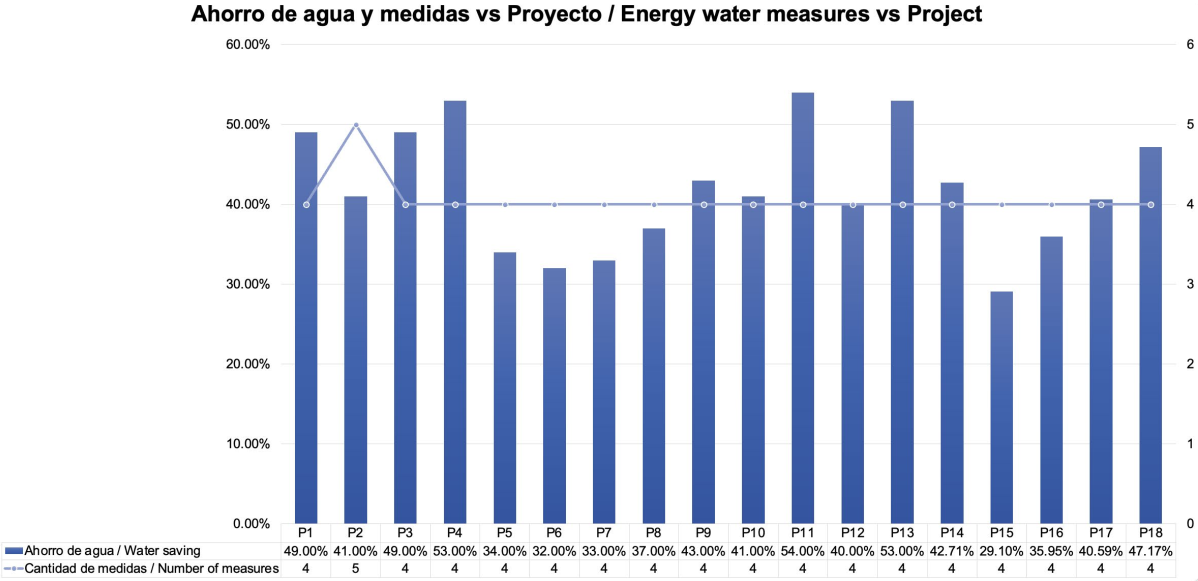


Figure 5. Water saving against project measures. Source: Preparation by the authors.

and kitchen faucets and sanitary equipment. Low-flow faucets were installed to reduce water and energy consumption intrinsically related to hot water consumption. Almost 100% of the buildings have implemented strategies such as installing low-flow faucets in bathrooms and kitchens, low-flow shower heads, and efficient single—or double-flush toilets.

On the other hand, 6% of the buildings implemented gray water treatment plants to reuse the water recovered on-site for toilets and irrigating vegetated areas, contributing to the end water savings.

Reducing water consumption is extremely important due to the water stress that Lima is currently experiencing. The average water saving was 41.92%. The Manco Cápac Building came first, with the highest savings at 54%, followed by Soleada and Lumiere with 53%. Soleada stands out regarding energy and water savings among all the evaluated buildings. The lowest savings achieved were obtained by Friendly Madrid with 32%, followed by Live Madrid with 33%. Even though Camfores was the only building that implemented a gray water treatment system on-site as an alternative source of drinking water, its savings remained close to the average of 41%. Figure 5 shows the savings achieved versus the measures taken. It was perceived that the percentage of water savings achieved is not necessarily related to the number of measures implemented. This is due to the specifications of the sanitary equipment and faucets. In addition, there are four mandatory compliance measures in this category, and there is only one additional project, which measures W15 (Wastewater Treatment and Recycling System).

MITIGATION STRATEGIES FOR MATERIALS' EMBODIED CARBON

The analyzed projects have considered versions 2 and 3 of EDGE. For version 2, 6 mandatory measures are indicated, and in the case of version 3, there are 11 mandatory measures. In the construction of buildings, diverse materials are used in structural and architectural elements, such as floor slabs, ceiling slabs, interior and exterior walls, floor finishes, window

Table 5. Summary of technical solutions related to the category of Materials' Embodied Carbon. Source: Preparation by the authors.

Construction materials	Percentage of buildings with solutions
M01*: Floor slabs	
Concrete slab reinforced in situ	44.44%
Lightweight concrete slab	44.44%
Lightweight concrete slab with polystyrene blocks	27.78%
M02*: Ceiling slabs	
Concrete slab reinforced in situ	44.44%
Lightweight concrete slab	61.11%
Lightweight concrete slab made of polystyrene blocks	27.78%
M03*: Interior walls	
Medium-weight hollow concrete blocks	44.44%
Wall reinforced in situ	66.67%
Aerated concrete blocks in autoclave	22.22%
Hollow bricks (with holes) with internal and external plaster	16.67%
Face bricks and concrete blocks	11.11%
M04*: Exterior walls	
Medium-weight hollow concrete blocks	38.89%
Wall reinforced in construction	11.11%
Aerated concrete blocks in autoclave	22.22%
Hollow bricks (with holes) with plaster on both sides	22.22%
M05*: Floor finishes	
Ceramic tile	66.67%
Vinyl floor	11.11%
Laminated wooden floor	55.56%
Terracotta tiles	11.11%
M06*: Window frames	
Aluminum	72.22%
M09*: Insulation of ceiling slabs	
Polystyrene	11.11%
Cellulose	16.67%

*Medida obligatoria

frames and glazing, screens, and insulation in the envelope. The concrete slab reinforced in situ and the lightened concrete slab were used in 44% of the buildings for the floor slabs. The lightened concrete slab prevailed in 61% of the ceiling slabs, followed by the reinforced concrete slab in situ in 44%. The exterior walls were built mainly with walls reinforced in situ (67%) and concrete blocks with medium-weight gaps (44%). In interior walls, concrete blocks with dense medium-weight gaps were the most used (39%), followed by autoclaved aerated concrete blocks (22%). In floor finishes, ceramic tiles and laminated wood flooring were applied in 67% and 56% of the buildings, respectively. Aluminum window frames were predominant in 72% of the cases. The insulation in the roof slabs and the slabs with direct contact with the ground were made with polystyrene bricks in 11% of the evaluated buildings.

The analysis of the construction materials conducted under the corresponding category is more exhaustive and detailed since an analysis of the life cycle of each material is made. Therefore, the lower the carbon equivalent generated throughout the life cycle of the material to be used, the lower the carbon footprint emitted and, in turn, the lower the impact on the planet. The average embodied carbon savings is 51.81%. In general, the Madrid en Vivo and Golf Los Incas buildings achieved the highest savings, with 69% demonstrating that they mitigated their carbon footprint during construction. Multifamiliar Farah obtained the lowest savings, with 30%, followed by Conde de la Vega with 35%. The carbon equivalent is established based on the material chosen and used in the buildings' construction stage. This can be reduced with the correct choice of material. For this, the EDGE software will be a great ally in the choice process since it will allow making the respective simulations based on the predetermined embodied carbon for each existing material and thereby project the savings in each respective certification category.

Figure 6 shows the savings achieved versus the measures taken. However, the percentage of embodied carbon savings achieved is not necessarily related to the number

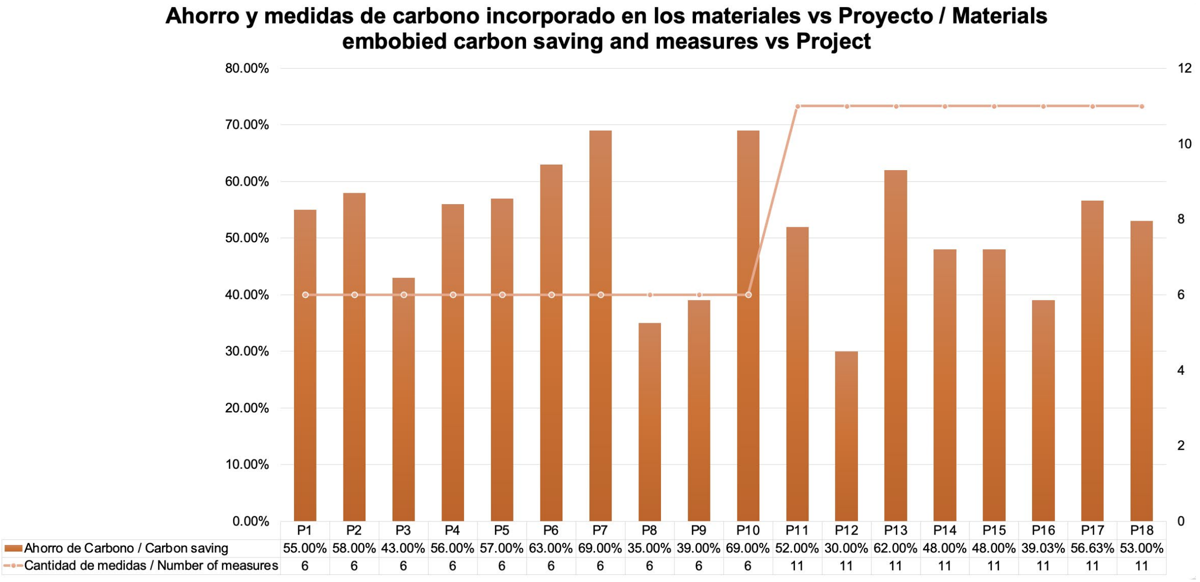


Figure 6. Embodied carbon savings against the project's material measures. Source: Preparation by the authors.

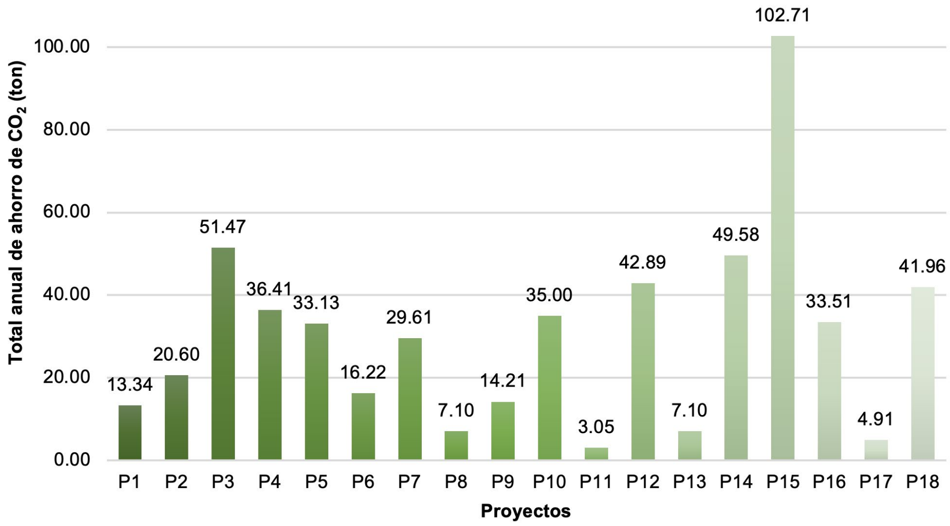


Figure 7. Total annual CO2 savings by Project. Source: Preparation by the authors.

of measures implemented. This is due to the choice of sustainable materials for building construction.

TOTAL ANNUAL CO_2 SAVINGS

The average CO_2 mitigation value for the buildings under study is 30.12 tons of CO_2 equivalent a year. It is essential to note that the CO_2 mitigation varies significantly, ranging from 3.05 to 102.71 tons. This contrast in the CO_2 savings between buildings is attributed to the diversity in the range of the evaluated structures. In particular, it is noted that Laureles achieved the highest annual CO_2 savings, reaching 102.71 tons, followed by Parque Verde Sur with 51.47 tons. On the other hand, the Manco Cápac Building registered the lowest savings, with only 3.05 tons of CO_2. Figure 7 graphically illustrates the total annual CO_2 savings for each evaluated building.

DISCUSSION

Based on the analysis, most of the projects studied are focused on the city of Lima. Due to geographical and regulatory characteristics, the results could vary if more data is obtained from other sectors of Peru.

In Peru, the implementation of EDGE has positively impacted the energy aspect of buildings. The measures adopted include the reduction of the glazing proportion on the exterior facade, external solar control devices, roof insulation, thermal insulation of external walls, glass with low-emissivity coating, energy-saving light bulbs, and lighting controls. The average energy savings achieved was 27.6%, slightly lower than the 29.7% recorded in a similar study in South Africa (Isimbi & Park, 2022), attributable to climatic conditions and local regulations.

Kartikasari et al. (2018) also highlight the improvement of energy efficiency using EDGE in Indonesia.

In the case of Latin America, in Colombia, new projects certified as sustainable buildings, more than 50% meet the minimum energy and consumption reduction percentages. In the case of the EDGE methodology, 24% did not meet the energy reduction percentage, 12% the water consumption, and 6% both. This does not imply a contradiction in what determines sustainable construction since obtaining certifications such as EDGE or LEED includes other quantifiable items that allow achieving certification (Rodríguez et al., 2021). On the other hand, with the implementation of EDGE, in the case of Mexico, significant reductions were obtained in energy demands (38.52%) and water consumption (46%) (Velázquez Robles et al., 2022). In the case of Peru, EDGE can be an important tool for water saving because a large part of the population of Peru is located on the coast, where water ends up being a vital resource (Samamé-Zegarra, 2021).

Under the water category, the measures adopted in Peru included water-saving shower heads, efficient faucets, efficient toilets, and a wastewater treatment and recycling system, which achieved an average savings of 41.92%. This result exceeds the savings of 31% recorded in a comparative study. The Peruvian buildings also opted for an alternative source of drinking water through the wastewater treatment and recycling system. Likewise, research in Mexico shows a 46% saving in water consumption, where measures such as low-flow showers and faucets, the rainwater collection system, and recycled gray water were used (Velázquez Robles et al., 2022).

As for embodied carbon, the most used materials in Peru were concrete slabs reinforced in situ, medium-weight hollow concrete blocks, and ceramic tiles. The average embodied carbon savings was 51.81%, slightly lower than the 54% observed in South Africa, where the reuse of structural elements was considered.

In addition to the results obtained, the projects certified under the EDGE standard have demonstrated clear environmental benefits, especially in reducing CO_2 equivalent emissions throughout the entire life cycle of buildings. These positive impacts are due to the implementation of energy efficiency, efficient water use, and sustainable material selection strategies, consolidating EDGE as an essential tool for promoting sustainable construction and climate change mitigation strategies.

CONCLUSIONS

This study shows the impact of EDGE certification on buildings in Peru. 557 units of 18 certified residential buildings were analyzed from November 1st, 2017, to January 29th, 2024, obtaining average savings of 27.6% for energy, 41.2% for water, and 51.81% for materials' embodied carbon.

The buildings reduced energy consumption by optimizing the window-wall ratio, the envelope's thermal insulation, low thermal transmittance glazing, and gas-powered water heaters. In addition, water efficiency measures were implemented, such as low-consumption faucets, sanitary equipment, and an alternative drinking water source through a gray water treatment plant for reuse in toilet flushing and irrigation of green areas. As for the construction, the frequent use of concrete slabs reinforced in situ and lightened concrete slabs on floors stands out, while those reinforced in situ and concrete blocks with medium-weight gaps were preferred on exterior walls. Concrete blocks with dense medium-weight gaps were predominant in interior walls. Ceramic tiles and laminated wood flooring were the most common floor finishes, and aluminum was preferred for window frames. In insulation practices, polystyrene bricks were frequently used in roof slabs and slabs with direct contact with the ground.

The research has limitations regarding the number of studies because only 18 final certificates were analyzed, and the results could vary with a more significant number of projects. The authors suggest replicating the following study in other countries to see the impact of the EDGE certification and conducting analyses to explore whether there is a correlation between the m^2 and the savings obtained. Also, it is suggested that the factors that generate the adoption of the EDGE certification or other environmental certifications be investigated.

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