Green buildings for the health care sector

Cost-effective measures for sustainable design

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Infrastructure and Energy Sector

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Social Infrastructure

GREEN BUILDINGS

FOR THE HEALTH CARE SECTOR

Cost-effective measures for sustainable design

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IDB

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Acronyms

DC: Diagnostic Center. Two-floor 5,000 m^2 building. There is a 400 m^2 irrigation area. There are not beds for patients or laundry service.

OC1: Outpatient Clinic. One-floor 300 m^2 building with a 150 m^2 landscaping area.

OC2: Outpatient Clinic. One-floor 1,500 m^2 building with a 300 m^2 landscaping area.

COP: 'Coefficient of Performance'. Dimensionless coefficient used to express the amount of heat or energy units than an equipment can release for each electrical energy unit. It is the result of the transformed heat divided by the electrical energy unit.

EDGE: 'Excellence in Design for Greater Efficiencies' It is an online platform, a green building standard and a certification system used in more than 150 countries. Edge application helps to determine the most cost-effective options to design a green building[1]. This platform is used to upload the project information, check its design efficiency. Moreover, it provides the costs of incremental investment and the savings in utilities according to the efficiency measures chosen.

MSH: Multi-Specialty Hospital. Three-floor 12,000 m^2 type of hospital project with a 1200m^2 landscaping area. There is laundry service, a kitchen and beds for patients.

PH: Public Hospital. Ten-floor 40,000 m^2 type of hospital project. With a 2000 m^2 landscaping area. Besides, there is laundry service, a kitchen, and beds for patients.

TH: Teaching Hospital. Six-floor 20,000 m2 hospital project with a 1,500 m^2 landscaping area. Besides, there is laundry service, a kitchen, and beds for patients.

IFC: 'International Finance Corporation'. Is a sister organization of the World Bank Group – is the largest global development institution focused on the private sector in developing countries.

kWh: Each kilowatt-hour represents the consumption of 1,000 Watts of power in an hour. It is a metric unit equivalent to 3,600 kilojoules.

NH: Nursing Home. Two-floor 3,000 m^2 type of project with a 300 m^2 landscaping area.

PP: Payback Period. Variable used to determine the number of years required to recover the capital investment with the savings or the net profits generated. The simple way to calculate it is dividing the capital investment by the average annual savings over the project's life span.

IRR: Internal Rate of Return. It is the interest rate that makes the Net Present Value of all cash flow equal to is zero.

NPV: Net Present Value is the value of the cash flows considering a discount rate compared to the initial capital investment. The project is considered feasible if the NPV is positive.

VRF: Variable Refrigerant Flow. It is a Heating, Ventilation, and Air Conditioning (HVAC) technology that uses refrigerant as the cooling and heating medium. Most VRF systems have very high equivalent efficiencies, since, in general, systems are designed for peak loads and actually work in that condition less than 2% of the time[2]. Therefore, a piece of equipment with high efficiency in partial loads will be better.

WWR: Window to Wall Ratio. It is defined as the ratio of the total area of the window or other glazing area (including mullions and frames) divided by the gross exterior wall area. EDGE estimates the base case for hospitals with a 30% WWR and sets an improved case of 20% WWR. However, depending on the architectural design, the project's 8 façades could be modified from 0% to 100%.

1 EDGE is an IFC registered trade mark,

2 ANSI/AHRI STANDARD 340/360

Executive summary

During 2018, 36% of the final energy consumption and 39% of CO_2 emissions were from buildings and the construction sector worldwide. 11% of these emissions were produced by the manufacturing process of construction materials such as steel, cement, and glass.

Infrastructure projects, particularly those in the health care sector, offer an opportunity to design, build, manage and invest in systems and facilities that use energy and water resources efficiently. Also, the sector provides an opportunity to reduce greenhouse gases emissions while achieving the main purpose of providing medical care to people in need. Implementing combined design and energy efficient measures results not only in saving of resources, but also in reducing the overall operational costs then impacting on its long-term sustainability.

The analysis conducted here identified the most cost-effective measures that make it possible to save energy and water consumption in the health care sector infrastructure projects. To do so, the tool Excellence in Design for Greater Efficiencies (EDGE) was used. It helps to quickly identify the most effective ways of reducing energy, water, and the embodied energy in the construction materials.

EDGE is an online platform, a green building standard to reach, and a certification system. Its online platform allows the user to input the building's parameters such as location and type, and to choose different options from a list of preset passive and/or active design measures. Besides, it assesses the impact each measure has on the building's performance. The building's certification is awarded by an independent party (Certifier) if the requirements set by EDGE have been met.

EDGE was used in this work mainly for two reasons: a) It is a simple and free system to assess the most cost-effective measures; and b) It provides a wide database that covers different cities and archetypes, which makes it possible to obtain comparable results.

This analysis uses a hypothetical sample of health care infrastructure analyzing different design alternatives for each case. 8 cities in the Latin America and Caribbean (LAC) region, located in different latitudes, were selected. They have different atmospheric conditions (average annual temperature, average annual rainfall, and altitude). For each city, 6 hypothetical cases that correspond to health care building types were assessed. Combining cities and facilities type represents 48 case studies.

8 cities:

» **Hermosillo - México**, dry, arid and warm climate.

» **Cártago - Costa Rica**, rainy tropical climate.

» **San Salvador - El Salvador**, tropical savanna climate and dry winter.

» **Quito - Ecuador**, humid climate and warm summer.

» **Santa Marta - Colombia**, tropical savanna climate and dry summer.

» **La Paz - Bolivia**, with temperate soft climate, dry winter and warm summer

» **Manaos - Brasil**, tropical monsoon climate.

» **Puerto Santa Cruz - Argentina**, semi-arid steppe, arid cold climate.

6 types of health care facilities:

» 300 m² **Outpatient Clinic**.

» 1500 m² **Outpatient Clinic**.

» 5000 m² **Diagnostic Center**.

» 12 034 m² **Multi-Specialty Hospital**.

» 20 017 m² **Teaching Hospital**.

» 3000 m² **Nursing Home**.

Based on the options given by EDGE two types of simulations were run for each of these case studies: a) using passive design strategies (S1), and, b) using active design measures, such as improving the efficiency of air conditioning equipment or using photovoltaic panels (S2). In total, 96 simulations were run.

Additionally, another hypothetical case study was carried out. It is a 40,000 m2 existing public hospital built in 2000 in the City of Buenos Aires. Measures simulated in this case aimed at reducing energy and water consumption were incorporated, with no architectural changes. For this additional case, 9 simulations were run. The aim of this case study was to get a deeper understanding of the measures that could be used in existing buildings and that could imply retrofit, or not.

Buenos Aires - Argentina, subtropical climate.

40,000 m² existing Public Hospital.

Running the simulations allowed us to conclude that EDGE provides valuable information to guide the design towards projects with more energy efficiency, less water consumption, and materials with less embodied energy during their life cycle.

The goal was to achieve a minimum reduction of 20% in energy, 20% in water use, and 20% in embodied energy in the materials by implementing passive and active design measures, or the combination of both.

The annual savings for new health care buildings, on average, were **109 kWh, 0.9 m^3 in water, 0.6 GJ** in embodied energy in the materials and **0.044 tCO_2 per construction square meter**, with an average incremental cost that does not exceed **USD 20/m^2.**

The annual saving for the existing hospital building was of **72 kWh and 0.86 m^3 in water, 2.11 GJ in embodied energy in the materials, and 0.044 tCO_2** per construction square meter, with an incremental cost of **USD13.25/m^2.**

Likewise, it was identified where the highest consumptions of energy, water and embodied energy in the materials in health care infrastructure projects take place depending on the weather and type of project. Also, the most cost-effective design measures and recommendations were identified.

Air conditioning systems and kitchen and laundry equipment account for the largest energy in health facilities. Water consumption relies on the size of the building, meaning on the number of bathrooms it has.

Besides using EDGE platform, an additional financial analysis was performed using the utility tariffs of the cities analyzed. Although there is a slight difference between the numbers informed by EDGE and the current utility tariffs, in both cases, the results of the payback period were favorable.

Lastly, it is important to mention that, although EDGE is a tool that helps choose design measures aimed at getting resources savings, there are other tools – such as thermo-energetic simulations or another specific software– that can be used if more detailed analysis is required.

Table 1. Payback period according to current utilities tariffs.

City	Payback period (years)
Cartago – Costa Rica	0.5-2.7
Hermosillo – Mexico	0-2
La Paz – Bolivia	0.2-3.5
Manaus – Brazil	0-1.9
Quito – Ecuador	0.6-6.2
Puerto Santa Cruz – Argentina	0.2-5.3
San Salvador – El Salvador	0.1-3
Santa Marta – Colombia	0-2.4

1. Background

In 2017, the Management of the Bank's Infrastructure and Energy Sector (INE/INE) and Social Sector (SCL/SCL) agreed to create the Social Infrastructure Unit to provide specialized technical support to programs and projects with infrastructure components financed by the Bank's Social Sector (SCL/SCL).

The Social Infrastructure Unit works closely with the Climate Change and Sustainable Development Sector (CSD/CCS) in promoting and supporting those countries whose social infrastructure projects include climate change mitigation and adaptation measures. This support is given in multiple stages of the project's life cycle. For example, in the preparation stage, when the CSD follows the methodology agreed by all the Multilateral Development Banks[1] to calculate the percentage of the amount of the loan, which can be considered Climate Financing.

In December 2018, the guide "Towards 30% Climate Finance: How Can Buildings Contribute to It?" [2] was launched in joint collaboration of the Social Infrastructure Unit and CSD/CCS. This guide explains how social infrastructure and other sector buildings can contribute to the fulfillment of the IDB group's 30% goal of climate financing by 2020.

This work, together with the guide and with the "Framework of Sustainable Infrastructure" [3], focuses on the health care sector infrastructure projects. These projects account for a high percentage of the portfolio of the Social Protection and Health Division (SCL/SPH).

The analysis was developed based on the contents and simulations done by Eric Fischel with the support of Gastón Michaud and Mariana Herrera, under the coordination and general edition of Wilhelm Dalaisón and Esperanza González-Mahecha, and the specific support of Ignacio Astorga, Michelle Carvalho Hallack and Virginia Snyder.

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2. Introduction

There are two strategies to face climate change: mitigation and adaptation measures. Climate change mitigation measures aim at reducing greenhouse gas emissions. As regards buildings infrastructure, these measures are focused on strategies for energy saving and efficiency, the use of renewable energies, and materials with low embodied energy during their life cycle. These measures, besides diminishing the impact that healthcare facilities have on climate change, allow substantial economic savings, which are important for the long-term sustainability.

Adaptation measures focus on the infrastructure adaptation to climate change effects. This way, it can be more resilient to events such as droughts, heat waves, rainfall, rising sea levels, that will take place more frequently and more intensely.

During 2018, 36% of the final energy consumption and 39% of CO_2 emissions were from buildings and the construction sector worldwide. 11% of these emissions were produced by the manufacturing process of construction materials such as steel, cement and glass [4]. Compared to 2017, emissions increased by 2%, whereas energy consumption increased by 1%. In that sense, the buildings sector poses a challenge, and a great opportunity to face climate change. Policy-makers, designers, developers, contractors, and other stakeholders in the construction value chain have a chance to decarbonize this sector.

The possibilities for design interventions are greater in new buildings than in old ones. For example, it is easier to maximize the natural available resources (sun, vegetation, rainfall, winds) in new buildings by considering orientation, geometry, and local weather conditions. Designing with these elements in mind (known as passive design strategies) decreases environmental impacts and reduces energy demands. Applying passive design measures reduces the need for and dependence on equipment and technology (known as active design measures). Measures such as efficient equipment and lighting, solar thermal collectors, and solar photovoltaic panels reduce the demand for electricity from the grid. It is necessary to analyze the combination of passive and active measures in each project design, always bearing in mind better efficiency and less costs during its life cycle.

In existing buildings, it is harder to work on passive strategies or choose certain construction materials. Therefore, efforts are generally focused on active measures that add efficiency.

Adding these measures to the designs helps reduce costs. However, it is always necessary to combine these measures with programs that promote user's behavior changes and show how they help to decrease the consumption of resources such as energy and water.

This analysis was developed using a tool called Excellence in Design for Greater Efficiencies (EDGE), of the International Finance Corporation (IFC). This tool quickly identifies the most effective ways of reducing the consumption of energy, water, and embodied energy in the construction materials. EDGE is an online platform, a green building standard to reach and a certification system. The online platform allows the user to input the building's parameters such as location and type, and to choose from a list of preset passive and/or active design measures. Besides, it assesses the impact each one of them has on the building's

performance[3]. The building's certification is awarded by an independent certifier, when it is verified that the building has met the requirements set by EDGE.

EDGE was used in this work mainly for two reasons: a) It is a simple and free system that provides an approach at the most cost-effective measures; and b) It provides a wide basis that covers different cities and types, and makes it possible to obtain comparable results. The certification system itself is not taken into consideration in this analysis.

EDGE has been specifically created for developing countries and is considered a simple methodology for assessing energy, water, and embodied energy in materials savings. EDGE consists of a set of mathematical equations based on the principles of climatology, heat transfer and building physics. The user enters the data for the design and the calculator charts the building's potential savings. Energy consumption is predicted using a quasi-steady-state model characterized by its ease of data collection, reproducibility and cost-effectiveness of inputs gathering for the model.

3 In 2019, so as to acknowledge higher savings, EDGE included the possibility of obtaining an "EDGE Advanced" certificate for those buildings that show a 40% reduction of energy consumption (the other two minimum requirements are not altered) and an "EDGE Zero Carbon" certificate for those buildings that show a 40% reduction of energy consumption, the other 60% must be achieved by means of renewable energies or carbon compensations.

This analysis seeks to identify the most cost-effective measures to obtain energy and water consumption savings in the health care sector projects based on the results obtained on EDGE online platform.

This analysis does not intend to be thorough and the results depend on the parameters and measures EDGE sets by default. However, it intends to assist project teams and decision-makers in identifying measures that not only save consumption, but also represent less investment costs and shorter payback periods.

For this analysis, different hypothetical case studies for health care facilities were conducted. Since this is a guiding document, it is highly recommended to carry out a more detailed analysis for each specific project considering the most cost-effective measures and technologies locally available identified in this study. This analysis was conducted in September 2019, with Version 2.1.5.

As a final remark, it is important to stress that this analysis is based on hypothetical cases, chosen from almost endless possibilities, with the aim of getting some general conclusions and guidelines on which measures are most effective at a lower cost and with less payback period.

3. Climate change and the health care sector

Climate change and the health care sector have many points in common. Climate change currently impacts human health in different ways. According to the Intergovernmental Panel on Climate Change (IPCC), it increases the risk of vector transmitted diseases, such as malaria and dengue, because of the rise in the frequency and intensity of rainfall and heatwaves, among others [5]. Besides, research indicates that climate change can be considered a threat for mental health. The losses and trauma caused by natural disasters, intensified by climate change, are associated with diseases such as post-traumatic stress disorder (PTSD), anxiety, depression, rage, and violence.

These effects are increased in low- and middle-income countries due to their vulnerability to extreme weather events, the low response capacity of their health care system and their poor infrastructure system. To face climate change, health care systems are called to action in different areas, such as: a) Early warning systems and communication; b) Monitoring the population's physical and mental health state; and c) Appropriate infrastructure to provide health services. This document addressed the point c.

Since the countries in the region have increased their health care investments, there is a potential to implement more economical and less carbon-intensive technology and infrastructure. As the World Bank (2017) points out in its report "Climate-Smart Healthcare" [6], health care infrastructure provides an opportunity to design, build, manage, and invest in health care systems as the same time as generate minimal amounts of greenhouse gases (GHG). In this sense, climate-smart health care systems would be aligned with both the region's development goals and the global climate change objectives

This perspective implies money saving, due to the reduction of energy costs, water resources and materials. These savings could be reallocated in prevention programs or to expand the coverage. This approach also has additional benefits such as the reduction of environmental pollution, including GHG, and more efficient health care systems. Low-carbon health care systems include [6]: Health care systems with local providers, building design and construction based on low emissions and energy efficiency, waste minimization and sustainable health care waste management, sustainable transportation and water consumption policies, etc.

4. Analysis methodology

This analysis uses sample hypothetical studies of health care facilities in different cities of the Latin America and Caribbean (LAC) region, analyzing different design alternatives for each case.

8 cities, located in different latitudes, were selected. They have different atmospheric conditions (average annual temperature, average annual rainfall, and altitude). For each city, 6 hypothetical studies that correspond to health care buildings types, were assessed. Combining cities and facilities type represents 48 case studies.

For each case two types of simulations were run: a) Using passive design strategies (S1), and b) using active design measures, such as improving the efficiency of air conditioning equipment and using photovoltaic panels to generate energy *in situ* (S2). In total, 96 simulations were run.

Additionally, another hypothetical case study was carried out. It is an existing public hospital in the City of Buenos Aires. Measures simulated in this case aimed at reducing energy and water consumption were incorporated, with no architectural changes. For this additional case, 9 simulations were run. The aim of this case was to further analyze measures that could be adopted in existing buildings and to obtain different possible options to reduce energy and water consumption.

This analysis was carried out with EDGE application. The goal was to achieve a minimum reduction of 20% in energy, 20% water use, and 20% in embodied energy in the materials, compared to common practices (or baseline) in construction in those cities.

As mentioned before, EDGE allows the user to input each building's characteristics to determine its behavior for the analyzed climate. The variation along these characteristics may be wide and, since these were hypothetical studies, it was agreed to employ and optimize the standard measures EDGE provides and use them in the same way for all the cases. For example, regarding the building's orientation, the assumption was a proportional configuration of the north, south, east, west, northwest, northeast, southeast and southwest facades.

5. Identifying the cities and their weather conditions

8 cities in the continent were chosen for this analysis. They have varied climate and geographic characteristics: From arid desert climates with little rainfall to steppe cold climates. Table 2 shows the main characteristics of the cities analyzed (temperature, location, and climate classification) according to Köppen-Geiger climate classification. For detailed information about the cities see Appendix 1.

Figure 1. Cities geographic location.

Table 2. Main characteristics of the cities analyzed.

City/Country	Average annual temperature (°C)	Maximum annual temperature (°C)	Minimum annual temperature (°C)	Average annual rainfall (mm)	Latitude (Deg)	Köppen-Geiger climate classification	
Hermosillo/México	20.67	28.0	13.0	26.70	29	Bwh	Dry, warm desert
Cartago/Costa Rica	19.37	20.5	17.6	1504.70	10	Af	Tropical rain forest
San Salvador/El Salvador	24.17	26.0	23.0	979.00	13.7	Aw	Tropical savanna with dry winter
Quito/Ecuador	14.00	14.0	14.0	2743.00	0.13	Cfb	Mild Temperate humid with hot summer
Santa Marta/ Colombia	25.75	26.0	25.0	1777.00	11.3	As	Tropical savanna with dry summer
La Paz/Bolivia	7.17	9.0	4.0	561.00	16.5	Cwb	Mild temperate with dry winter and warm summer
Manaus/Brazil	27.25	28.0	26.0	1811.00	3.1	Am	Tropical monsoon
Puerto Santa Cruz/ Argentina	15.42	24.0	8.0	135.00	50	Bsk	Steppe (semi-arid) with arid cold

WHAT IS KÖPPEN-GEIGER CLIMATE CLASSIFICATION?

Köppen-Geiger climate classification divides climates into five big groups and many types and sub-types. Each climate is represented by a variable number of letters with the following meaning:

The first one is a capital letter ("A", "B", "C", "D" and "E") that refers to the region climate group: tropical, dry, temperate, continental and polar.

The second one is a lower-case letter that refers to the climate type within the climate group, regarding the amount and distribution of rainfall.

The third small letter refers to the monthly mean air temperature of the warmest month and the annual mean temperature.

In groups "B" or "E", where the second letter is also a capital one, the rainfall and temperature are annual total references.

Table 3. Köppen Geiger Classification – First and second letter.

First and second letter		
Type	**Description**	**Criterion**
A	Tropical climates	$T_{min} \geq +18$ °C
Af	Tropical rain forest	$P_{min} \geq 60$ mm
Am	Tropical monsoon	$P_{ann} \geq 25(100 - P_{min})$ mm
As	Tropical savvana with dry summer	$P_{min} < 60$ mm in summer
Aw	Tropical savvana with dry winter	$P_{min} < 60$ mm in winter
B	Dry climates	$P_{ann} < 10\ P_{th}$
BW	Desert (arid)	$P_{ann} \leq 5\ P_{th}$
BS	Steppe (semi-arid)	$P_{ann} > 5\ P_{th}$
C	Mild Temperate	-3 °C < T_{min} < +18 °C
Cs	Mild Temperate with dry summer	$P_{smin} < P_{wmin}$, $P_{wmax} > 3\ P_{smin}$, $P_{smin} < 40$ mm
Cw	Mild Temperate with dry winter	$P_{smax} > 10\ P_{wmin}$, $P_{wmin} < P_{smin}$
Cf	Mild Temperate, fully humid	Not Cs or Cw
D	Snow	$T_{min} \leq -3$ °C
Ds	Snow with dry summer	$P_{smin} < P_{wmin}$, $P_{wmax} > 3\ P_{smin}$, $P_{smin} < 40$ mm
Dw	Snow with dry winter	$P_{smax} > 10\ P_{wmin}$, $P_{wmin} < P_{smin}$
Df	Snow, fully humid	Not Ds or Dw
E	Polar	$T_{max} < +10$ °C
ET	Tundra	$T_{max} \geq 0$ °C
EF	Frost	$T_{max} < 0$ °C

Table 4. Köppen Geiger Classification – Third letter.

Third letter		
Type	**Description**	**Criterion**
h	Hot arid	$T_{ann} \geq +18$ °C
k	Cold arid	$T_{ann} < +18$ °C
a	Hot summer	$T_{max} \geq +22$ °C
b	Warm summer	$T_{max} < +22$ °C, 4 $T_{mon} \geq +10$ °C
c	Cool summer	$T_{max} < +22$ °C, 4 $T_{mon} < +10$ °C, $T_{min} > -38$ °C
d	Cold summer	$T_{max} < +22$ °C, 4 $T_{mon} < +10$ °C, $T_{min} \leq -38$ °C

Source Chen, D. and H. W. Chen, 2013: Using the Köppen classification to quantify climate variation and change: An example for 1901–2010. Environmental Development, 6, 69-79, 10.1016/j.envdev.2013.03.007.

6. Case studies and types of health care facilities

6 types of health care facilities were chosen based on some of the options available in EDGE. For each type, minimum characteristics were defined, some of which correspond to information EDGE sets by default. The following table shows a summary of the main characteristics. More detailed information for each of them can be found in Appendix 2.

Table 5. Main characteristics of the 6 buildings analyzed.

Type of building	Area (m^2)	Floors	Landscaping area	Average occupancy rate	Laundry and kitchen
Outpatient Clinic I (CPA1)	300	1	60	70%	No
Outpatient Clinic II (CPA2)	1,500	1	300	70%	No
Diagnostic Center (DC)	5,000	2	400	70%	No
Multi-Specialty Hospital (MSH)	12,034	3	1200	70%	Yes
Teaching Hospital (TH)	20,017	6	1500	70%	Yes
Nursing Home (NH)	3000	2	300	70%	Yes

7. Simulations: passive design and active design

Two simulation were run for the 48 case studies (8 cities and 6 types). In each of them, the measures provided by EDGE to calculate energy, water and embodied energy in materials were included.

EDGE assumes certain design characteristics that must be ratified or rectified when entering the project's data. This way, EDGE sets a base case that already has some measures and typical constructive practices in the countries where the projects are carried out. If the user does not adjust this information, EDGE will assume these characteristics both for the base case and for the recommended savings. Additionally, EDGE requires specific mandatory information for certain measures. These are called minimum measures and are identified with an asterisk (*).

7.1 Energy

In this category, the measures were defined to reach the EDGE standard –a minimum 20% saving in comparison to the base case.

The following table shows the measures available in the platform.

Table 6. EDGE Energy Saving Measures[4].

*HSE01. Reduced window to wall ratio in the exterior façade
HSE02. Reflective paint/tiles for roof: solar reflectivity (albedo) 0.7
HSE03. Reflective paint/tiles for external walls: solar reflectivity (albedo) 0.7
HSE04. External shading devices - Annual average shading factor (ASSF) 0.61
*HSE05. Insulation of roof surfaces - U-value: 0.297
*HSE06. Insulation of external walls - U value: 0.289
HSE07. Low-E coated glass - U-value: 3 W/m². K and SHGC: 0.45
HSE08. Higher thermal performance glass - U-value: 1.95 W/m².K and SHGC: 0.28
HSE09. Natural ventilation – Corridors
HSE10. Natural ventilation - Lobby, waiting and consultation areas
HSE11. Natural ventilation – Patient rooms
*HSE13. Variable refrigerant volume (VRV) cooling system COP of 3.5
*HSE14. Air conditioning with air cooled chiller - COP of 3.3
*HSE15. Air conditioning with water cooled chiller - COP of 5.2
HSE20. Variable speed drives in ahu
HSE21. Variable speed drives pumps
HSE22. Sensible heat recovery from exhaust air 60% efficiency
HSE29. Energy – saving light bulbs – Internal spaces (except OT)
HSE30. Energy – saving light bulbs – External spaces
HSE32. Lighting controls for corridors
HSE33. Occupancy sensors in bathrooms
HSE35. Solar hot water collectors - 60% of hot water demand
HSE36. Solar photovoltaics - 10% of total energy demand

4 Not all the measures offered by EDGE are included, just the most relevant ones and those chosen for the case studies. The measures with * are the minimum required by EDGE, for which mandatory information of the project has to the entered.

The measures for each simulation were chosen following this criterion[5]:

Table 7. Main differences between energy simulations.

ENERGY	
Simulation 1	**Simulation 2**
It includes both the minimum measures and the mandatory EDGE information with its default values, such as passive strategies measures.	Besides the minimum measures and the mandatory EDGE information with its default values, only active design strategies are included. Measures such as external shading devices and natural ventilation are left out.
These measures include: External shading devices –to avoid and/or reduce the effect from direct solar radiation in the project– and natural ventilation in lobbies, corridors and patients' rooms, which may help reduce the energy loads.	These measures include: VRF high efficiency cooling systems, solar hot water collectors for 60% of hot water demand and solar photovoltaic panels for 10% of the electric demand.
Additionally, though not mandatory, efficient lighting is present in all cases: Saving light bulbs like LED or fluorescent in internal or external spaces, automatic controls and occupancy sensors.	

5 It is important to take into account that EDGE does not consider energy saving measures related to medical equipment, therefore this factor is not considered for this analysis. When EDGE mentions equipment and their energy saving, it refers to electromechanical equipment

7.2 Water

In this category, the measures were also chosen to reach the EDGE standard –a minimum 20% saving in comparison to the base case.

The following table shows the measures available in the platform.

Table 8. EDGE Water Saving Measures[6].

*HSW01. Low-flow showerheads - 7 liters/min
*HSW02. Low-flow faucets in all bathrooms 2 liters/min
*HSW03. Dual flush for water closets in all bathrooms 6 liters for the first flush, 3 liters for the second flush
*HSW04. Water efficient urinals in all bathrooms - 2 liters per flush
*HSW07. Water efficient dishwashers - 6 liters/min
HSW09. Water efficient landscaping - 4 liters/m2/day
HSW12. Grey water treatment and recycling system

The measures for each simulation were chosen following this criterion:

Table 9. Main differences between water simulations.

WATER	
Simulation 1	**Simulation 2**
It includes the minimum measures and the mandatory EDGE information without flow variation regarding the default values.	Additional measures are added to S1.
These measures include: Flows of 7 liters/min for showers and 2 liters/min for bathroom washbasins, 6 liters for the toilet's first flush and 3 liters for the second one, 2 liters per flush for urinals and 6 liters/min for kitchen sinks.	These measures include: Grey water treatment and, for higher scale projects (MSH, TH), efficient use of water for landscaping areas.

6 Not all the measures offered by EDGE are included, just the most relevant ones and those chosen for all the case studies. The measures with * are the minimum ones. EDGE requires mandatory information about them

7.3 Materials

Materials were carefully chosen to be used in all types of buildings. Besides, they allowed the comparison of costs per construction square meter.

Most of these materials reach the standard of 20% saving in embodied energy. They also positively affect the energy category, reducing the demand for this resource. Thus, operational costs related to air conditioning and heating decrease.

The following table shows the materials chosen according to the categories available in EDGE and the criterion for their selection.

Appendix 4 shows the summary of the measures considered in the 96 simulations. All of these reached the following savings compared to the baseline: 20% in energy, 20% in water and 20% in embodied energy in materials.

Table 10. EDGE Materials efficiency measures chosen.

MEASURE	MATERIAL	JUSTIFICATION
*HSM01. Floor slabs	*In situ* reinforced concrete slab 350 mm.	Widely used material in the region for this kind of structure. Default dimensions (350 mm) and reinforcing steel (35kg/m²) are used.
*HSM02. Roof construction	*In situ* reinforced concrete slab 200 mm.	Material that can be used for all the types of buildings. It supports a minimum of electromechanical equipment.
*HSM03. External walls	3-D wire panel with 'shot-crete' both sides and core of expanded polystyrene	High insulation efficiency material.
*HSM04. Internal walls	3D wire panel with 'shot-crete' both sides and core of expanded polystyrene*	To keep the same criterion as with external walls
*HSM05. Flooring	Ceramic tile	Widely used material in the region's health care buildings
*HSM06 Window frames	Unplasticized PVC (UPVC)	High-efficiency material and lower incremental cost than others
HSM07. Walls insulation	Mineral wool (U: ~ 1.86 W/m²k) /A	Widely used material in the region, high efficiency, and low cost
HSM08. Roof insulation	Fiber glass (U: ~ 1.99 W/m²k) /A	Widely used material in the region, high efficiency, and low cost

* According to EDGE User Guide, the 3-D wire panel with 'shot-crete' both sides consists of the following elements: i) Welded reinforcing mesh of high wire diameter 3mm and a mesh size 50 × 50 mm; ii) Diagonal wire (stainless or galvanized) of diameter 4 mm; iii) Core of expanded polystyrene of thickness 50 – 120 mm; iv) Concrete sprayed on the wire structure. That is why, although the software (version 2.1 5) calls the material just "3D wire panel with 'shot-crete' both sides", it includes this insulation and, therefore, this document includes the core of expanded polystyrene as part of the material description

Tips

Reflective paint on walls and surfaces is effective. However, its cost-effectiveness depends on the climate, the kind of wall and surface. This kind of paint is not necessary if high-thermal inertia materials are chosen.

Bioclimatic architecture is a good strategy to reduce the energy demand for cooling. However, due to the complexity of health care facilities , air quality, specific temperature of the environments, and the desired comfort conditions should prevail.

The grey water treatment and recycling system represents a high water saving and a low incremental cost.

UPVC window frames have a lower incremental cost and less embodied energy than aluminum window frames.

Efficient lighting should always be used –by means of saving light bulbs or occupancy sensors– even if the design is bioclimatic and takes full advantage of natural lighting. Otherwise, the 20% saving standard will not be reached.

Reflective paint and external shading devices are very useful to save energy in warm climates. However, in cold climates it is necessary to include thermal insulation, since it reduces the heating energy requirements. Although climate thermal insulation is useful in warm climates, the color of the surface will its efficiency, since it reduces the solar radiation effect.

The use of water-efficient irrigation systems is more profitable in large areas. For small areas, the incremental cost is too high compared to the savings. Especially in these cases, it is recommended to use native species to avoid artificial irrigation.

One of the most efficient material is the 3-D wire panel with ‘shot-crete’ both sides and core of expanded polystyrene. It reduces the need for thermal conditioning equipment.

* For example, in top notch centers, health stations or residencies, a bioclimatic architecture might be enough. However, special care areas or surgery centers may require other thermal and air quality conditions where, even in favorable conditions, bioclimatic architecture is not an option. Even inside a hospital, some sectors can be solved without active measures, while others may require specific equipment.

8. Simulations results: savings

8.1 Energy

Two simulations were run for each type and city. The following Figures show the savings in energy.

In the case of **Outpatient Clinic 1 (OC1)** there were more savings by using active measures (S2) that passive ones (S1). Compared to the baseline for S1, the saving is between **22% and 36%**, whereas for S2, the saving is between **43% and 48%**.

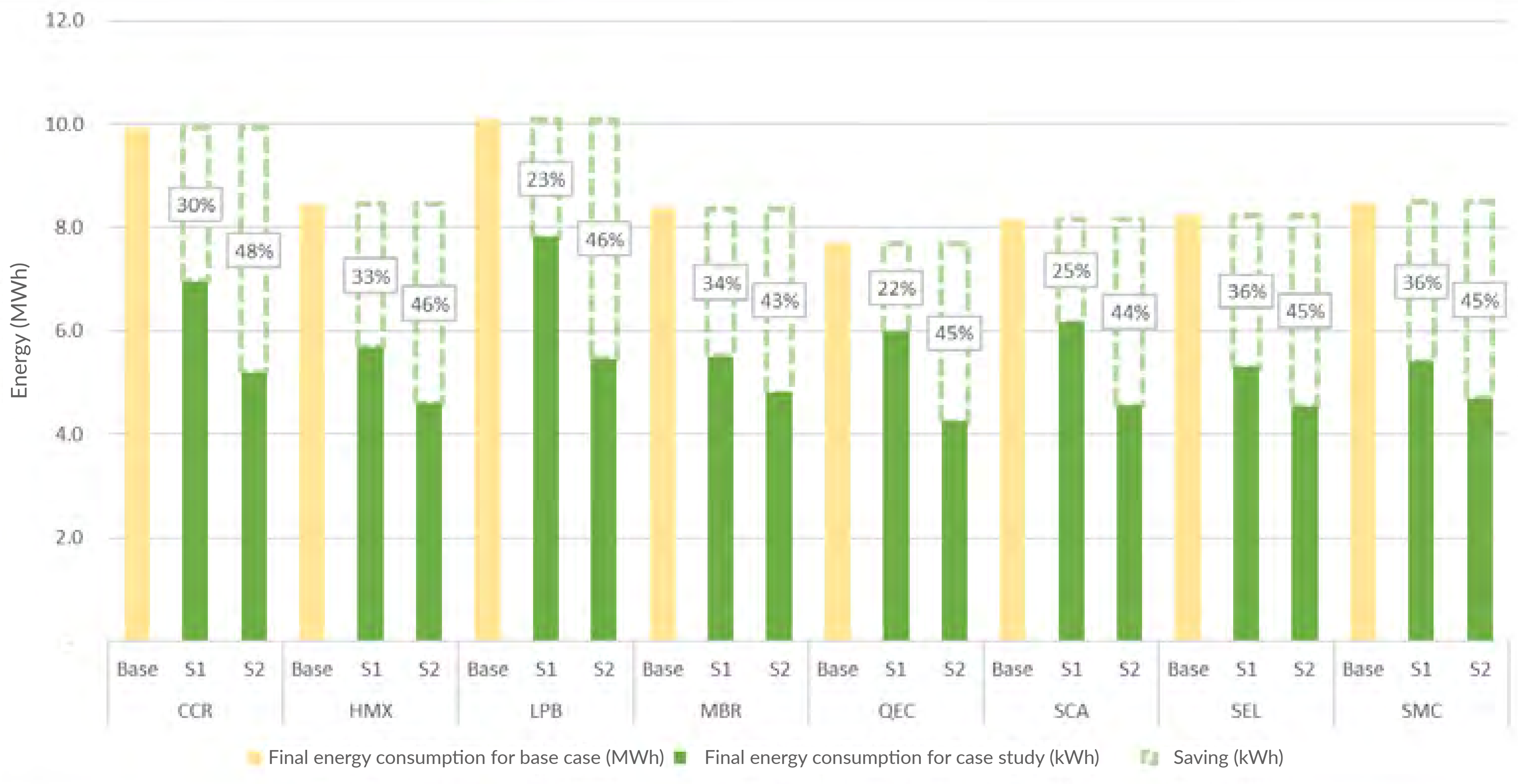
This kind of building usually consumes between 8.1 MWh and 10.0 MWh per month, depending on the city. The consumption can be between 5.1 MWh and 7.9 MWh per month applying passive measures, and between 4.1 MWh and 5.1 MWh per month with active ones.

In **Outpatient Clinic 2 (OC2)** there are more savings by using active measures (S2) than passive ones (S1). For S1, the saving is between **20% and 31%**, whereas for S2, the saving is between **35% and 40%**.

Besides, this type of building usually consumes (base case) between 34.0 MWh and 40.0 MWh per month, depending on the city. Energy saving strategies allow a reduction between 21.5 MWh and 30.0 MWh per month for S1, and between 20.0 MWh and 29.0 MWh per month for S2.

In **Diagnostic Center (DC)** the saving gap between S1 and S2 in the same city is reduced. However, the energy saving varies from 22% to 50% between the different cities.

Figure 2. Outpatient Clinic 1- Energy savings per city.



Energy saving measures allow reductions between 81.0 MWh and 110.0 MWh per month for S1, and between 75.0 MWh and 92.0 MWh per month for S2. Whereas the consumptions for the base case are between 116.0 MWh and 181.0 MWh per month.

Another interesting fact is that in La Paz, Bolivia, energy consumption is much higher than in the rest of the cities because of the heating demand. It is also where more energy savings can be reached.

Multi-Specialty Hospitals (MSH) show differences with the previous cases. These are more complex buildings, with high incidence of medical and electromechanical equipment. They have high energy consumption, between 380.0 MWh and 610.0 MWh per month.

Figure 3. Outpatient Clinic 2- Energy savings per city.

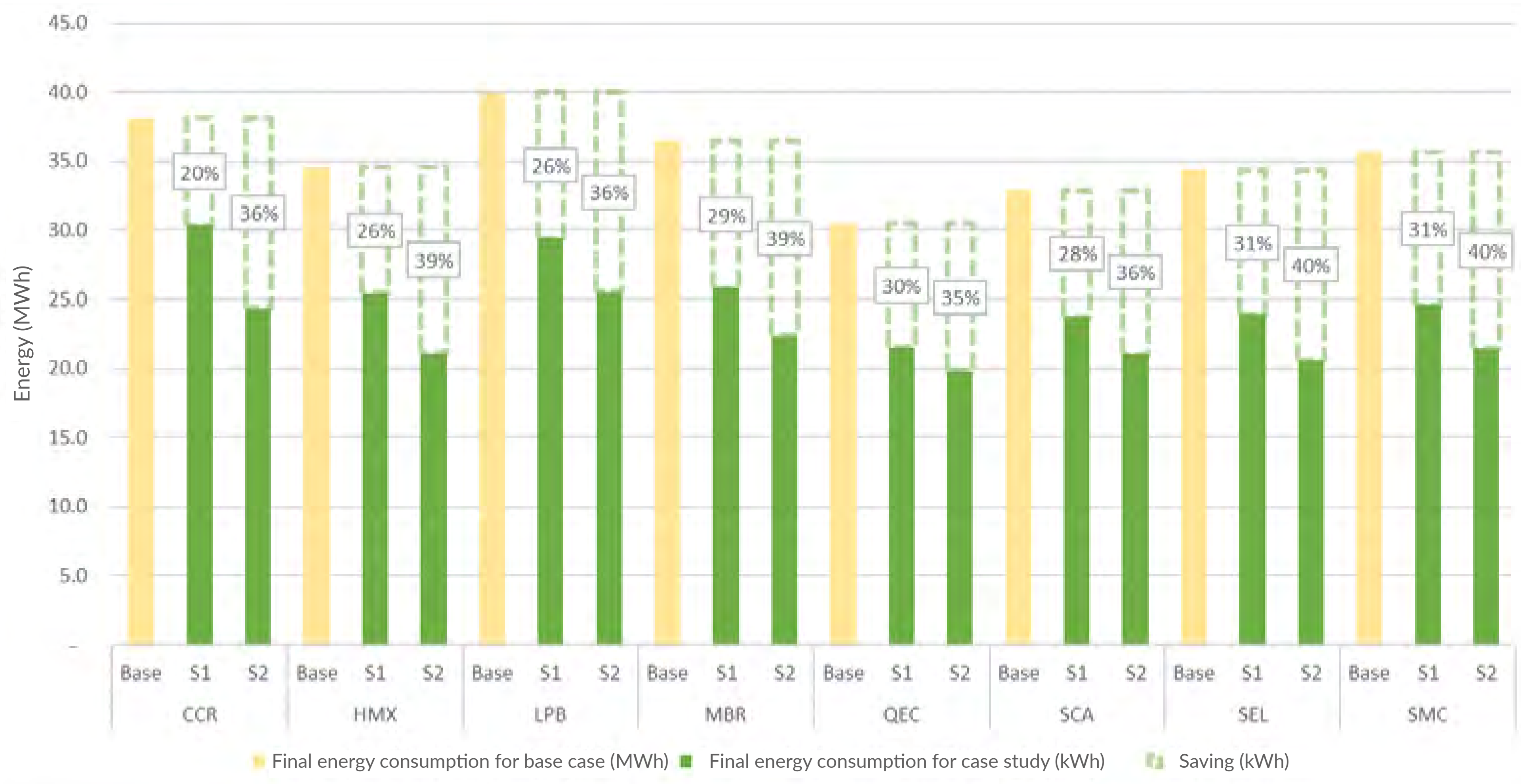


Figure 4. Diagnostic Center - Energy savings per city.

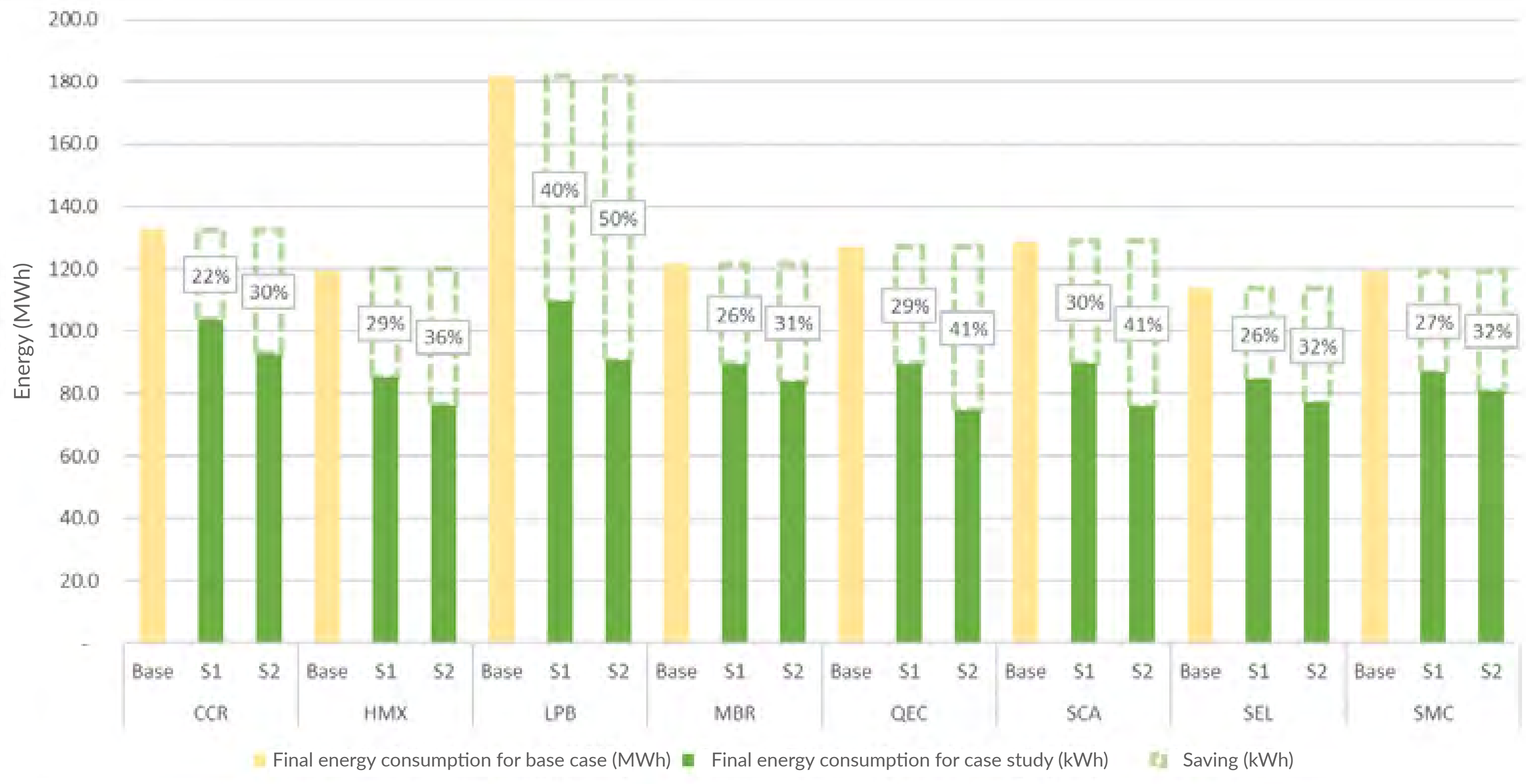


Figure 5. Multi-Specialty Hospital - Energy savings per city

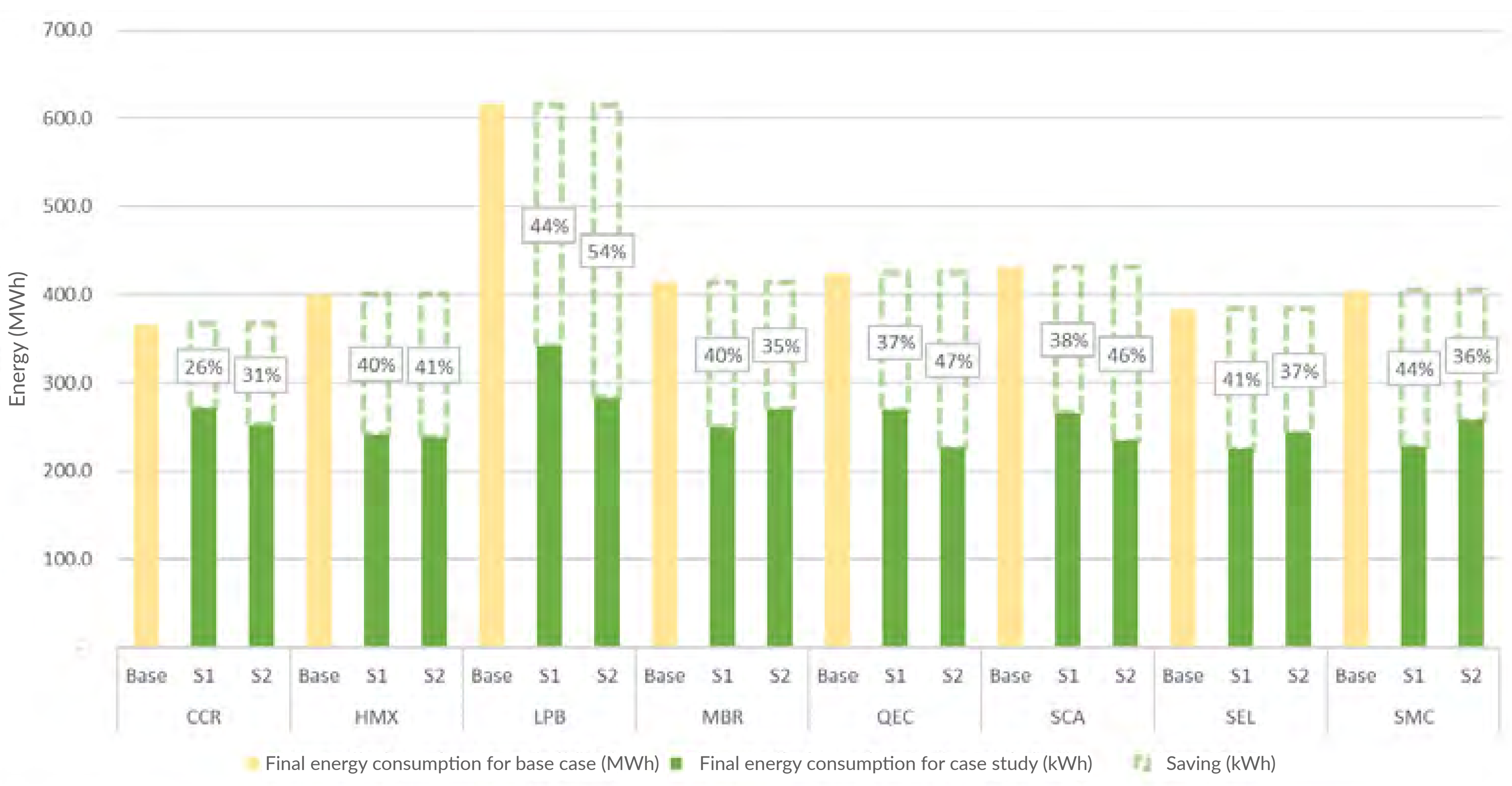
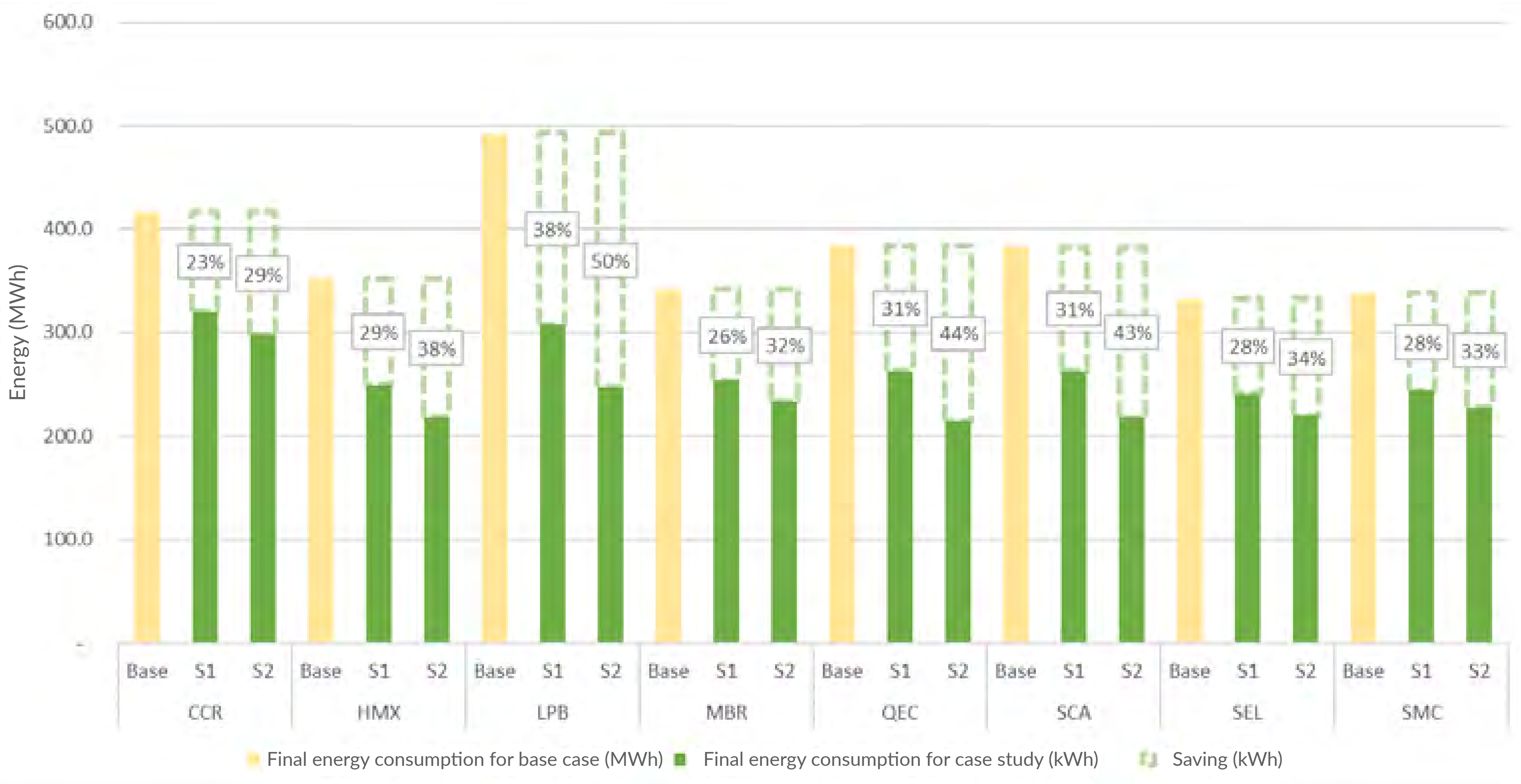


Figure 6. Teaching Hospital - Energy savings per city.



There is almost no difference in saving between S1 and S2 in this type of building and in the Diagnostic Center.

The savings obtained in S1 and S2 vary in each country. The lowest saving percentage, 26%, is found in the S1 of Cartago, Costa Rica, and the highest one, 54%, in the S2 of La Paz, Bolivia. However, the latter has the highest consumption in the base case.

In Hermosillo, Mexico (HMX) the use of natural ventilation and external shading devices in S1 represents a saving of 9.27%. In S2 there is a saving of 10.21%. This simulation includes measures of solar hot water collectors for 60% of hot water demand and solar photovoltaic panels for 10% of the electric demand.

In this case, the difference between S1 and S2 is around 1%. Nevertheless, the incremental cost of S2 increases almost in USD 200,000 due to the high cost of the equipment required for the chosen measures.

Teaching Hospitals (TH), as well as Multi-Specialty Hospitals, are complex buildings where the equipment has high incidence in the energy consumption. The usual consumption of this type of building is between 332.0 MWh and 493.0 MWh per month.

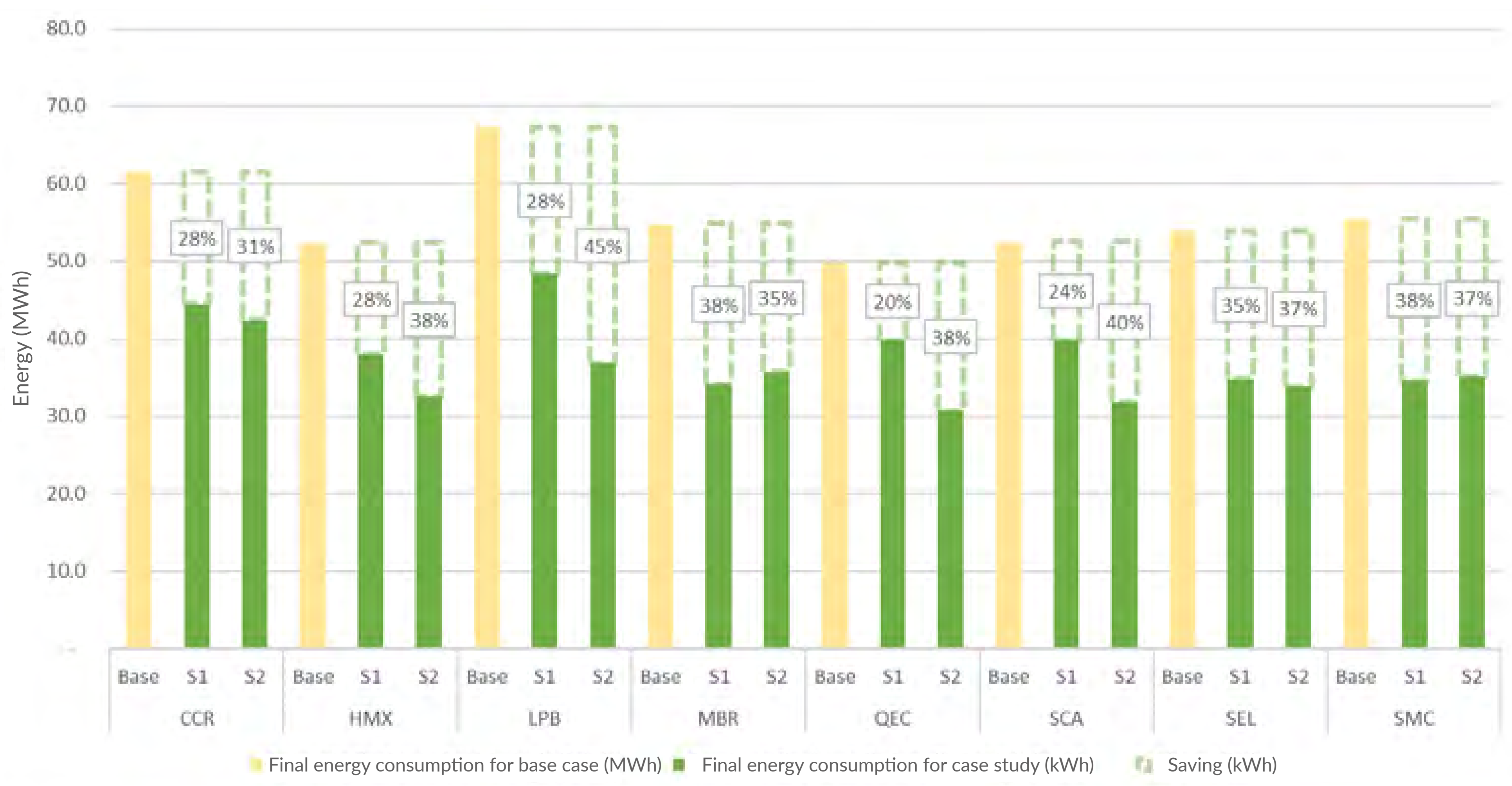
The energy saving varies between 23% and 50%, the same as the previous cases. S2 is the one that yields the best performance due to the active energy-saving measures used.

Lastly, in the case of the **Nursing Home (NH)**, the usual energy consumption is between 49.8 MWh and 67.2 MWh per month.

In this case, energy saving varies between 20% and 38% in S1, and between 31% and 45% in S2 when compared to the base case.

The case of Santa Marta, Colombia is a special one: S1 presents 1% more of saving in the energy category because the measures of external shading devices together with natural ventilation make up a saving of 15.44%. Nevertheless, in S2 the solar hot water collectors for 60% of hot water demand and the solar photovoltaic panels for 10% of the electric demand make up a saving of 12.34%. This shows that in cities with high temperatures, there is more potential to optimize the design by implementing passive design strategies.

Figure 7. Nursing Home - Energy savings per city.



HOW MUCH ENERGY DO HEALTH CARE BUILDINGS CONSUME?

Table 11. Energy consumption according to the building.

Type	Surface (m²)	Lowest monthly consumption (MWh)	Highest monthly consumption (MWh)	Average monthly consumption (MWh)	Average monthly consumption (kWh/m2)
Outpatient Clinic (OC1)	300	8.1	10.0	9.05	30.0
Outpatient Clinic (OC2)	1,500	34.0	40.0	37.0	24.7
Diagnostic Center	5,000	116.0	181.0	148.5	29.7
Multi-Specialty Hospital (MSH)	12,000	380.0	610.0	495.0	41.3
Teaching Hospital (TH)	20,000	332.0	493.0	412.5	21.0
Nursing Home (NH)	3,000	49.8	67.2	58.5	19.5

HOW DO HEALTH CARE FACILITIES CONSUME ENERGY?

After analyzing the information of the global consumption per type, buildings were classified in two groups: 1) Without hospitalization[7] and 2) With hospitalization[8].

Thus, it is possible to analyze how these buildings consume energy:

Those in group 1 (without hospitalization) in general do not have high-consumption electromechanical equipment, or equipment in kitchen and laundry, which those in group 2 have. That is why the highest energy consumption is reported in this kind of equipment.

The simulations run are compared below with example for each group in the city of Cartago, Costa Rica. In the example of Teaching Hospital (TH) there is a catering and laundry service component that has high incidence, which does not appear in the Diagnostic Center (DC).

Figure 8. Energy consumption / m² / year. CCR-DC-Simulation 1 and 2.

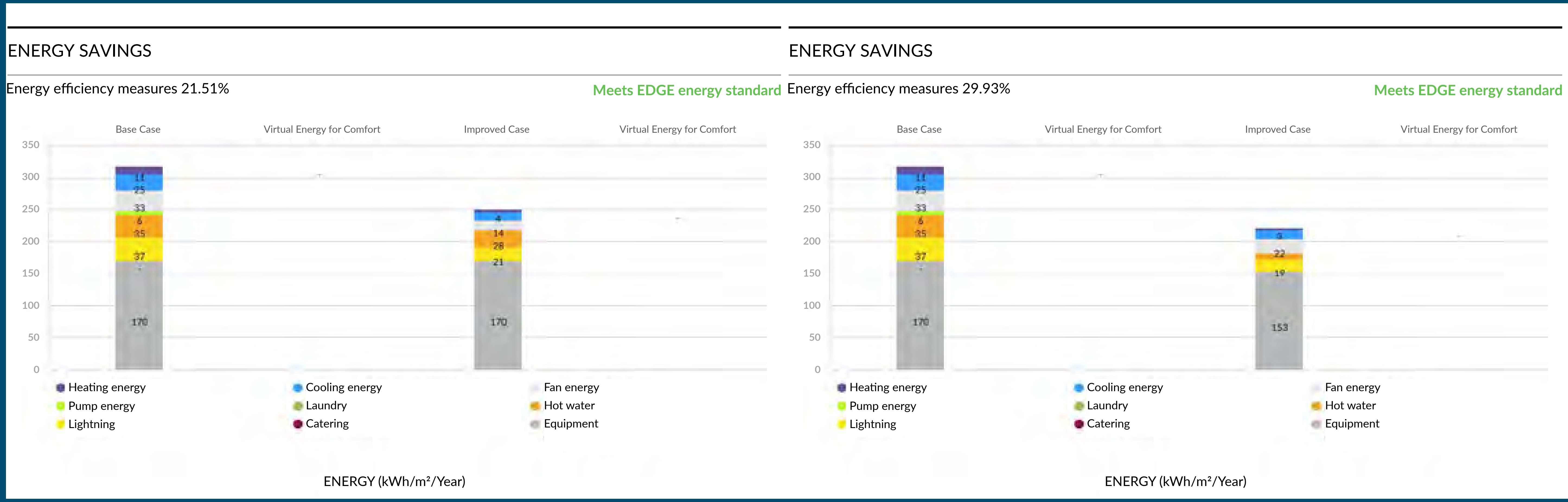
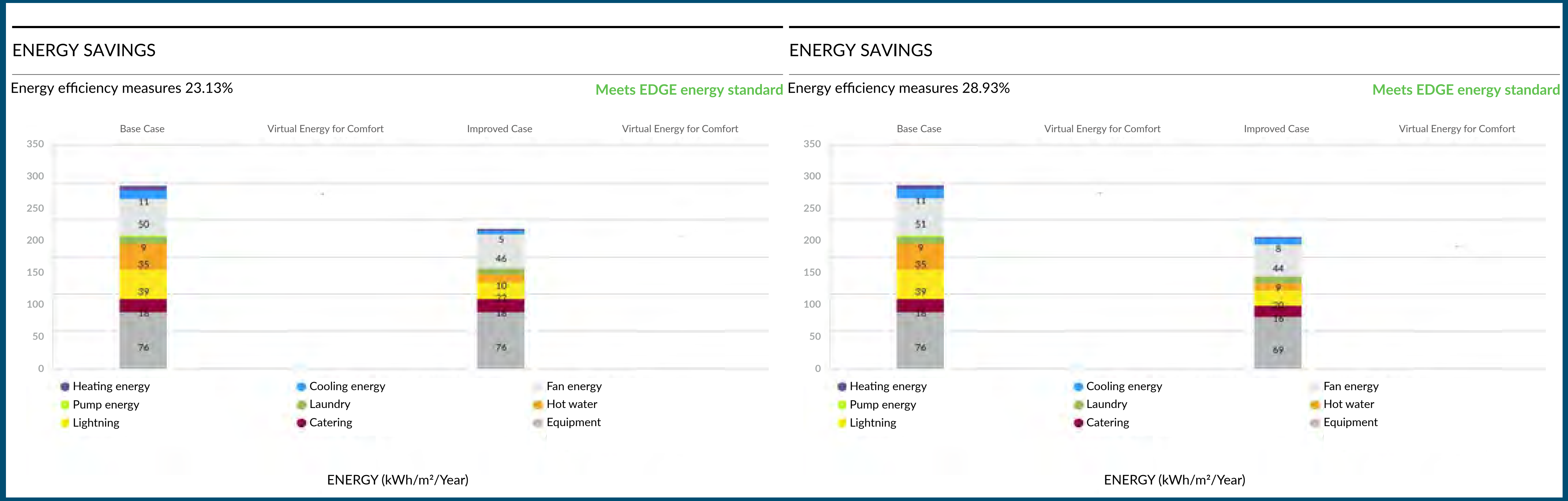


Figure 9. Energy consumption / m² / year. CCR-TH-Simulation 1 and 2



7 Including OC1, OC2, DC and NH. Although the latter has accommodation, it is not considered hospitalization

8 Including MSH and TH.

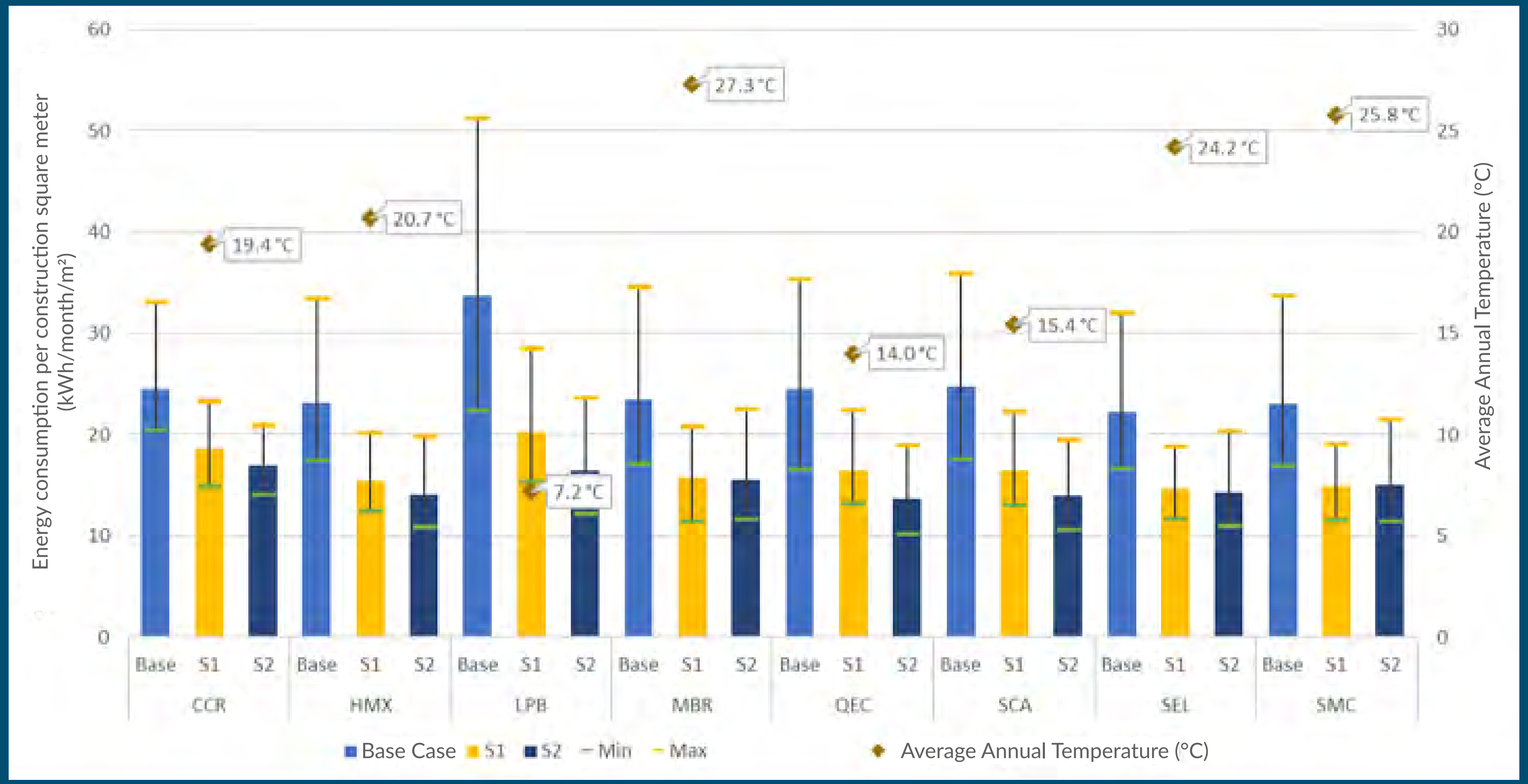
THE SPECIAL CASE OF LA PAZ, BOLIVIA

The case of La Paz, Bolivia has the highest energy consumption in its baseline. As mentioned above, the heating demand has great incidence.

If the consumption per square meter (m2) of all types is analyzed, it is concluded that the consumption per square meter in La Paz, Bolivia is significantly higher than in the other cities. Likewise, the average temperature is significantly lower.

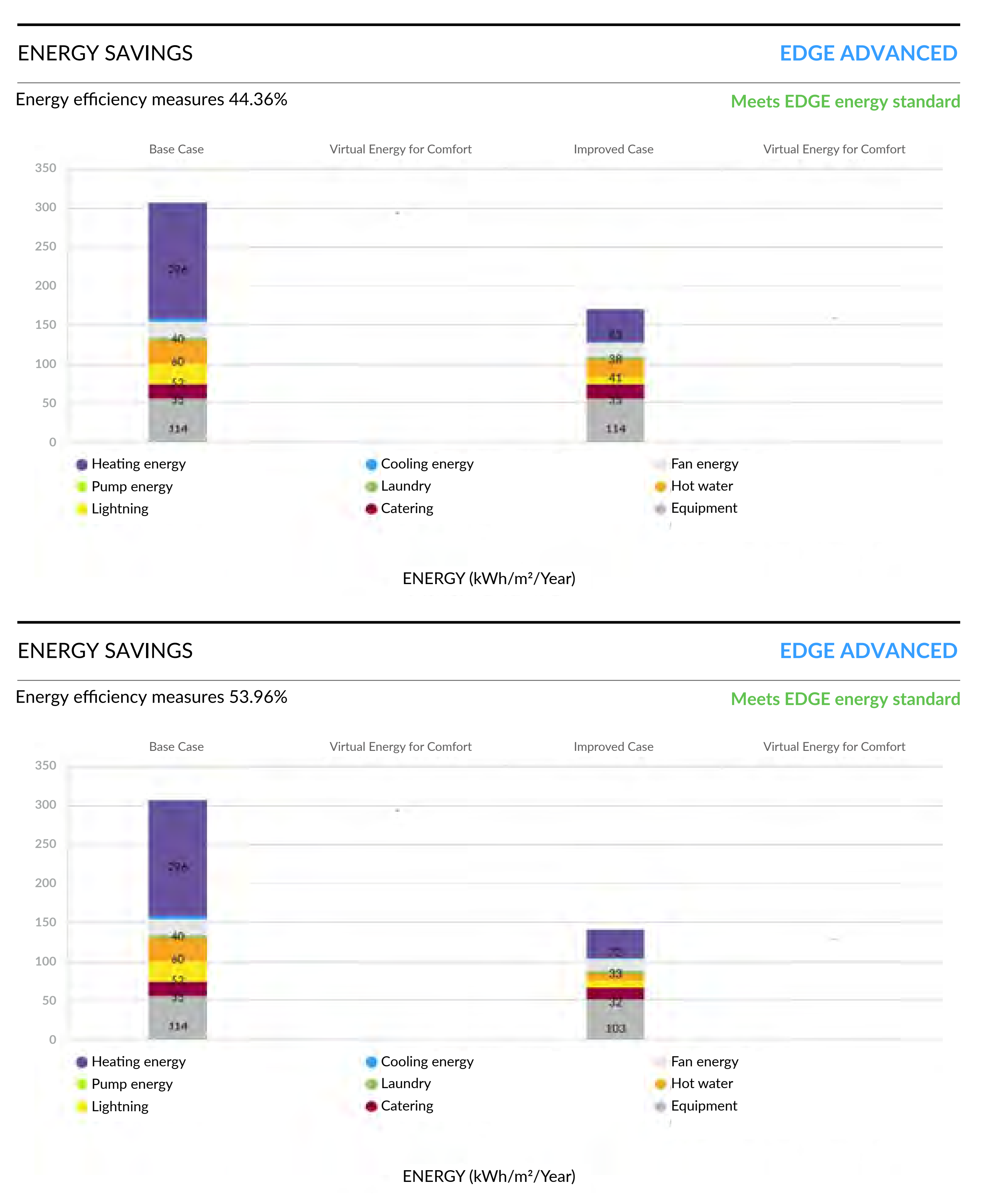
Analyzing Multi-Specialty Hospital, it is observed the impact cold climate has in the energy consumption for heating.

Figure 10. Average energy consumption per m^2 per city.



Note: The bars show the maximum and minimum values of the types.

Figure 11. Annual energy consumption (m^2 / year) Simulations 1 and 2.



8.2 Water

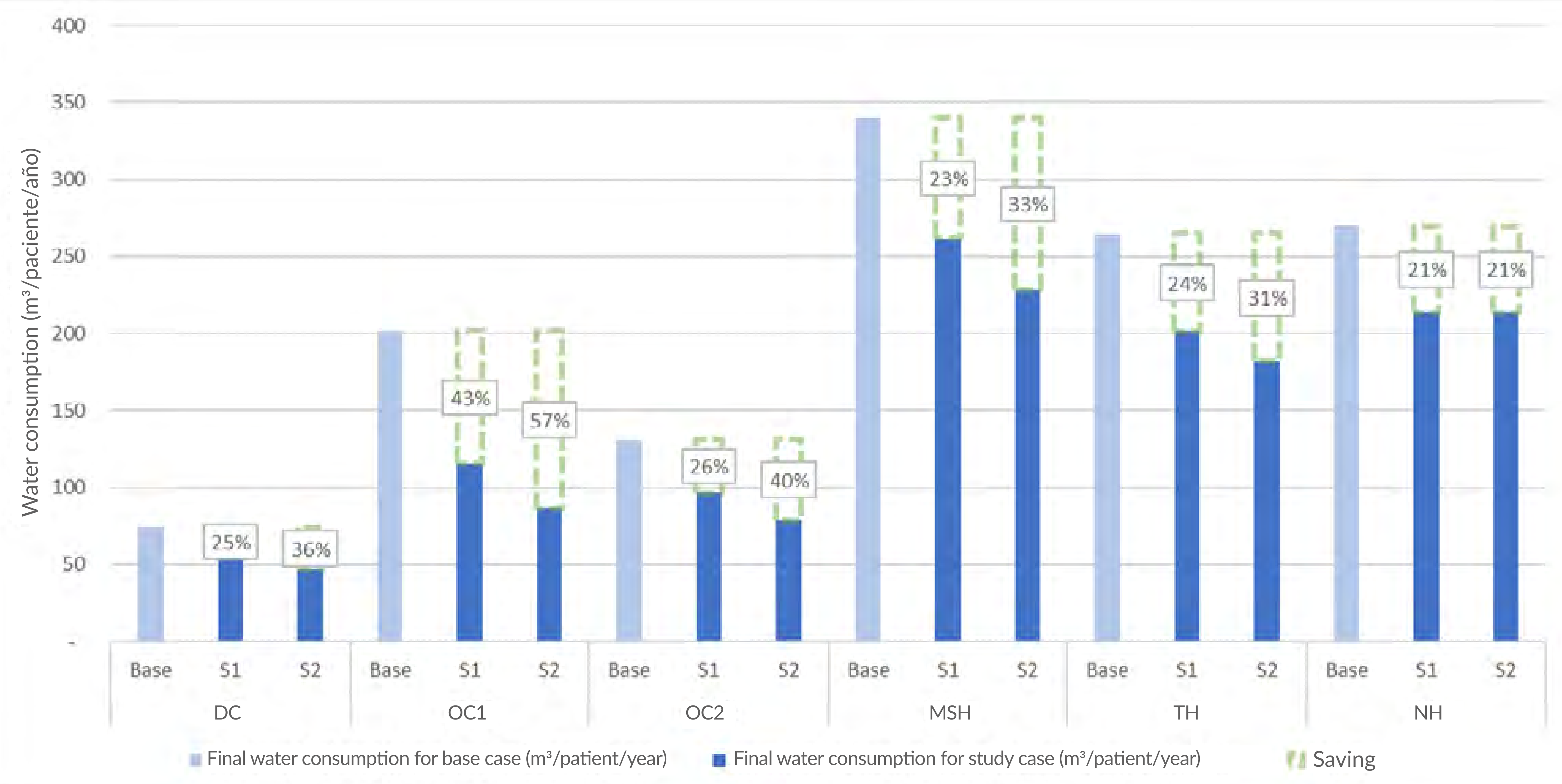
As regards water saving, two simulations for each type and city were run using the same methodology. In this case, the results are shown as average per city for all the types, since there were no significant differences between them.

The same saving measures were used for all the types. The result was the water consumption value per year per square meter, as well as the saving for S1 and S2.

The types of buildings could be classified according to the distribution of the final use of drinking water. **Two types of buildings** are identified: Those with **beds and laundry** (MSH, TH and NH), and those without them (OC1, OC2 and DC). The savings achieved for the types without beds were between 21% and 43%. Whereas, for the types with beds were between 23% and 33%.

When efficient faucets and toilets are implemented there is high consumption and saving. The size of the saving depends on the number of bathrooms the number of patients the building accommodates. However, if the catering service is added to buildings with beds and laundry, water consumption increases significantly.

Figure 12. Average daily water consumption (m³/patient) - Simulations 1 and 2.



HOW DO HEALTH CARE FACILITIES CONSUME WATER?

Buildings that do not have beds and laundry service show a similar drinking water consumption behavior. The following Figure shows the drinking water consumption distribution for the Diagnostic Center, both for S1 and S2. This distribution is similar for OC1 and OC2. The highest consumption and saving can be seen when adding the categories of faucets and bathroom fittings. Therefore, it is concluded that there is a direct relation between surface and water consumption.

Besides, the drinking water consumption distribution in the Teaching Hospital, both for S1 and S2, is very similar to that in a Multi-Specialty Hospital. Although the consumption proportion in faucets and bathroom fittings is directly related to the building's scale, food and laundry services make the difference in consumption.

Figure 13. Daily water consumption per patient. CCR-DC-Simulation 1 and 2.

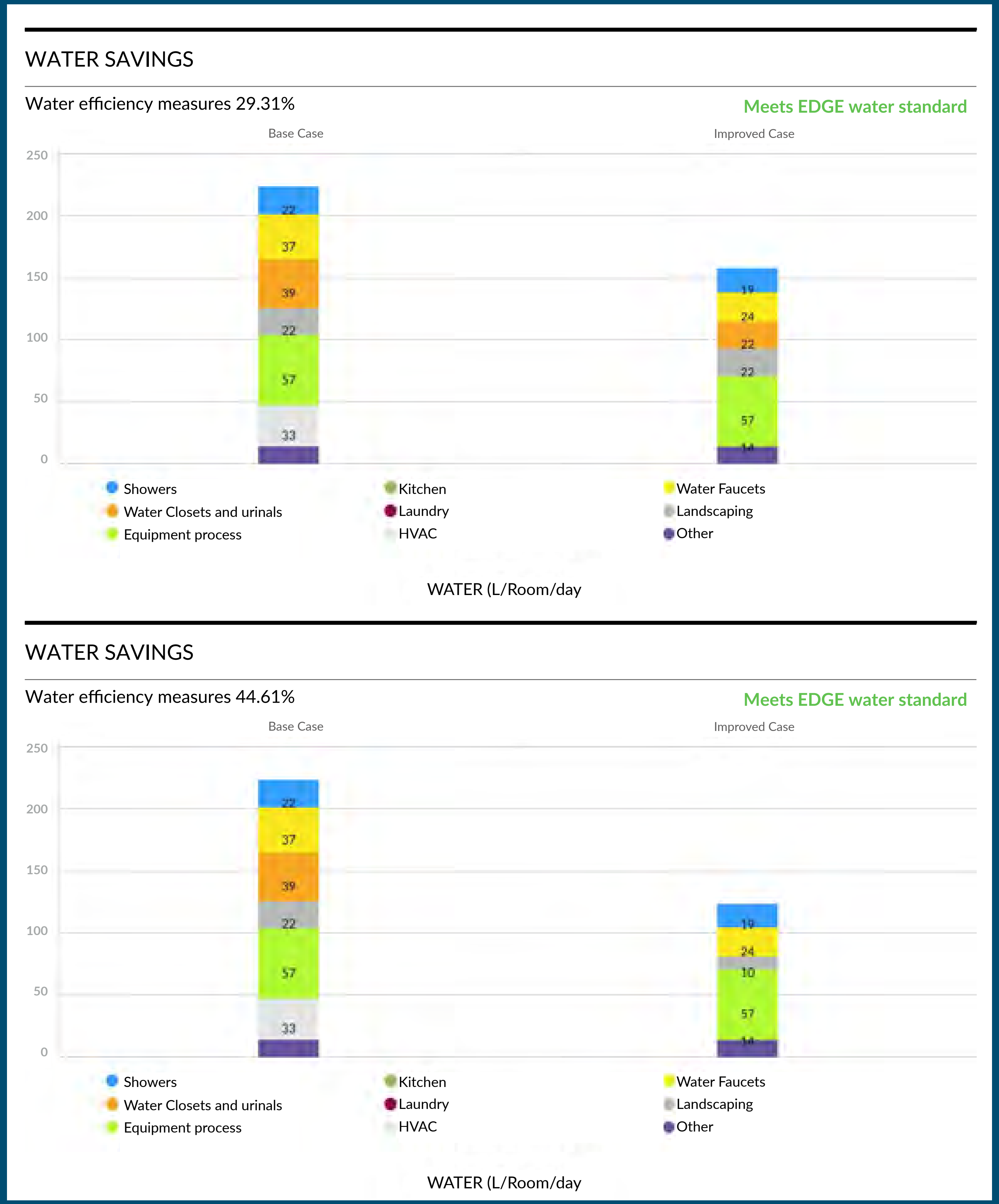


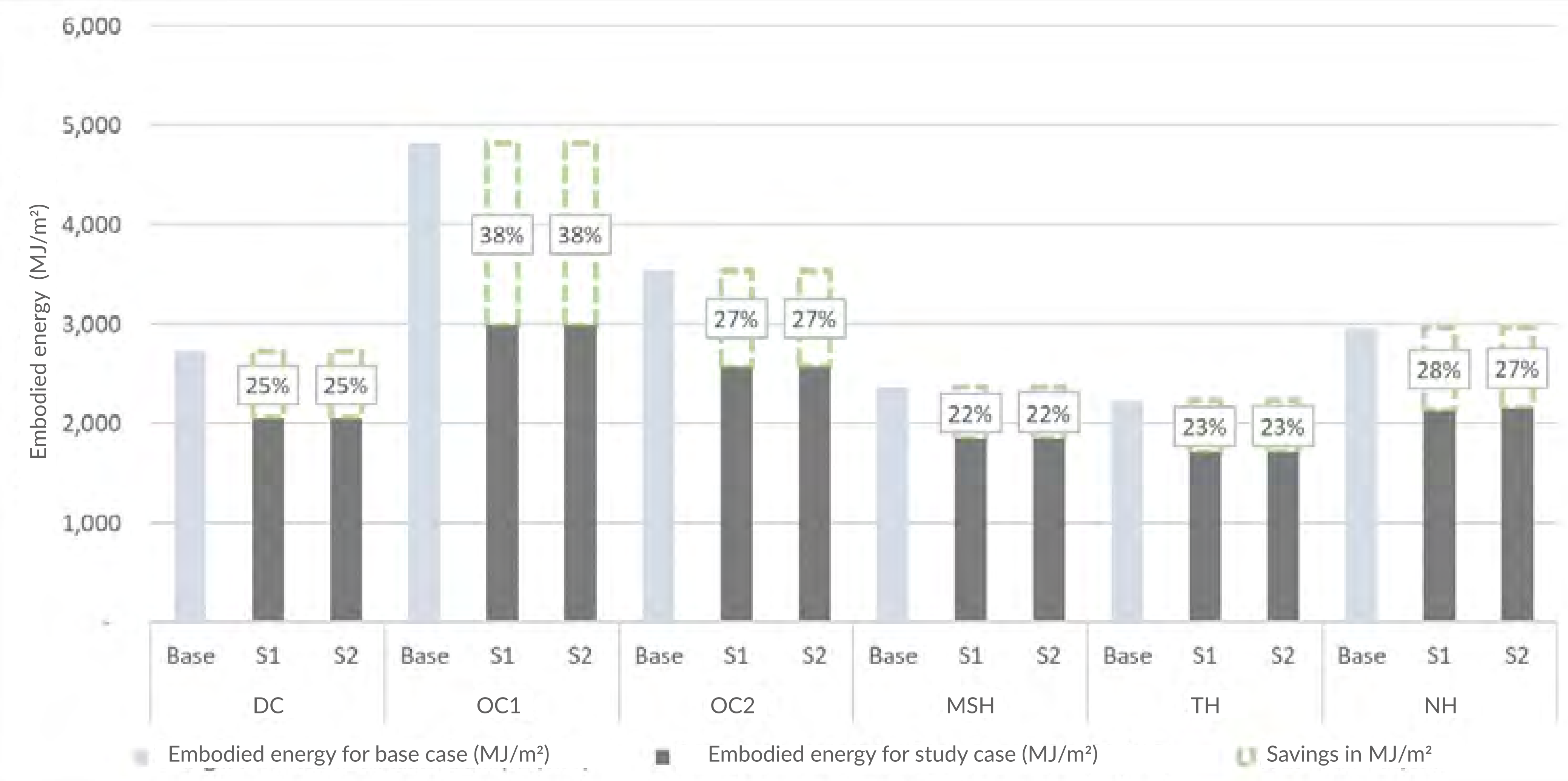
Figure 14. Daily water consumption per patient. CCR-TH Simulation 1 and 2.

8.3 Materials

There is no difference between the materials chosen for S1 and S2 –as explained in the previous chapter–, therefore, the results are virtually the same. As stated before, after several interactions with different kinds of material in EDGE, the combination that achieved the lowest incremental cost with the highest embodied energy saving was chosen.

In the case of materials, depending on the type of building, the embodied energy saving was between 22% and 38% compared to the baseline.

Figure 15. Average embodied energy in materials Simulation 1 and 2.



3D WIRE PANEL WITH ‘SHOT-CRETE’ AND POLYSTYRENE

Its for external and internal walls has a high impact on the embodied energy in materials and, additionally, affects the building’s conditioning needs. In the following example it can be seen how this solution, together with the use of U PVC window frames, reduces the embodied energy in materials by 24.76% for the case of the Diagnostic Center in Cartago, Costa Rica.

Similar results are observed when using the same material in a more complex building type, such as a Teaching Hospital, in the same city.

Figure 16. Embodied energy in materials / m^2 CCR-DC-Simulation 1 and 2.

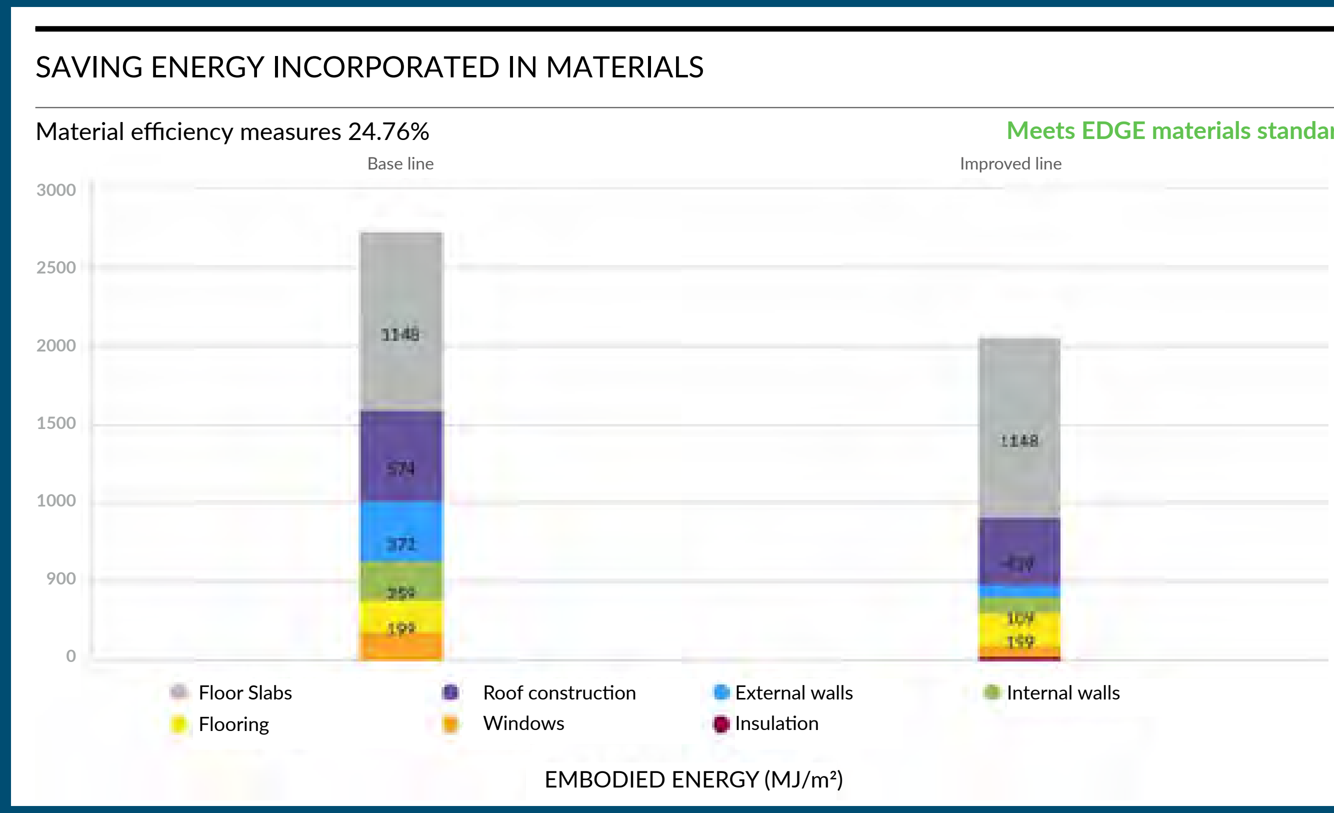
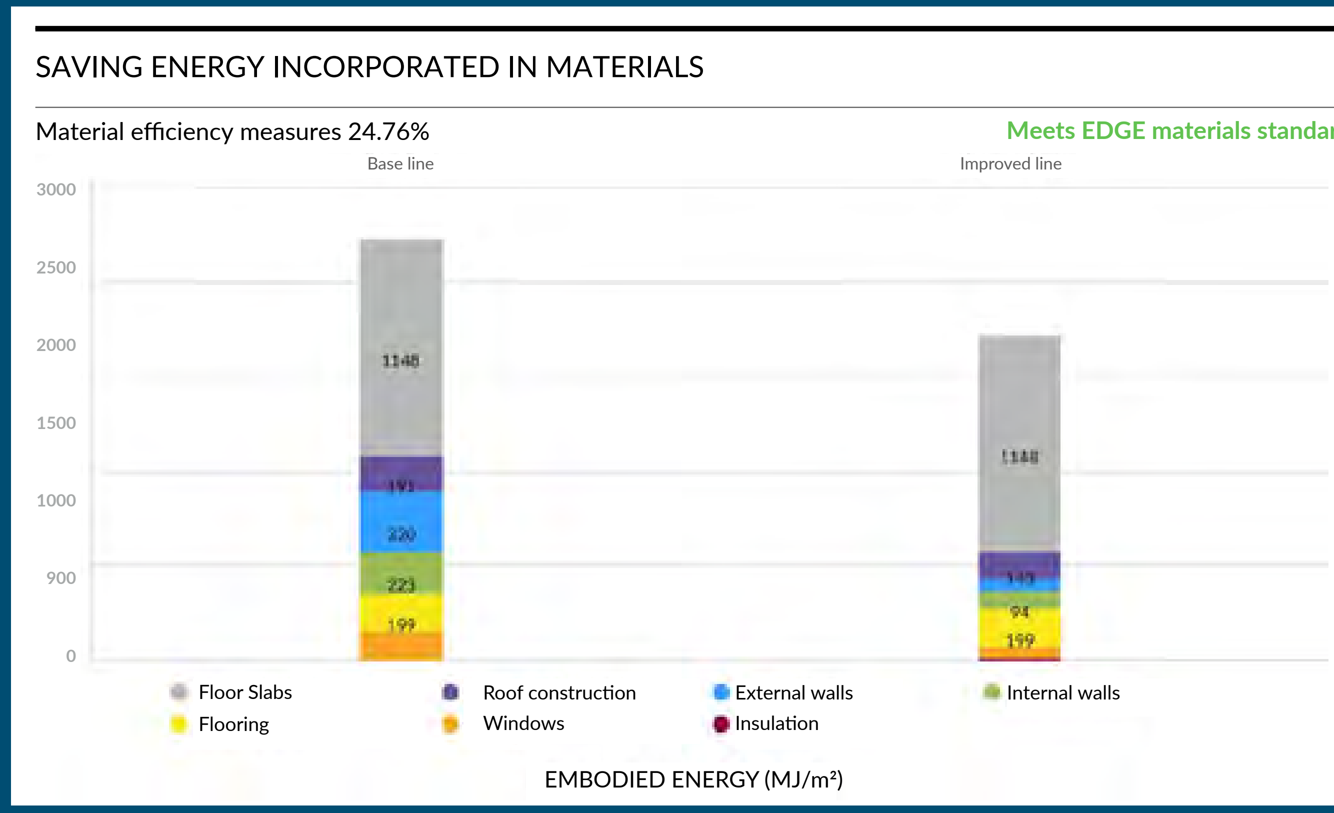


Figure 17. Embodied energy in materials / m^2 CCR-TH Simulation 1 and 2.



HOW MUCH CAN WE SAVE?

ENERGY

On average, 109 kWh per square meter of construction.

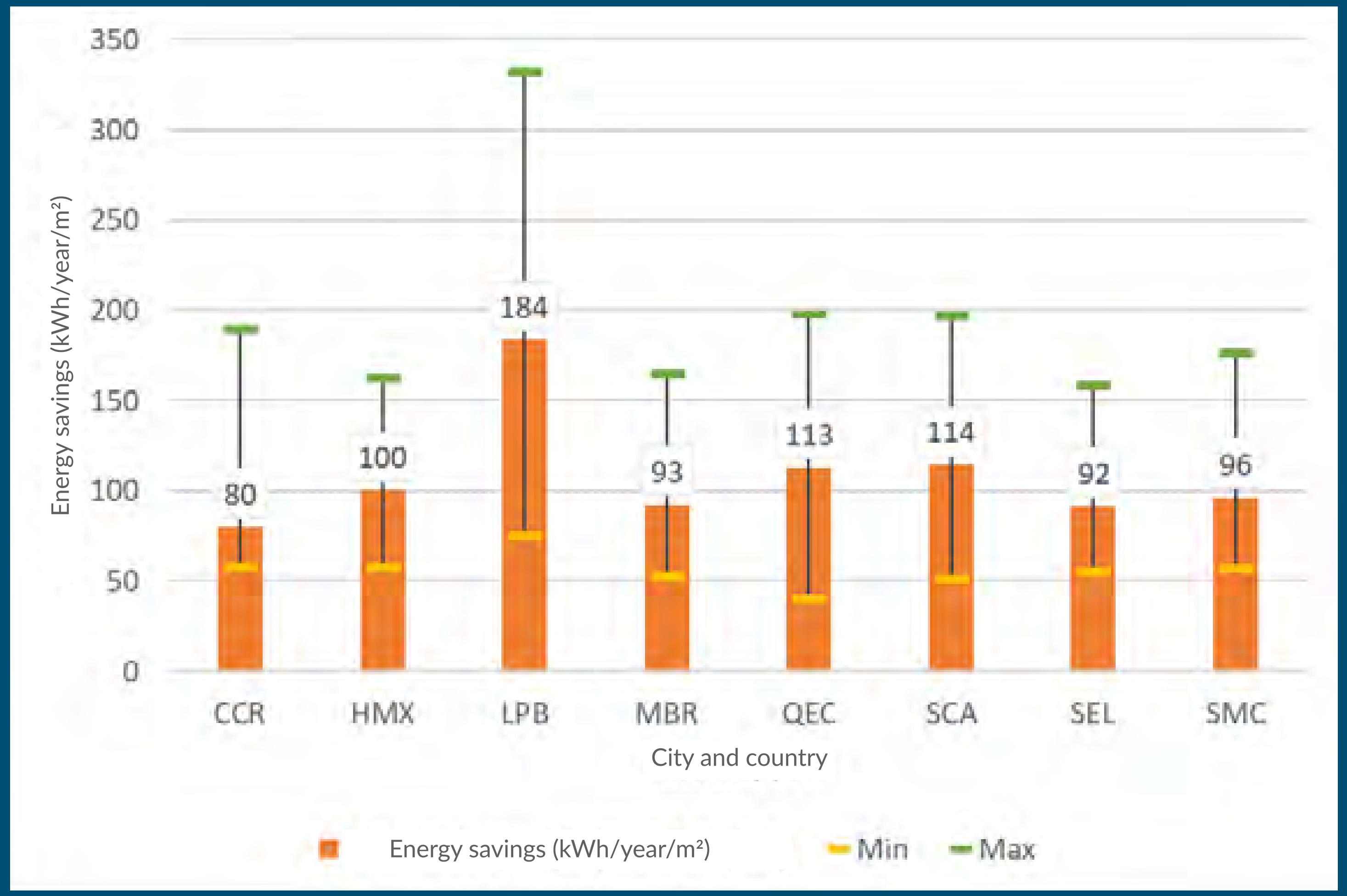


Figure 18. Annual energy savings per m² for different cities.

EMBODIED ENERGY IN MATERIALS

On average, 0.6 GJ in materials per square meter of construction.

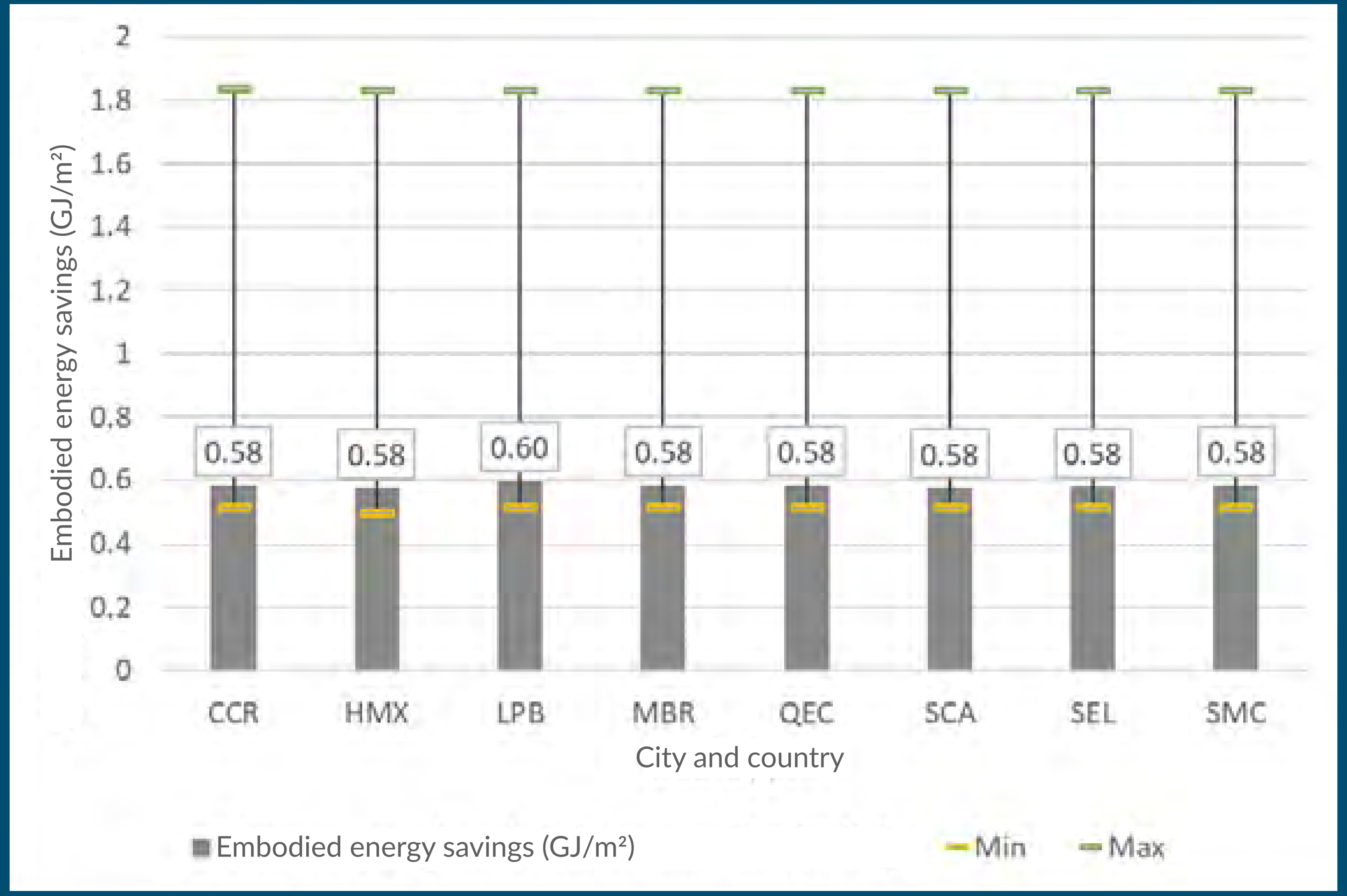


Figure 20. Embodied energy savings per m² for different cities.

WATER

On average, 0.9 m3 of water per square meter of construction.

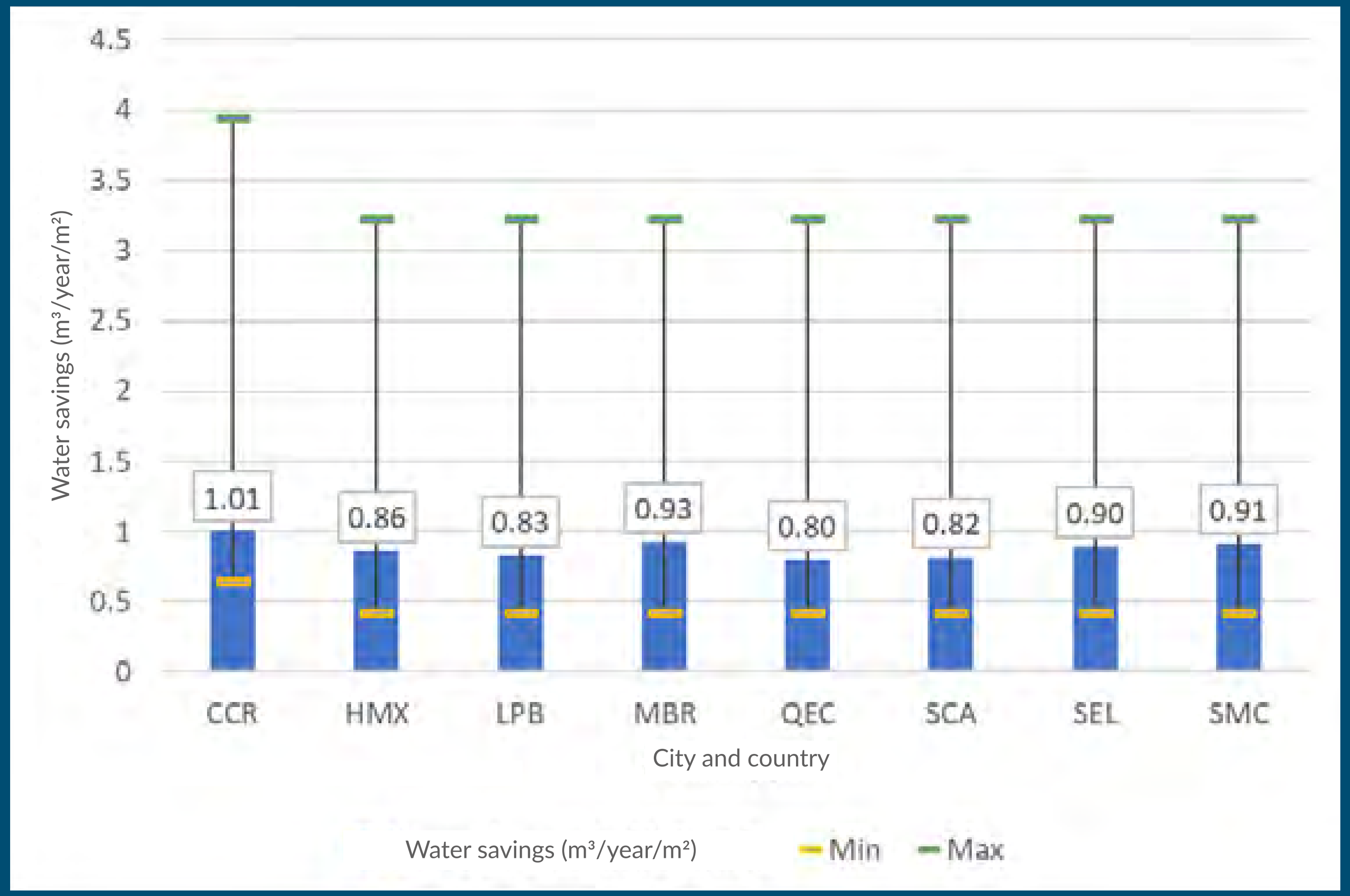


Figure 19. Annual water savings per m² for different cities.

CO_2 EMISSIONS

On average, 44 kCO_2 per square meter of construction.

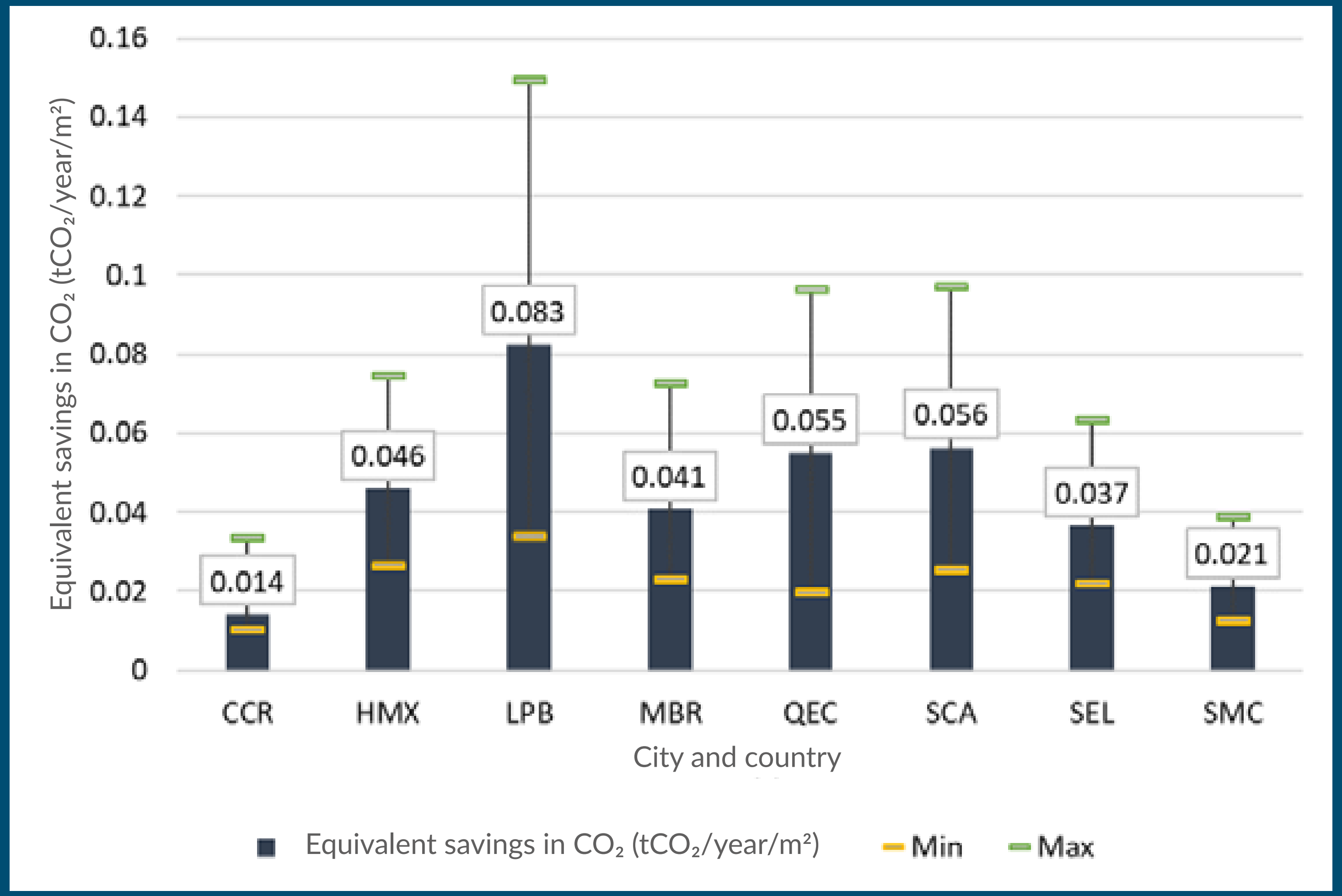


Figure 21. Emissions savings per m² for different cities.

Tips

It is vital to introduce energy-saving strategy measures that are simple to implement, technically feasible and with the shortest payback period possible. It is necessary to assess the energy saving and the cost of implementation, operation and maintenance.

According to the analysis between investment and energy saving, the best balance is obtained when 60% of the hot water demand is covered by solar hot water collectors and 10% of the electric demand is covered by solar photovoltaic panels.

The passive measures are more cost-effective when the climate is warm, dry, with high temperatures and low humidity. However, these measures will probably be less cost-effective in a cold climate, where more insulation and heating are required.

Using VRF air conditioning systems significantly reduces water consumption since they do not need drinking water for the condenser's cooling processes.

Recycling grey water for toilet flush and bathroom fittings has a high impact on saving drinking water. In the simulations, the saving is between 5% and 15%, depending on the type of building.

Grey water recycling is more cost-effective than rainwater recycling from the investment standpoint.

9. Financial analysis of the case studies

There are two key elements to consider from a financial standpoint: Incremental cost of the measures added and the potential saving in the utilities cost.

EDGE application was taken as a basis for the financial analysis and to calculate the previous indicators, since it considers both factors: Incremental cost and utilities tariff. Nevertheless, since EDGE updates utilities tariffs every 3 years approximately, the financial analysis was also performed using the current utilities tariffs as of October 2019[9].

Incremental cost: It is the additional cost for implementing the efficiency measures, compared to the baseline.

Saving in the utilities tariff: : It is the monthly savings in utility tariffs due to the measures implemented.

9 EDGE sets construction and utilities tariffs as a result of the periodic update, which are used by default. Nevertheless, the values are editable and can be modified. The User Guide recommends checking the default costs and adjusting them if necessary.

9.1 Financial analysis using EDGE

EDGE has a data base of construction and utilities tariffs per city. These are based on average global data and are updated periodically. The results are shown as a guide to compare the measures.

Costa Rica has the most expensive utilities, as the following Figure shows.

To compare the different types and cities/ countries, the incremental cost, and the saving in utilities per square meter were calculated[10].

To compare the different types and cities/ countries, the incremental cost, and the saving in utilities per square meter were calculated.

10 The deviation bars in the utilities tariff variable represent the minimum and maximum values the variable can use for combinations of types and simulations.

Cartago, Costa Rica also has the highest **incremental cost** per square meter compared to the rest of the cities. **In Cartago, the incremental cost is higher than USD 21/m²**, whereas in other cities it varies between **USD 10/m² - USD 17/m². Hermosillo, Mexico has the lowest value**.

A project's financial economic feasibility depends on many factors. This document focuses on the financial analysis by calculating some basic indicators for each scenario.

Figure 22. Electricity and water costs per country according to EDGE.

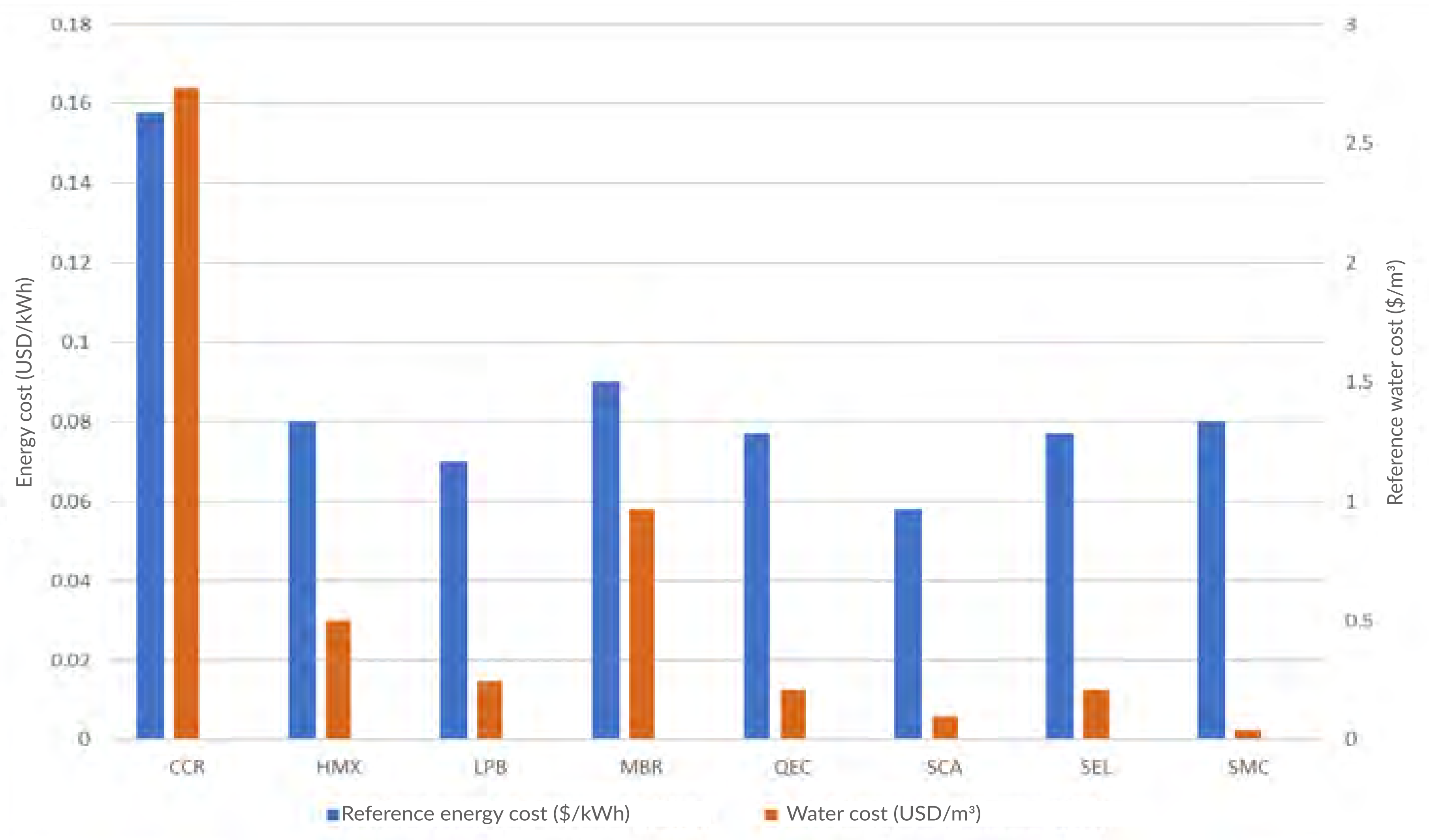
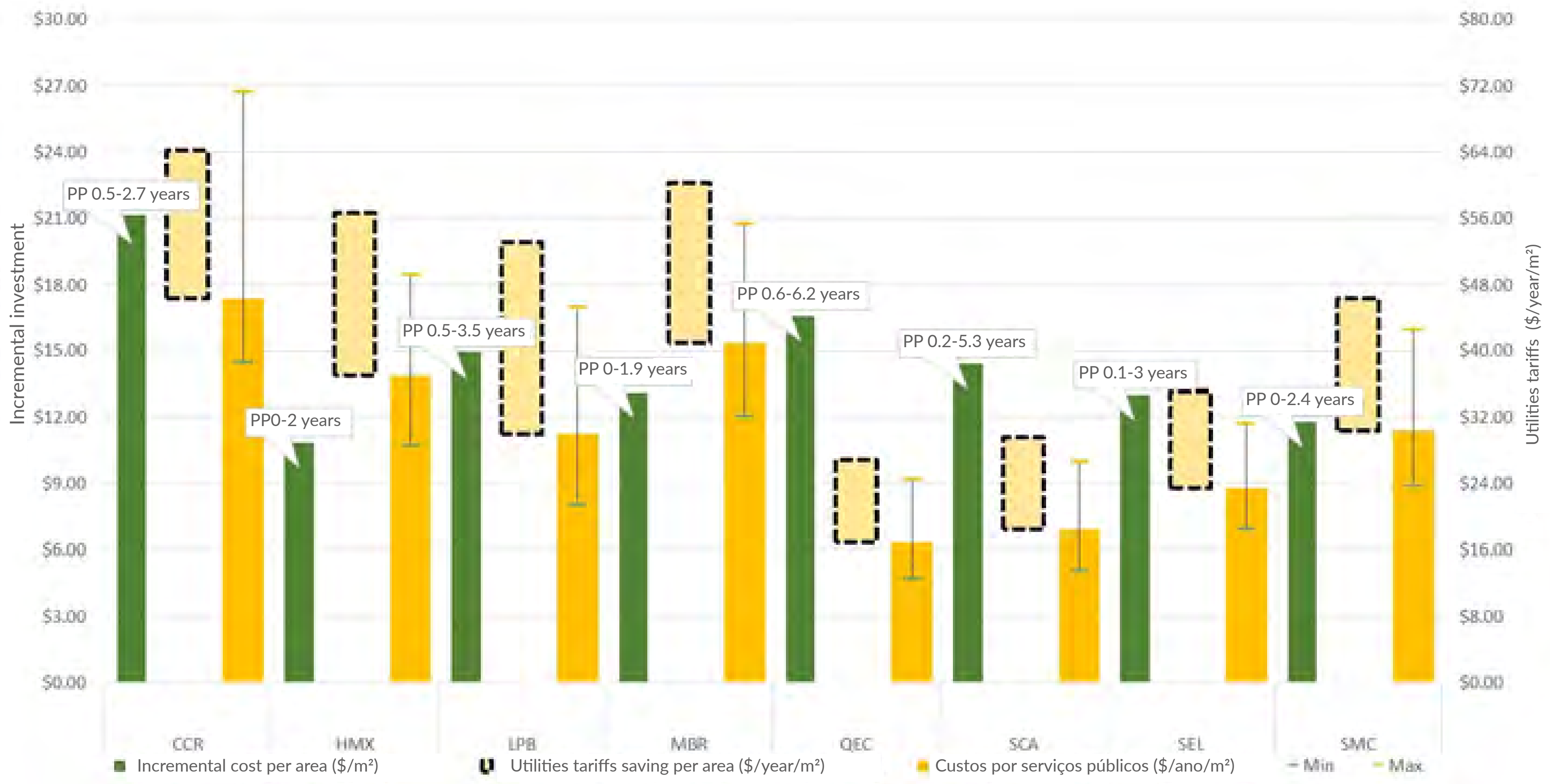


Figure 23. Incremental cost per m^2 and savings in different cities per year.



Net Present Value (NPV): It determines the equivalence in time 0 of a project's future flows and compares it with the initial investment. The incremental cost is the initial investment, and the utilities savings, the project's future flows. Besides, it was calculated with a discount rate of 10% and 15 years of flow.

Internal Rate of Return (IRR): Discount rate that makes the Net Present Value (NPV) equal to zero.

Payback Period (PP): Years needed to recover the initial investment. It is obtained from dividing the incremental cost by the average saving of the first year.

This analysis sheds attractive financial results on the different simulations. For example, the average of Cartago, Costa Rica, shows a positive VPN. This means that the project generated value or that the utilities saving is higher than the incremental cost of the investments needed to obtain a certification such as EDGE. For the same case, the IRR is 73% which is higher than the discount rate chosen (10%). In other words, the performance rate is higher than the required rate of return for the investment. Therefore, every USD 21 extra invested per square meter, represents a USD 15 saving per square meter every year.

9.2 Financial analysis according to current utilities tariffs

After analyzing the financial results of the simulations run on EDGE, a calculation based on the research of current utilities tariffs was made. Thus, the financial analysis was improved and contrasted in two different ways.

The utilities tariffs used were the result of a market price research with companies of each city/country. The type of building and consumption expected were considered, for electricity. The energy and water cost values used for this second analysis and their references are in Appendix 7.

Figure 24. Financial indicator of the cities.

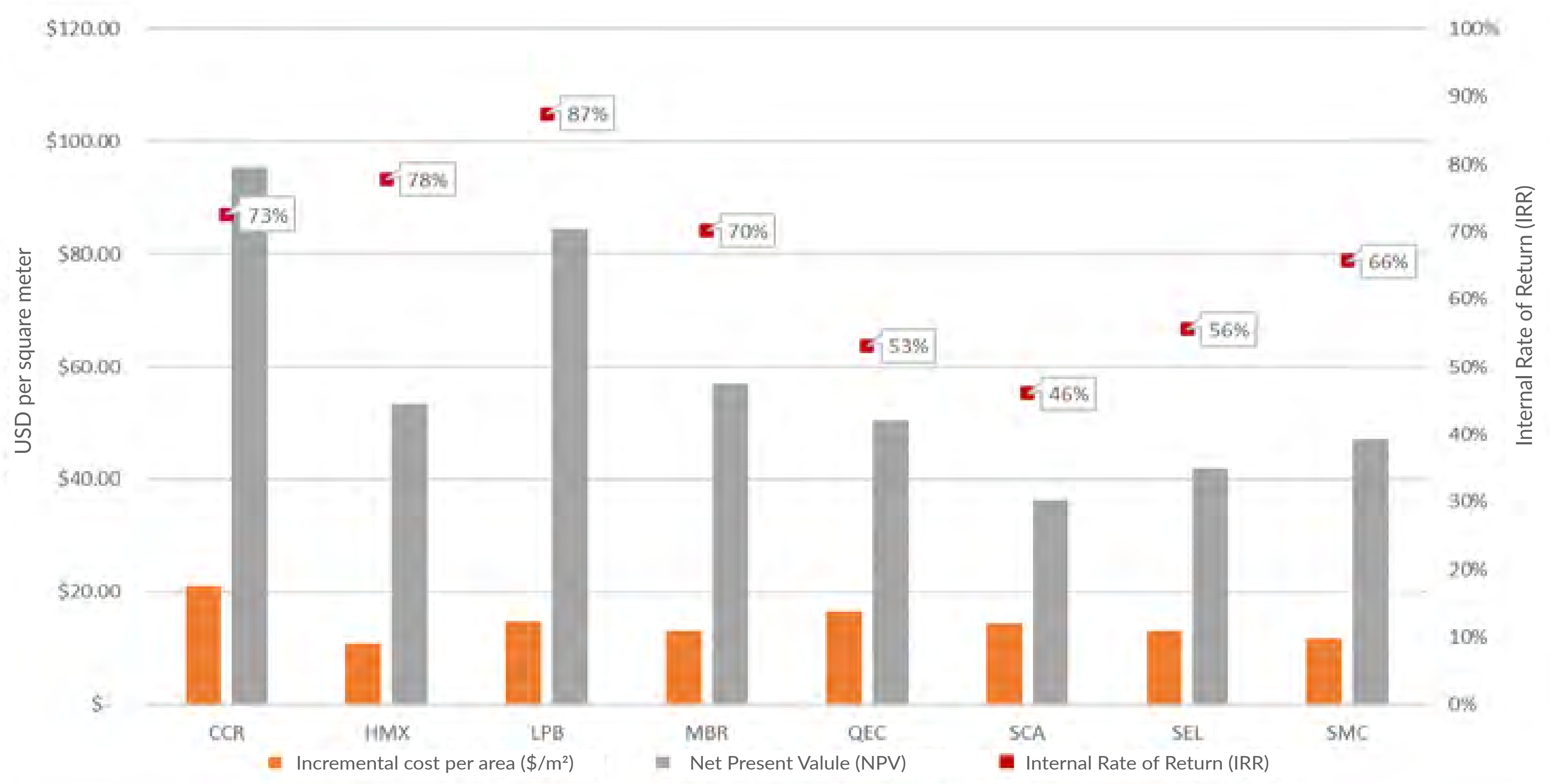
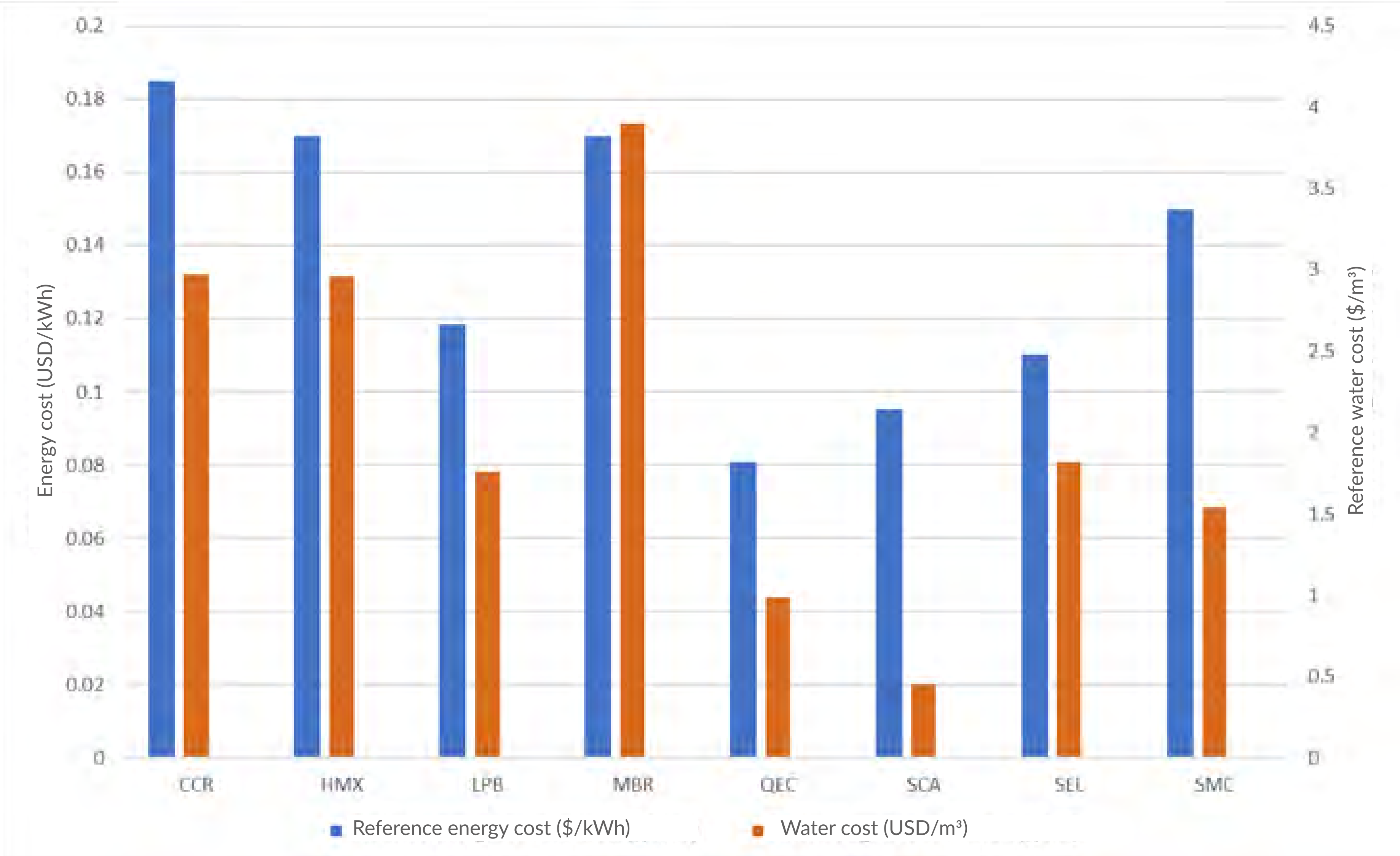


Figure 25. Electric and water utilities tariffs per country according to market prices.



This analysis confirmed that, although water and electricity costs in Cartago, Costa Rica are still high –as EDGE showed–, the difference is not that significant. Likewise, the water tariff in Manaus, Brazil seems to be higher than the rest of the cities. With this information, the financial indicators were recalculated.

This second analysis, which considers current utilities tariffs, shows a reduction in returns. This is because the incremental cost remains steady (according to EDGE calculation), while there is a higher saving due to the payment of the utility's tariffs. Puerto Santa Cruz, Argentina, shows the most significant change because the PP is now 5.3 years, while in the first analysis it was 9 years.

The IRR is above 10%. This shows that the saving measures chosen with EDGE are economically feasible.

In conclusion, the financial indicators show attractive results. Besides, although EDGE utilities may be outdated (they are updated every 3 years), the design measures chosen generate savings in acceptable payback periods

Figure 26. Incremental cost per m² and savings per city with utilities costs according to market prices.

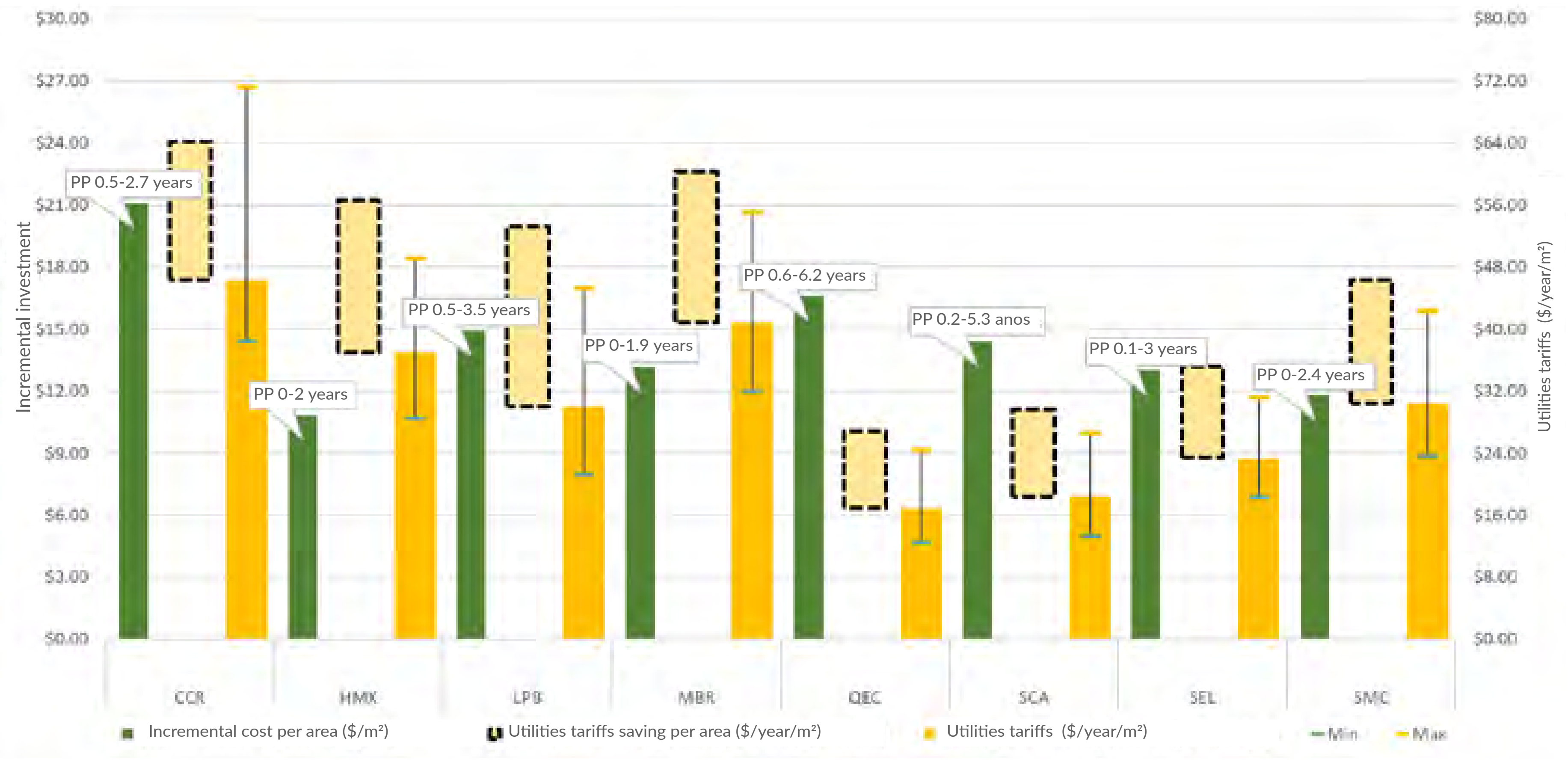
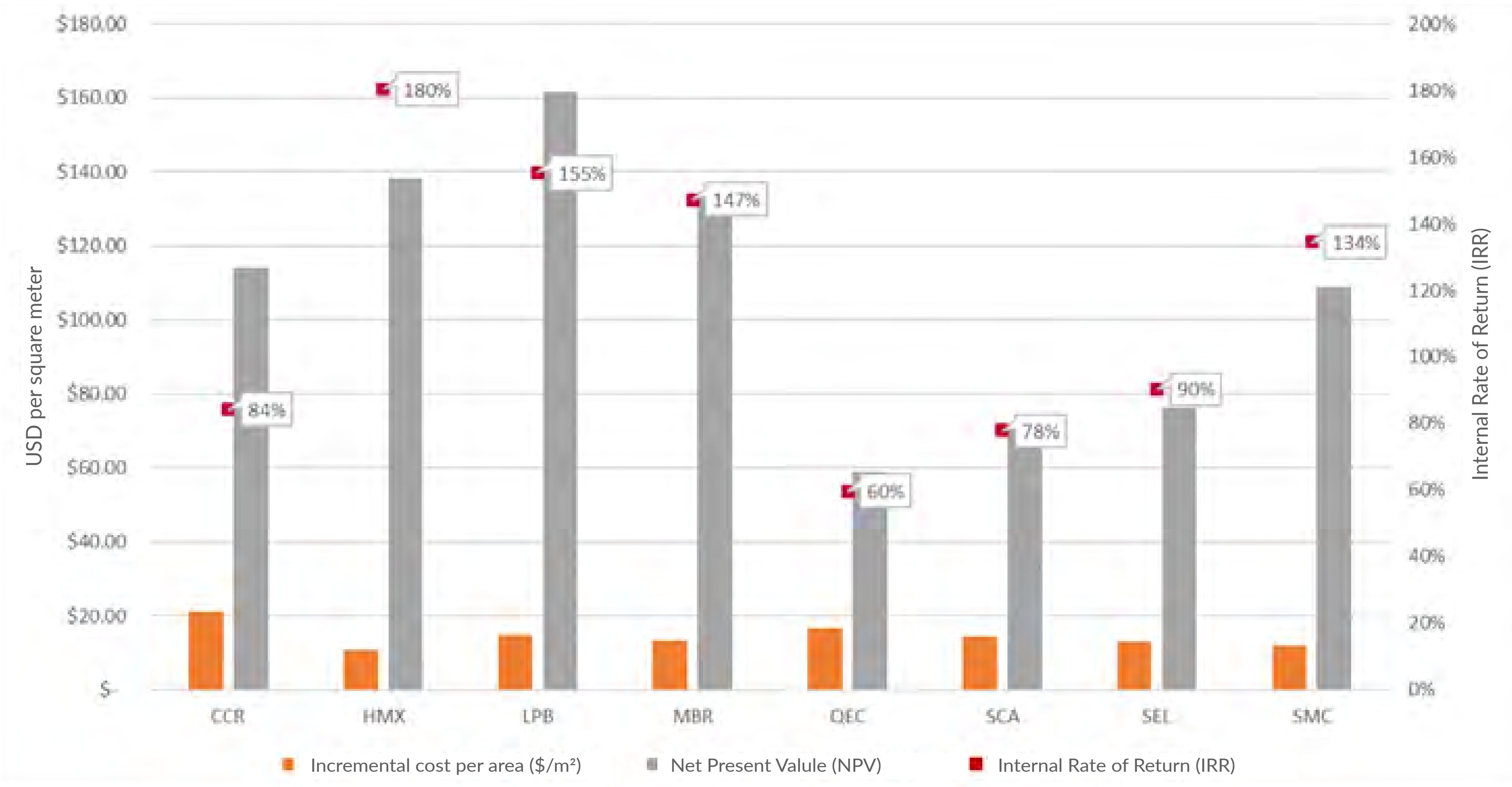


Figure 27. Financial indicators by city with researched utilities costs.



COMPARATIVE TARIFFS

Table 12. Edge tariffs vs. current utility tariffs.

	EDGE		Current	
	Energy cost ($/kWh)	Water cost ($/m³)	Energy cost ($/kWh)	Water cost ($/m³)
Cartago – Costa Rica	0.16	2.73	0.18	2.97
Hermosillo – Mexico	0.08	0.50	0.17	2.96
La Paz – Bolivia	0.07	0.25	0.12	1.76
Manaus – Brazil	0.09	0.97	0.17	3.90
Quito – Ecuador	0.08	0.21	0.08	0.98
Puerto Santa Cruz – Argentina	0.06	0.10	0.09	0.45
San Salvador – El Salvador	0.08	0.21	0.11	1.82
Santa Marta – Colombia	0.08	0.04	0.15	1.54

10. Existing hospital

It is a hypothetical example of a 40,032 m2 existing Public Hospital built in 2000, located in Buenos Aires, Argentina. No architectural modifications are planned. However, some measures will be incorporated to get at least 20% savings in energy and water compared to the baseline. Appendix 5 outlines the details of the project and of the weather conditions.

According to EDGE methodology, “reusing existing material” should be entered in the category *materials* when dealing with existing buildings of 5 or more years. This is not relevant for this analysis, although it is relevant to obtain EDGE certification, because it ensures the compliance of the 20% reduction in the materials’ components. Therefore, besides the design characteristics of the existing building, the only information provided is the energy and water measures aimed at obtaining cost-effective results.

However, there are changes in some of the materials with the aim of improving energy efficiency. For example, by increasing walls or windows insulation, or by adding solar protection on façades, materials are added to the project. These raise the incremental cost and also result in more energy-efficient systems.

For this additional case, 9 simulations were run. Simulations a, b, c and d are focused on passive saving strategies. Simulations e, f, g, and h are focused on active ones. Simulation i considers only the entry of the required measures (marked with * in the online platform) and analyzes the final cost-efficiency behavior.

Appendix 6 summarizes the different simulations and savings for this case.

10.1 Simulation a

In this simulation, the result is 29% saving in energy and 24.77% in water.

Measures considered:

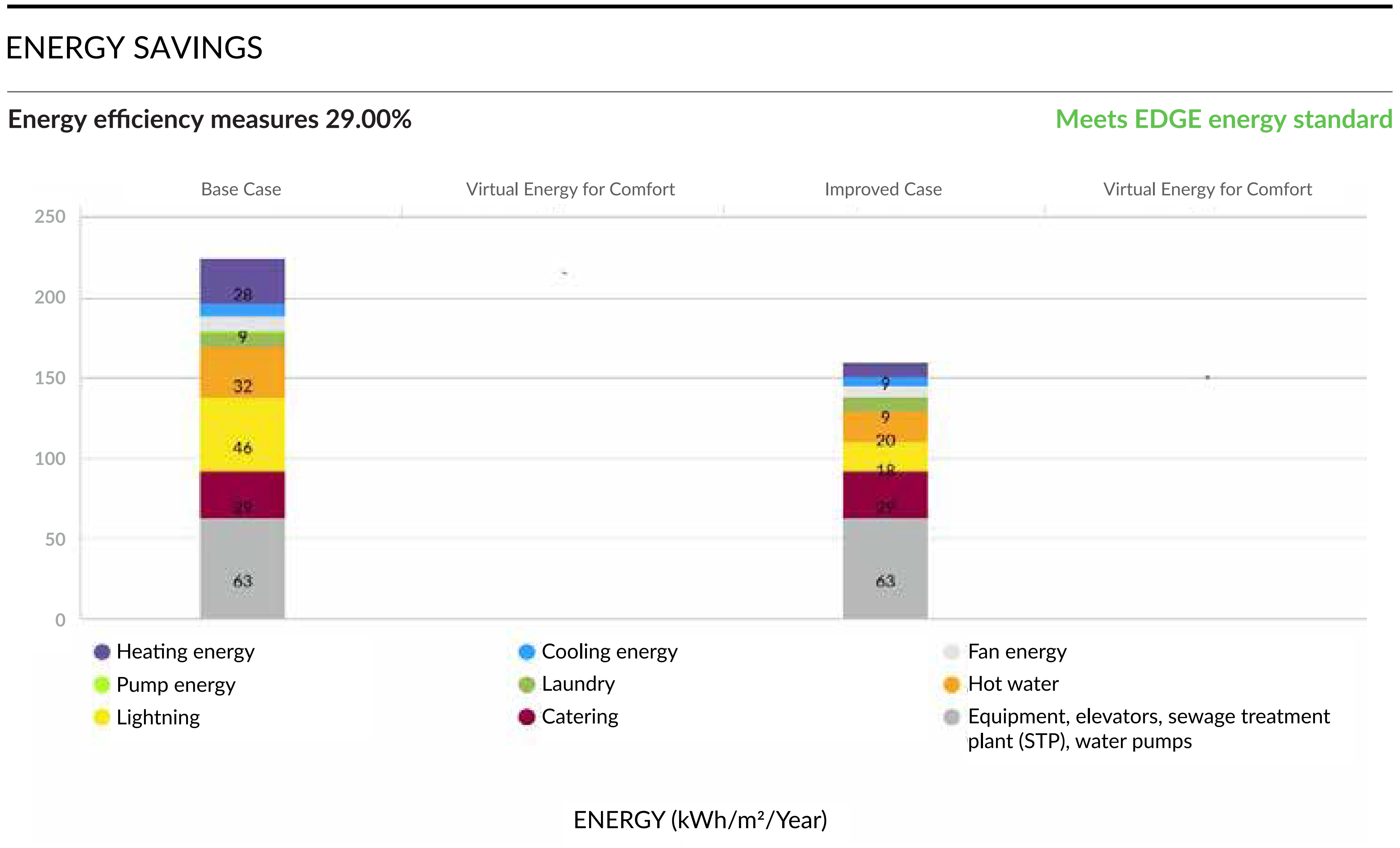
Energy: The minimum measures EDGE recommends by default. Efficient lighting in all the spaces and passive measures such as external shading devices and natural ventilation in corridors, lobby and patients rooms were added.

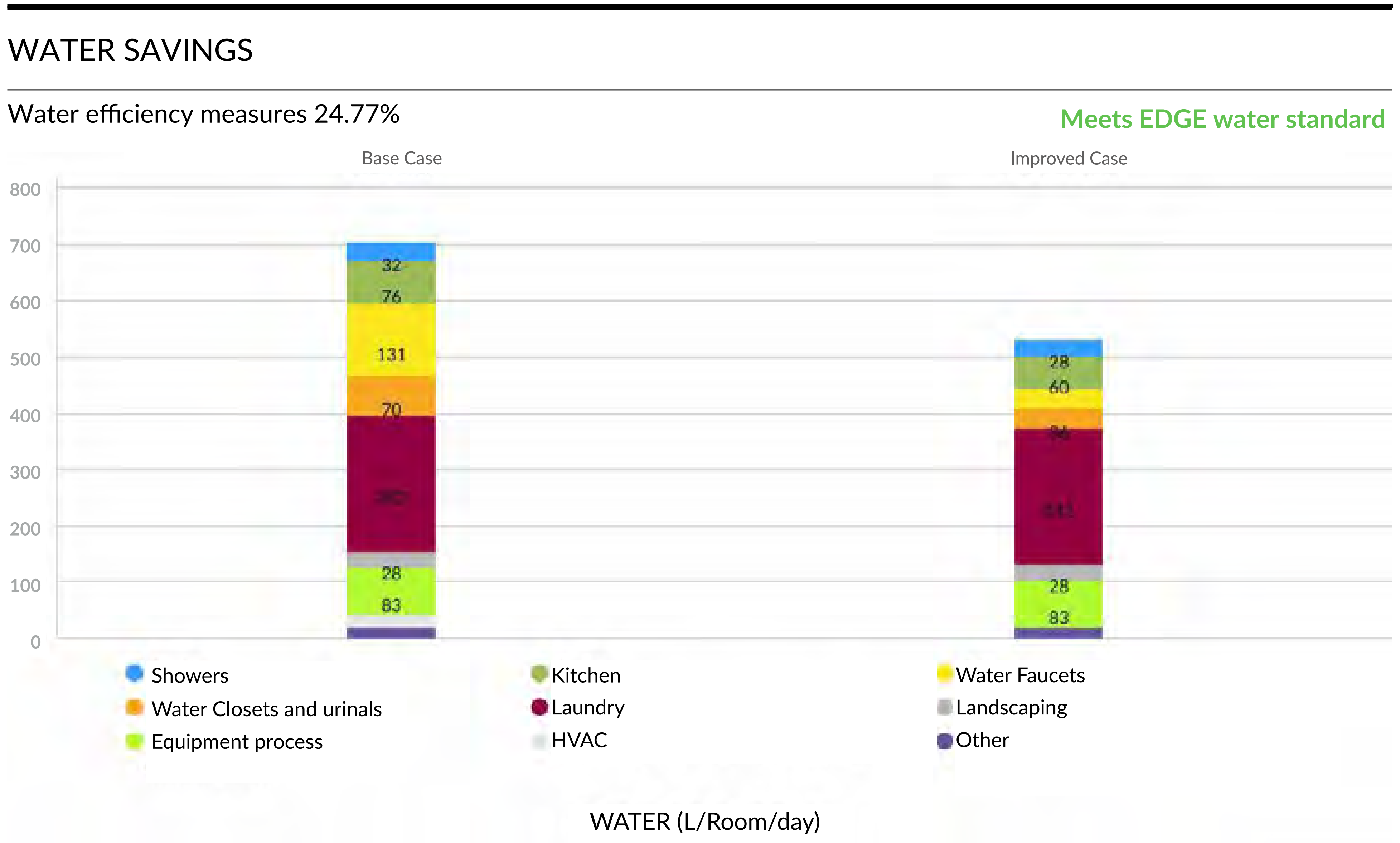
Water: The minimum measures recommended by default without additions or flow changes. The flows and flushes of the saving line proposed by EDGE were used:

- Showerheads: 7 liters/min.
- Bathrooms washbasins: 2 liters/min.
- Double flush water closets: 6 liters for the first flush and 3 liters for the second flush.
- Urinals: 2 liters per flush.
- Kitchen sinks: 6 liters/min.

In this simulation the rinse water reclamation system to reuse rinse water for wash cycle laundry is excluded because it has a high incremental cost compared to the low efficiency increase.

Figure 28. Simulation a results summary for BAA-PH case.





10.2 Simulation b

This simulation shows 29.36% energy saving and 26.36% water saving.

Measures considered:

Energy: The minimum measures EDGE recommends by default, efficient lighting in all spaces, and the below listed additional measures:

- Reflective paint on floor and walls.
- High thermal performance glass.
- VRF air conditioning system, with 3.5 COP. It is a cooling system that provides the project with more efficiency at a low incremental cost.

Wate: The minimum measures EDGE recommends. Additionally, the flows and flushes were adjusted for:

- Showerheads: 6 liters/min.
- Dry urinals (0 liters per flush).

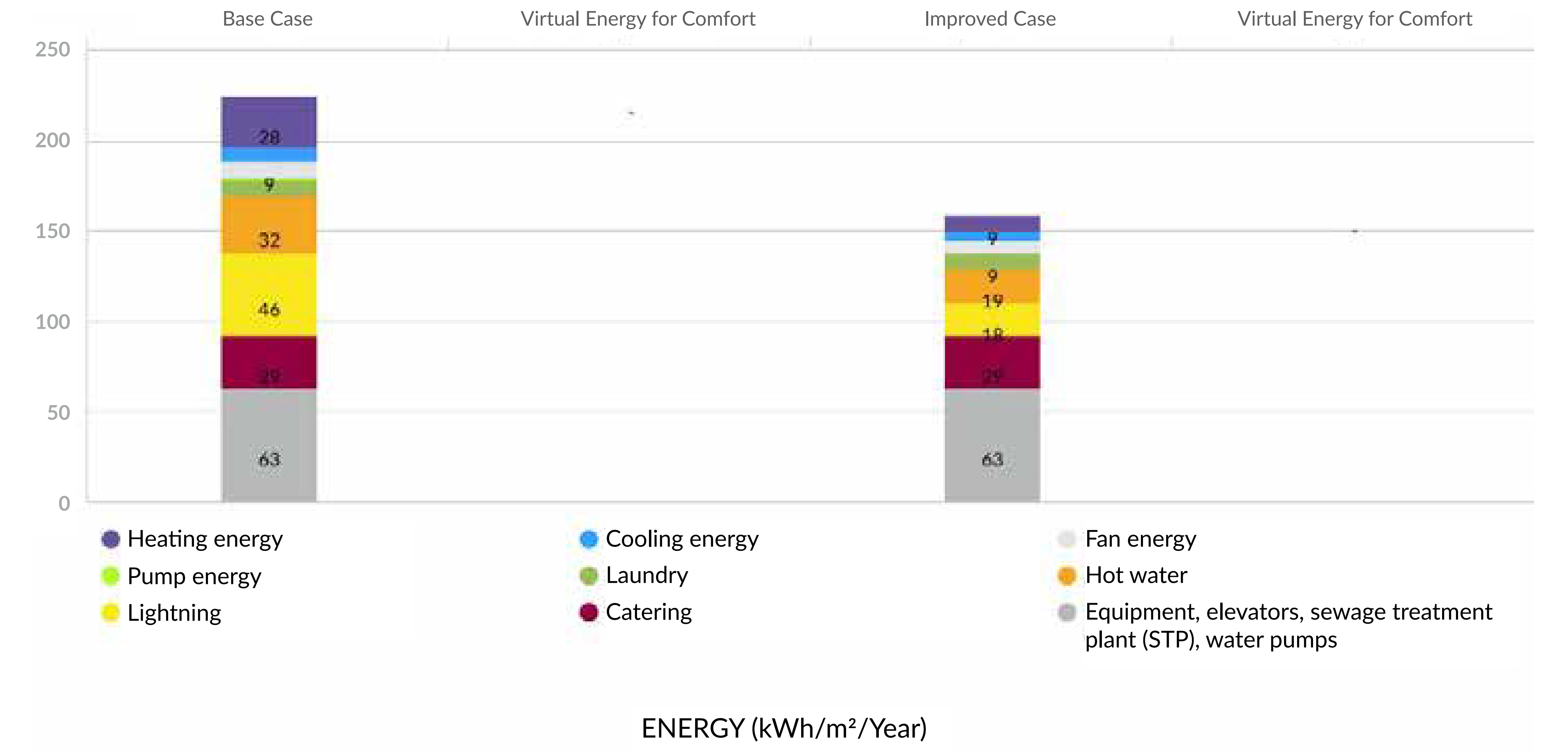
The rinse water reclamation system to reuse rinse water for wash cycle laundry is excluded because it has a high incremental cost for the project, as was the case in simulation a.

Figure 29. Simulation b results summary for BAA-PH case.

ENERGY SAVINGS

Energy efficiency measures 29.36%

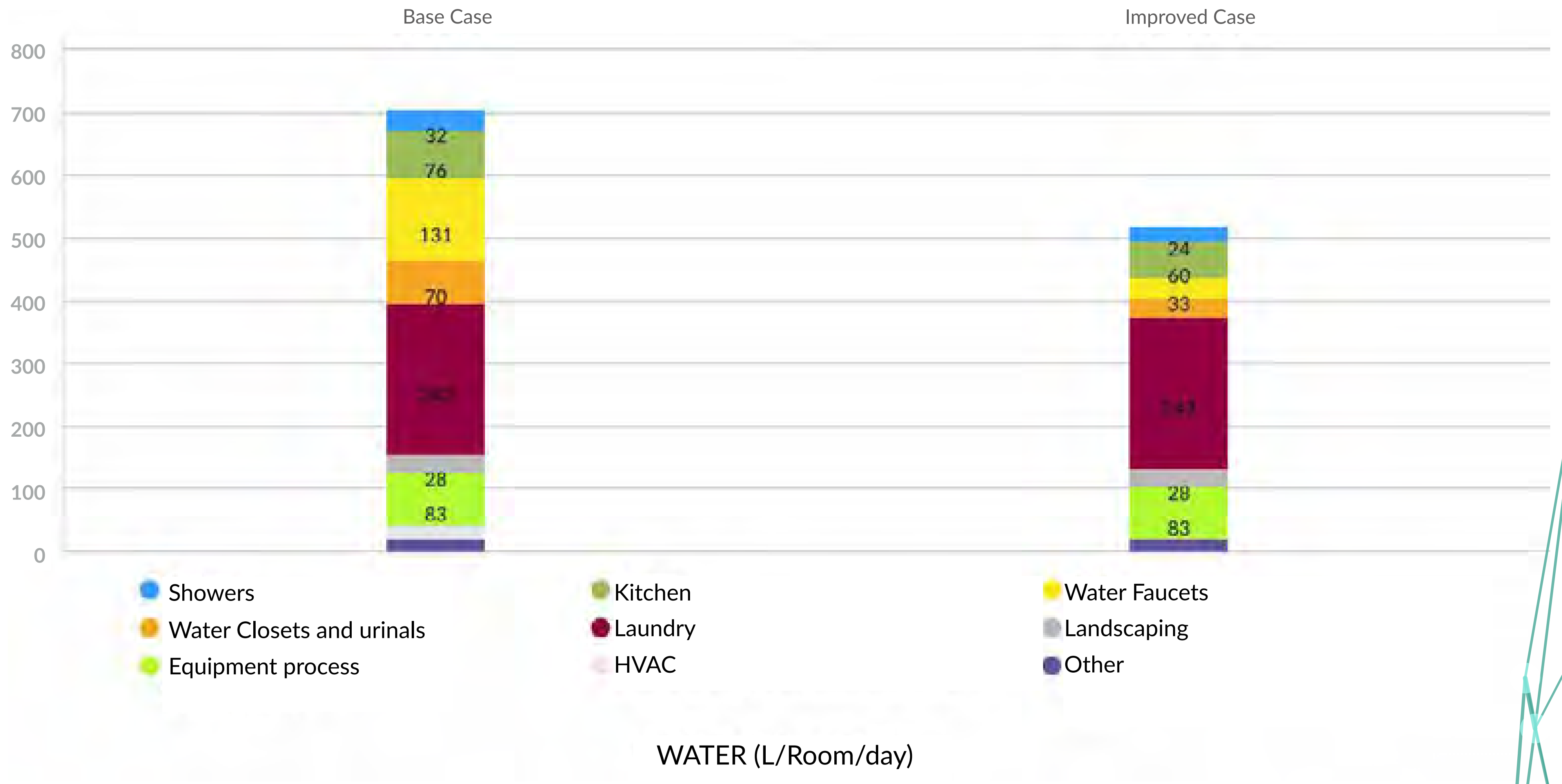
Meets EDGE energy standard



WATER SAVINGS

Water efficiency measures 26.36%

Meets EDGE water standard



10.3 Simulation c

This simulation shows 29.17% energy saving and 32.78% water saving.

Measures considered:

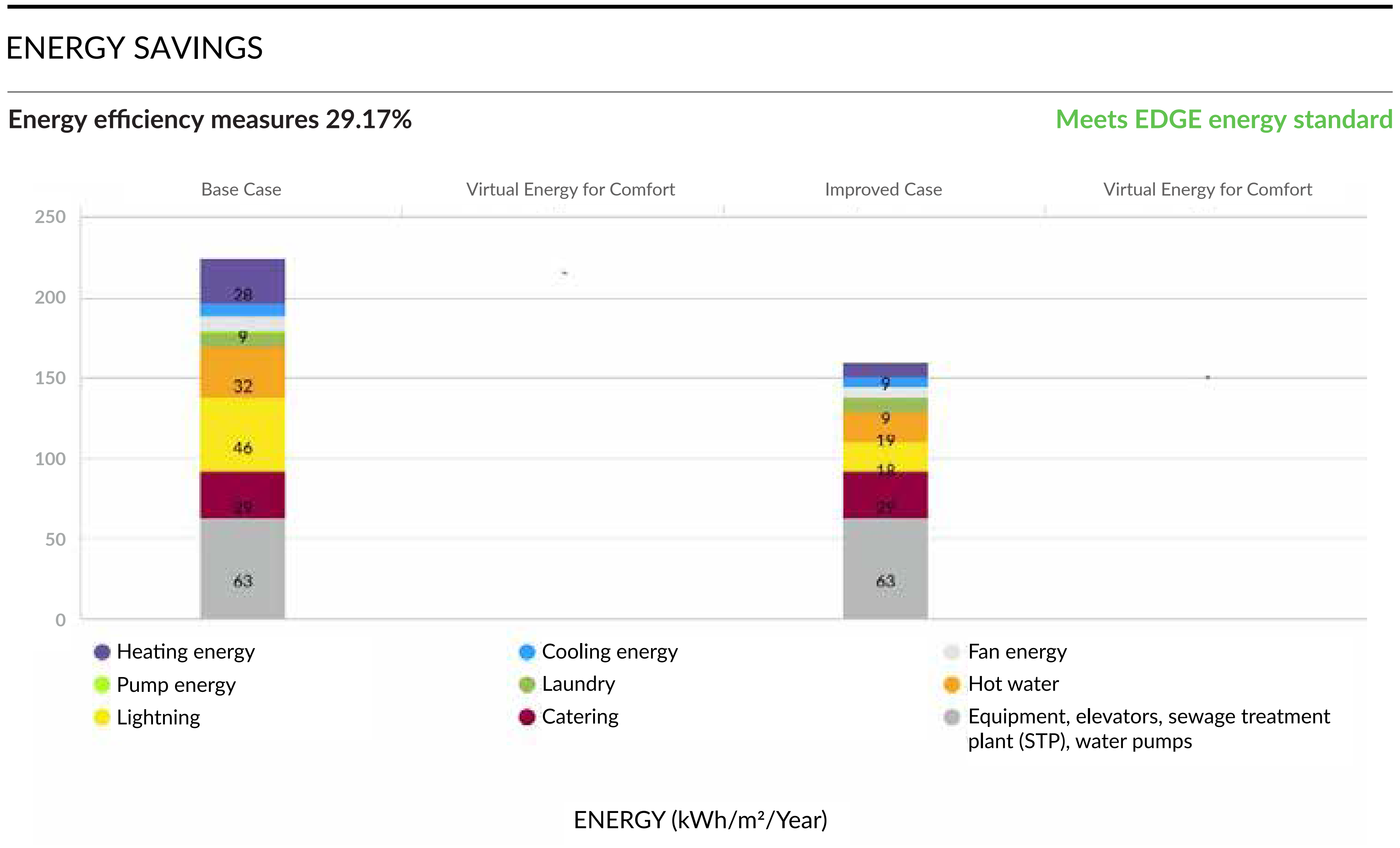
Energy: Based on EDGE standard values, variable speed in the air handlings and in the pumps is included, together with the measures incorporated in simulations a and b.

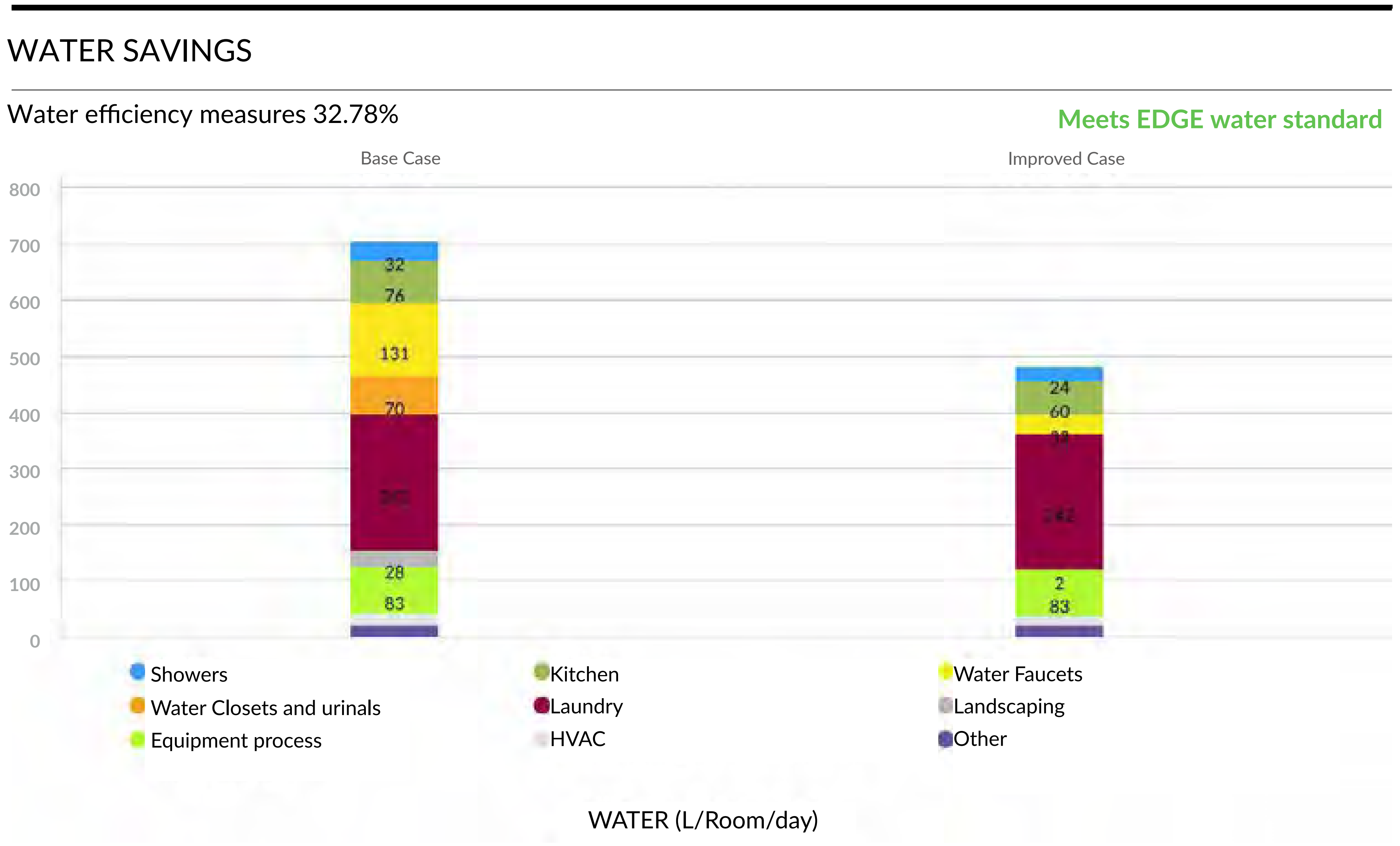
Water: The following measures were considered:

- Showerheads: 6 liters/min.
- Bathrooms washbasins: 2 liters/min.
- Double flush water closets: 6 liters for the first flush and 3 liters for the second flush.
- Dry urinals (0 liters per flush).
- Kitchen faucets: 6 liters/min.

Grey water recovery was also included. However, the rinse water reclamation system to reuse rinse water for wash cycle laundry was excluded.

Figure 30. Simulation c results summary for BAA-PH case.





10.4 Simulation d

This simulation incorporates solar hot water collectors (active design measure). Otherwise, the 20% saving in energy standard would not be met. With this simulation, the savings obtained were 23.35% in energy and 31.75% in water.

Measures considered:

Energy: The minimum measures. Besides, external shading devices, low e-coated glass, and air-cooled chiller with a COP of 3.3 were added.

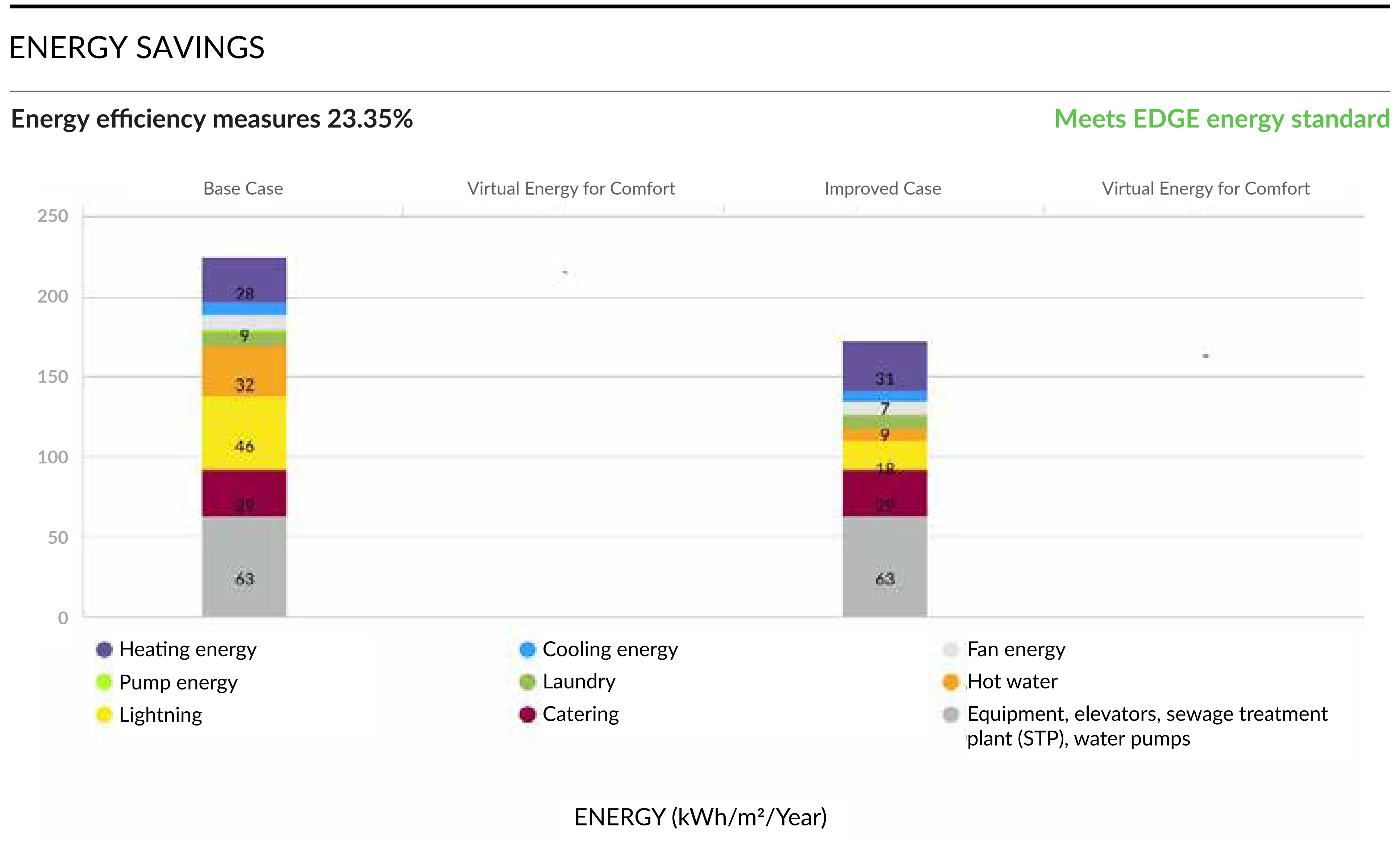
An active strategy was incorporated: Solar hot water collectors for 60% of hot water demand to exceed the 20% saving in the category.

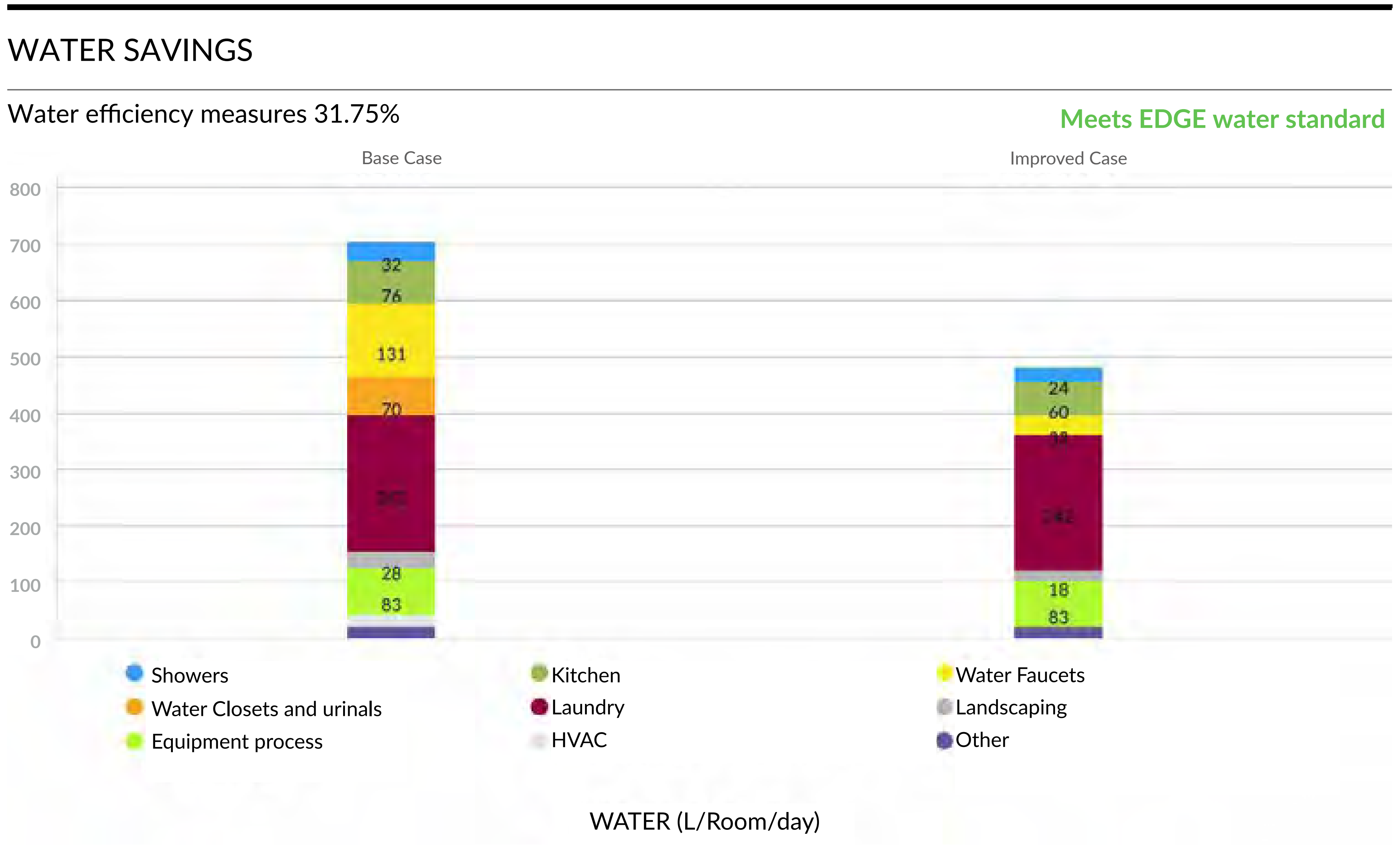
Water: Minimum measures with the following flow adjustments:

- Showerheads: 6 liters/min.
- Double flush water closets: 6 liters for the first flush and 3 liters for the second flush.
- Sink: 2 liters/min.
- 2 liters per flush in urinals.
- Kitchen faucets: 6 liters/min.

A strategy to recover grey water was included.

Figure 31. Simulation d results summary for BAA-PH case.





10.5 Simulation e

This simulation did not include passive measures. Electromechanical equipment commonly used in hospitals was incorporated, together with its envelope design. The savings obtained were 31.73% in energy and 31.87% in water.

Measures considered:

Energy: An air conditioning with water cooled chiller system, with a COP of 5.2, was included since it is a widely used cooling system in hospital projects.

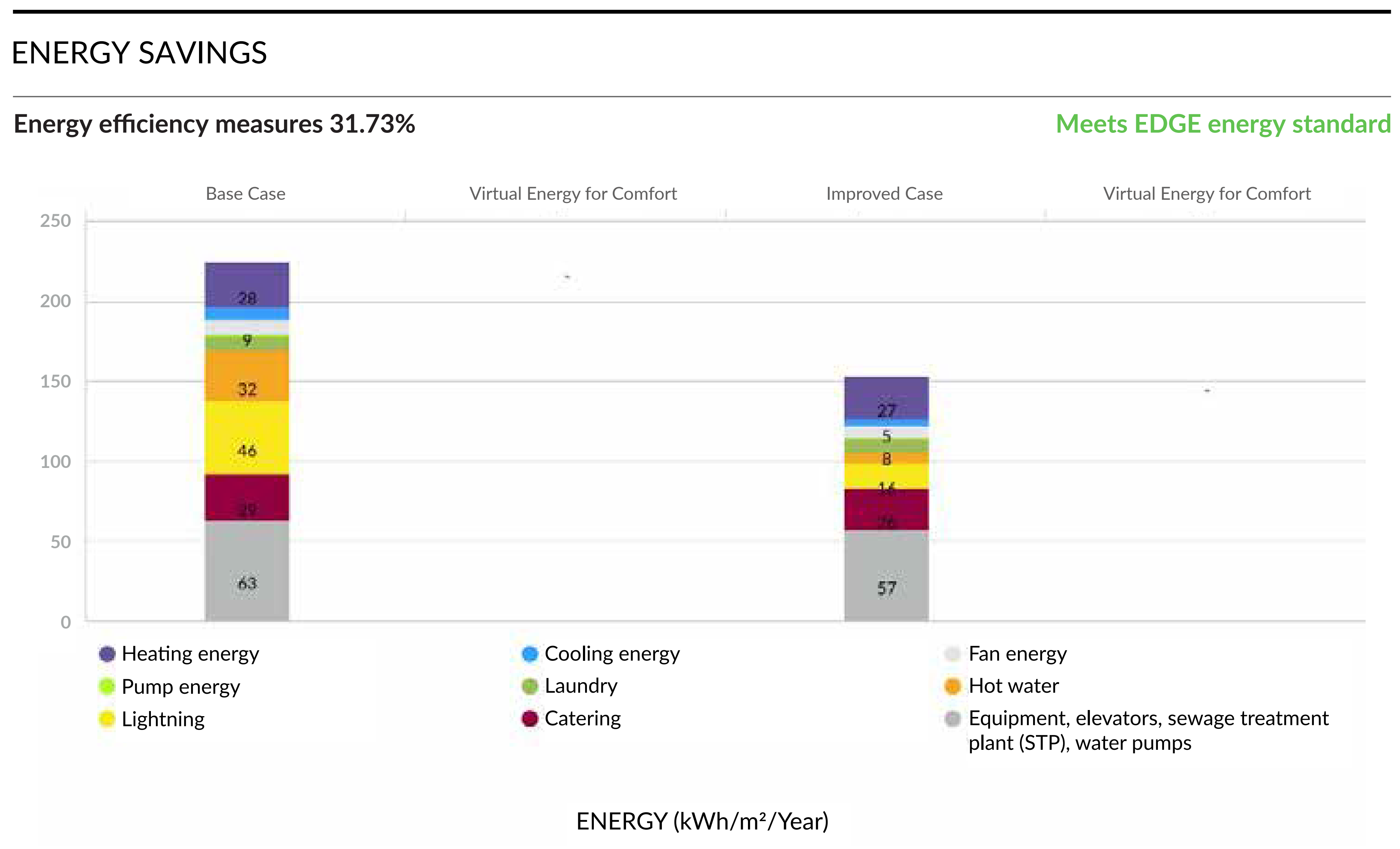
60% of hot water demand was covered by solar hot water collectors and 10% for other final uses was covered by solar photovoltaic panels.

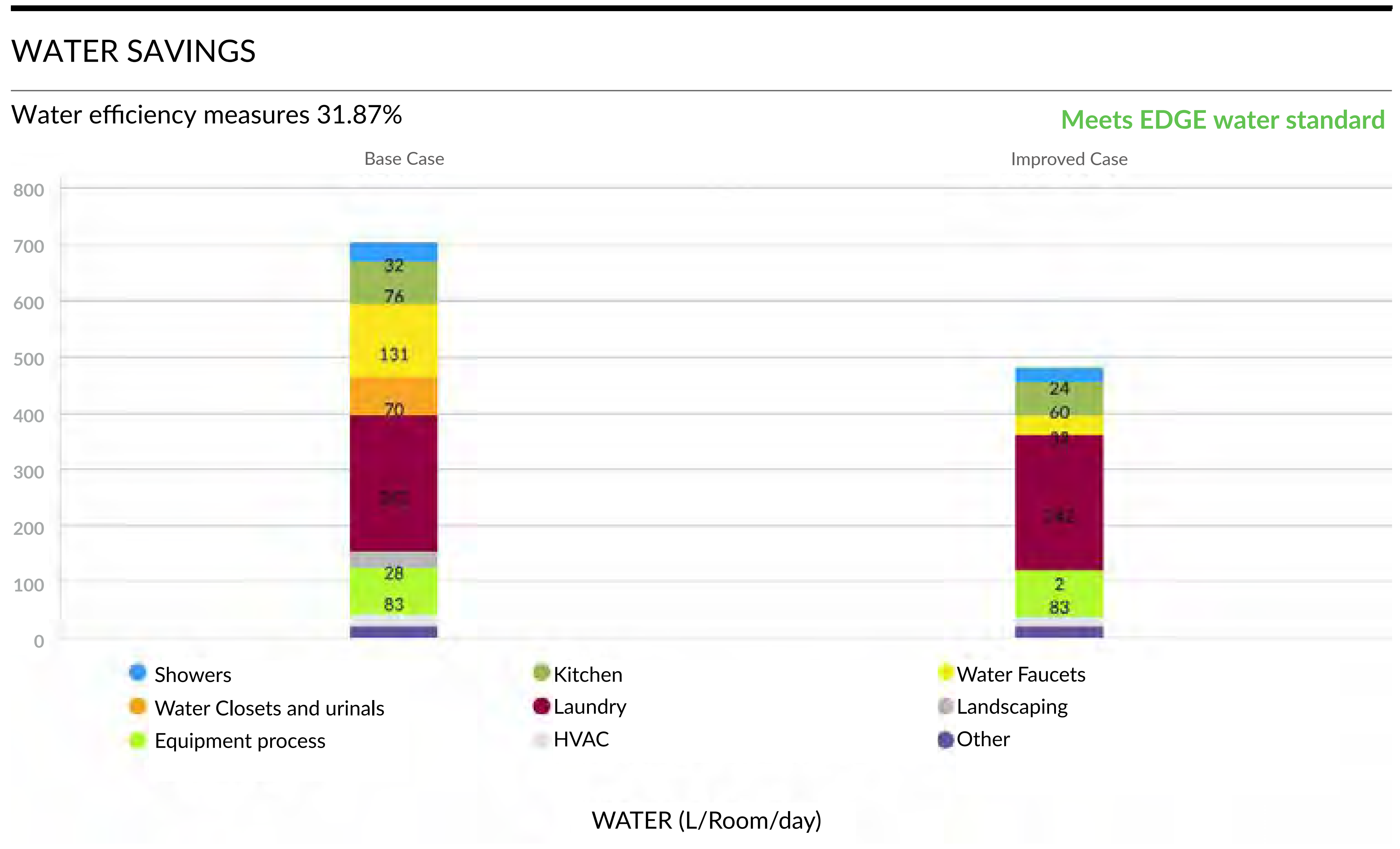
Wate: Minimum measures with the following flows adjustments:

- Showerheads: 6 liters/min.
- Double flush water closets: 6 liters for the first flush, 3 liters for the second flush.
- Dry urinals (0 liters per flush)
- Sink:.2 liters/min
- Kitchen faucets: 6 liters/min.

Grey water recovery was also included, together with the efficient use of water for irrigation. However, the rinse water reclamation system to reuse rinse water for wash cycle laundry was left out.

Figure 32. Simulation e results summary for BAA-PH case.





10.6 Simulation f

This simulation reaches savings of 31% in energy and 32.25% in water.

Measures considered:

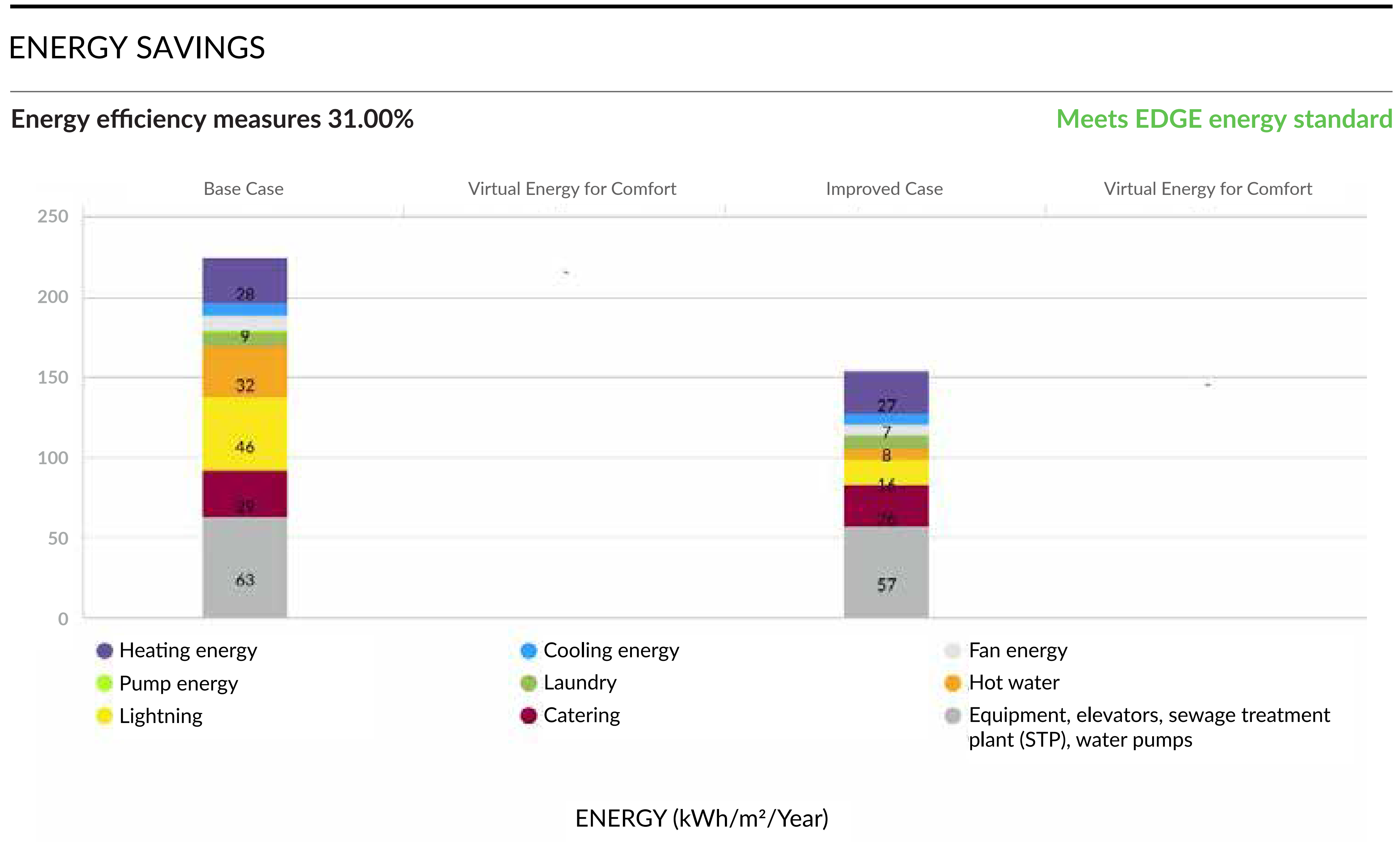
Energy: Air conditioning with air cooled chiller system, with a COP of 3.3, and solar hot water collectors for 60% of the demand were used. Likewise, solar photovoltaic panels were incorporated for 10% of the electric demand of the project.

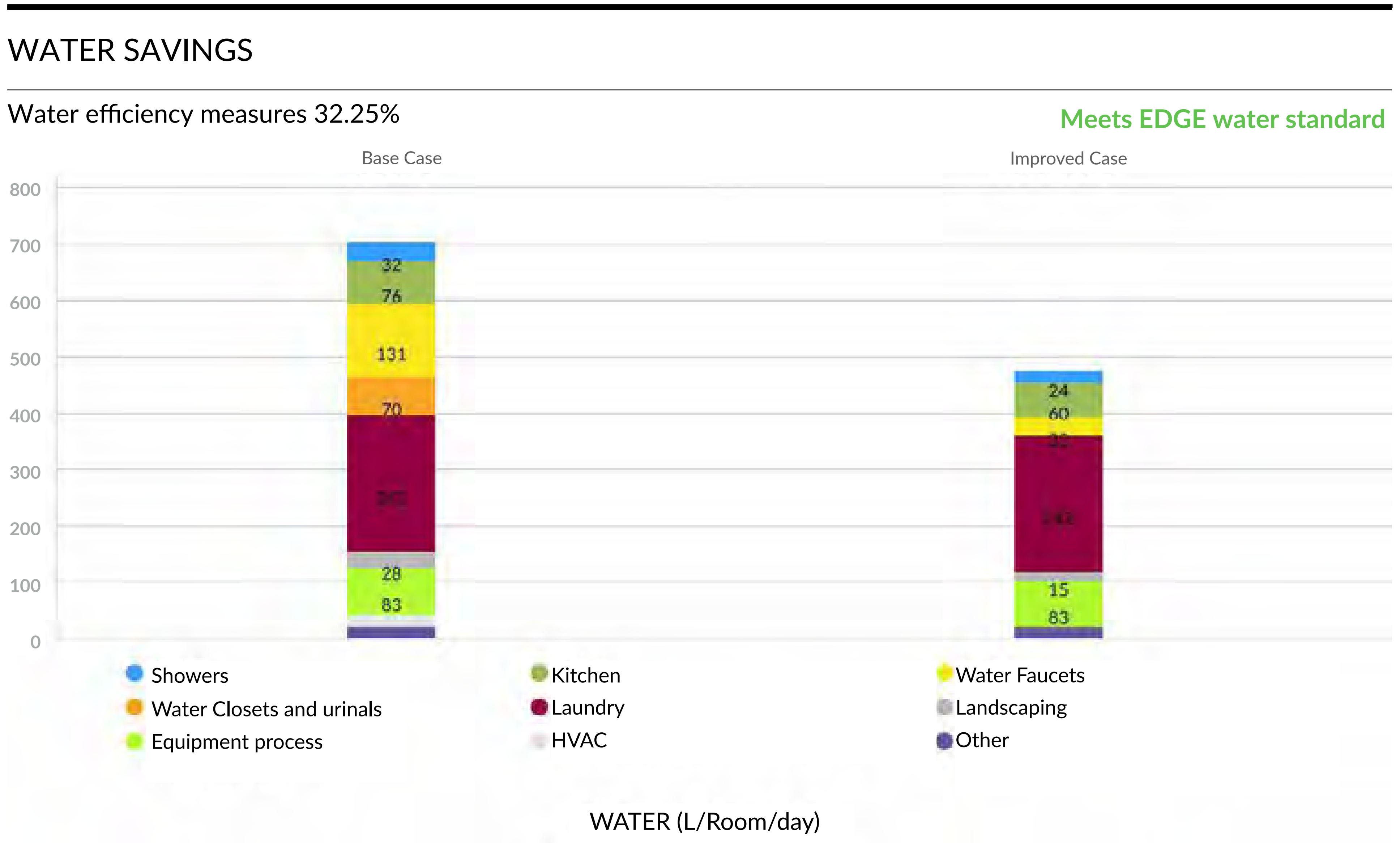
Water: The following flows were used:

- Showerheads: 6 liters/min.
- Single flush water closets: 6 liters for the first flush.
- Dry urinals (0 liters per flush).
- Sink: 2 liters/min.
- Kitchen faucets: 6 liters/min.

Grey water recovery was included as in the previous simulation, together with the efficient use of water for irrigation. However, the rinse water reclamation system to reuse rinse water for wash cycle laundry was left out.

Figure 33. Simulation f results summary for BAA-PH case.





10.7 Simulation g

42.74% savings in energy and 34.09% in water were obtained with this simulation.[11]

Measures considered:

Energy: Reflective paint on roof and walls, high thermal performance glass, and an air-cooled chiller system with a COP of 3.5 were included.

Variable speed units in the pumps and sensible heat recovery from exhaust air were added with 60% efficiency.

The following were also added: Solar hot water collectors for 60% of the demand and solar photovoltaic panels for 10% of the total energy demand of the project.

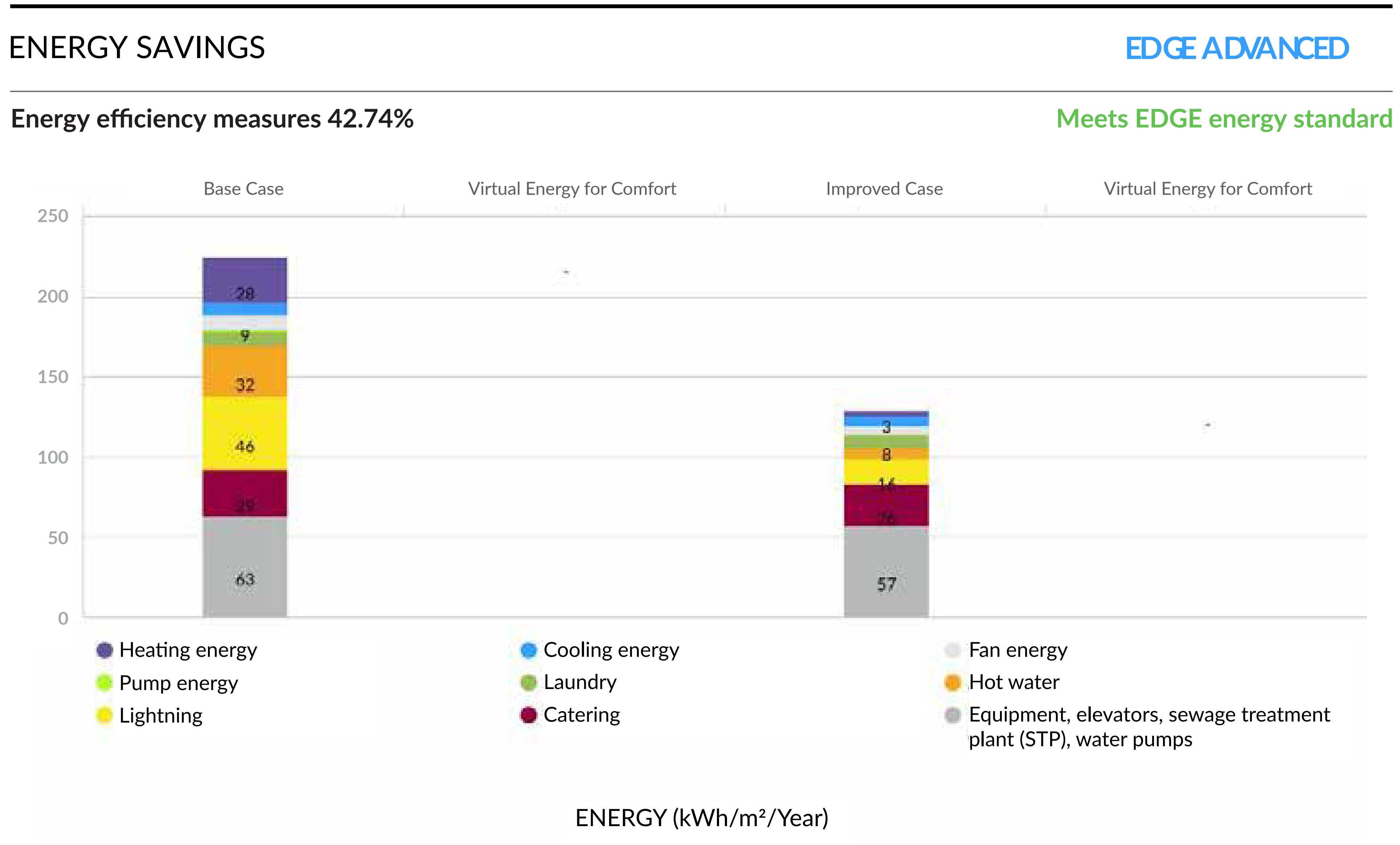
Water: The following flows were used:

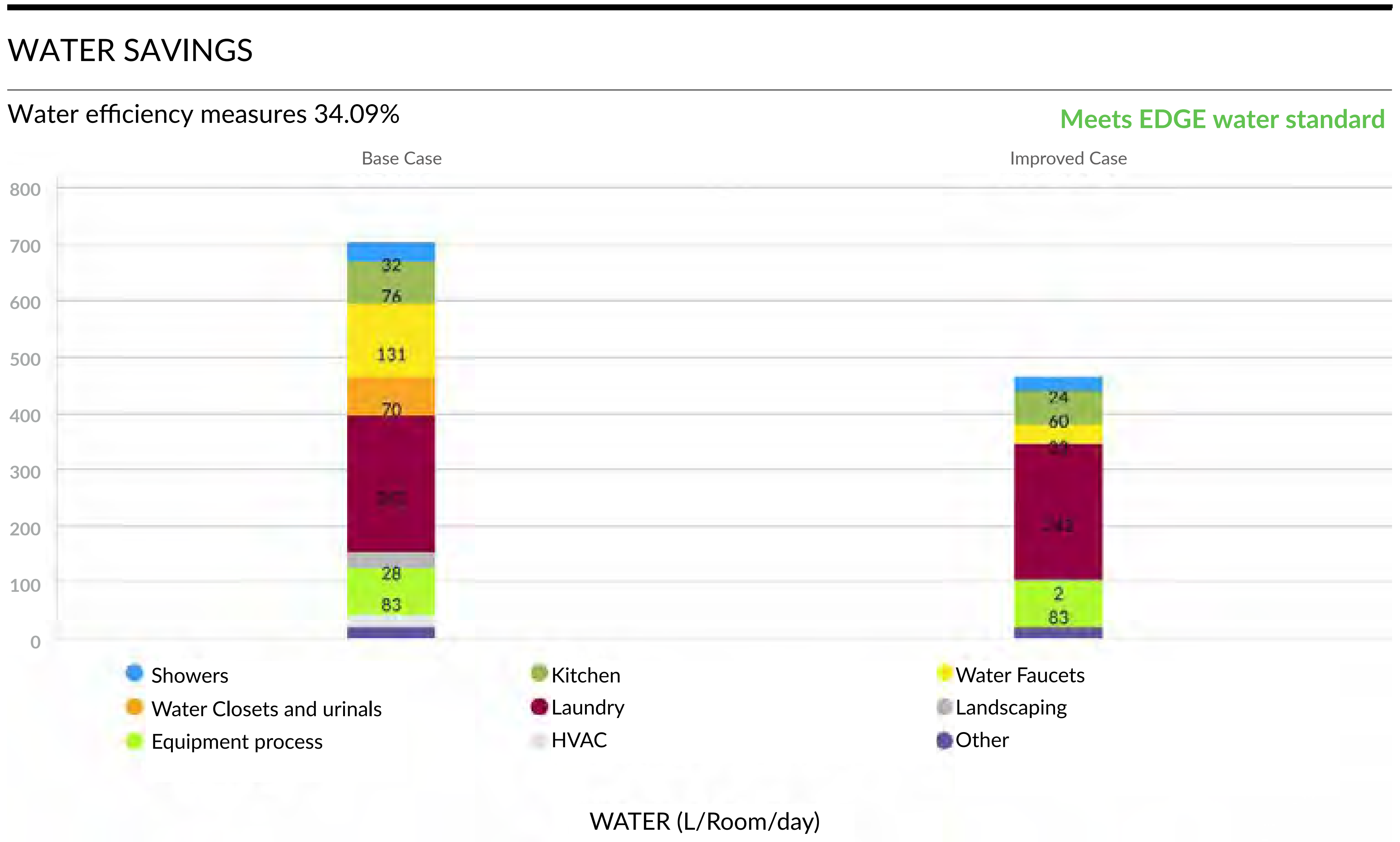
- Showerheads: 6 liters/min.
- Dry urinals (0 liters per flush).
- Sink: 2 liters/min.
- Kitchen faucets: 6 liters/min.

As in the previous simulation, grey water recovery was included, together with the efficient use of water for irrigation. However, the rinse water reclamation system to reuse rinse water for wash cycle laundry was left out.

11 With the savings obtained, an EDGE Advanced certificate would be achieved

Figure 34. Simulation g results summary for BAA-PH case.





10.8 Simulation h

For this simulation, the savings achieved were 40.29% in energy and 32.25% in water.[12]

Measures considered:

Energy: High thermal performance glass and a VRF air conditioning system with a COP of 3.5 were included.

The following were also added: Solar hot water collectors for 60% of the demand and solar photovoltaic panels for 10% of the project's total energy demand.

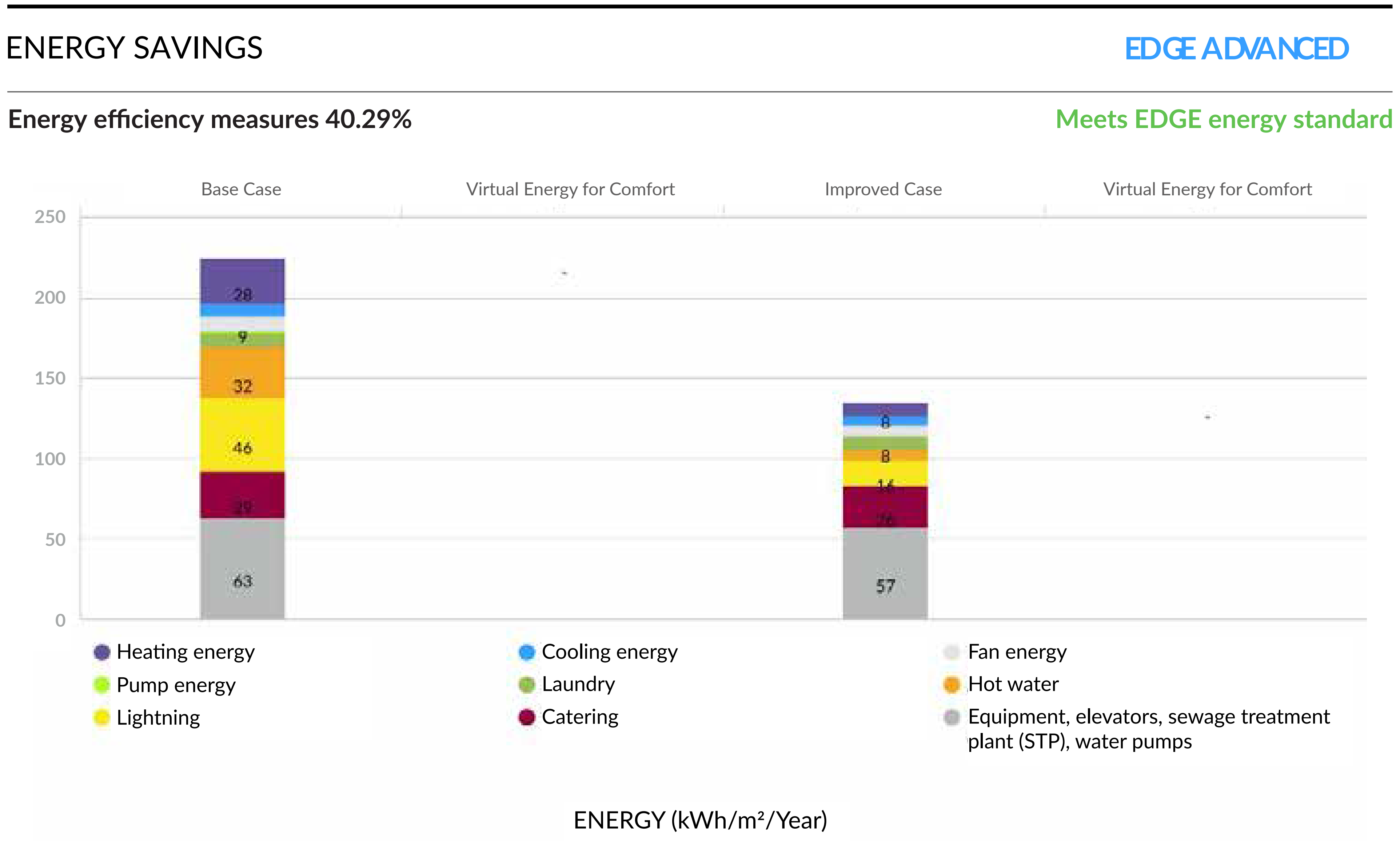
Water: The following flushes were used:

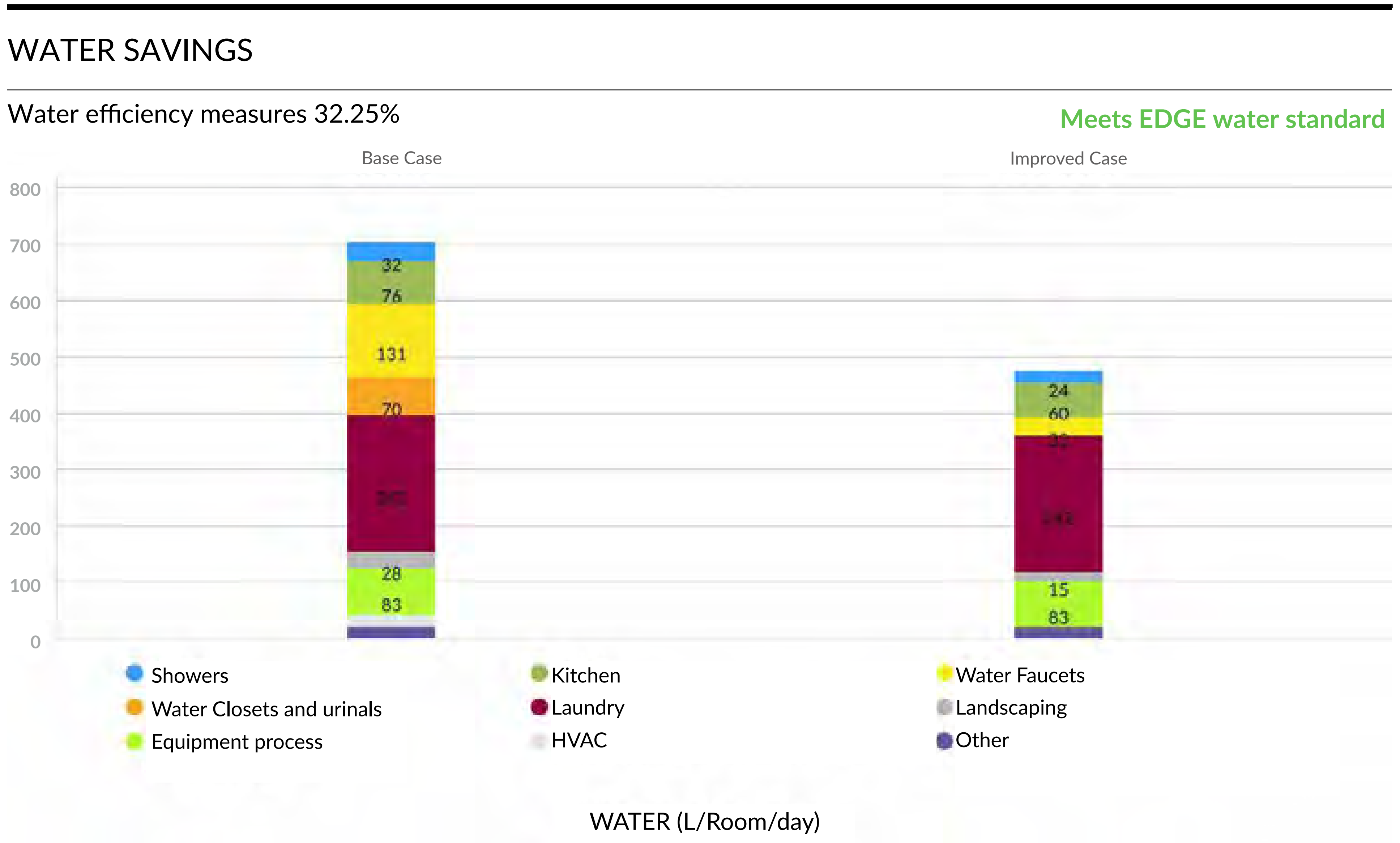
- Showerheads: 6 liters/min.
- Dry urinals (0 liters per flush).
- Sink: 2 liters/min.
- Kitchen faucets: 6 liters/min.
- Water closets: single flush of 6 liters/min.

Additionally, grey water recovery was included, together with the efficient use of water for green areas. Once again, the rinse water reclamation system to reuse rinse water for wash cycle laundry was left out.

12 With the savings obtained, an EDGE Advanced certificate would be achieved.

Figure 35. Simulation h results summary for BAA-PH case.





10.9 Simulation i

This exceptional case had the aim of reaching the EDGE standard with the greatest saving and the lowest incremental cost possible. Only the minimum measures identified by EDGE were used, without editing the coefficients. When it was not possible to reach the standard, other measures were gradually added seeking the standard at the lowest incremental cost possible.

The savings obtained were 23% in energy and 24.77% in water.

Measures considered:

Energy: : Initially, the following measures were adopted, but it was not possible to reach the standard:

- Reduced window to wall ratio in the exterior façade - 20% WWR.
- Insulation of roof surfaces - U-value: 0.442.
- Thermal insulation of external walls - U value: 0.446.

By adopting these measures, savings of 6.27% were reached with an incremental cost of USD 305,573.95.

The VRF air conditioning system with 3.5 COP was added in a second stage. With this measure, the saving was almost 15% with an incremental cost of USD 80,000.

Lastly, the following measures were implemented:

- Energy-saving light bulbs for external spaces.
- Lighting controls for corridors.
- Occupancy sensors in bathrooms.
- Solar hot water collectors for 60% of the demand.

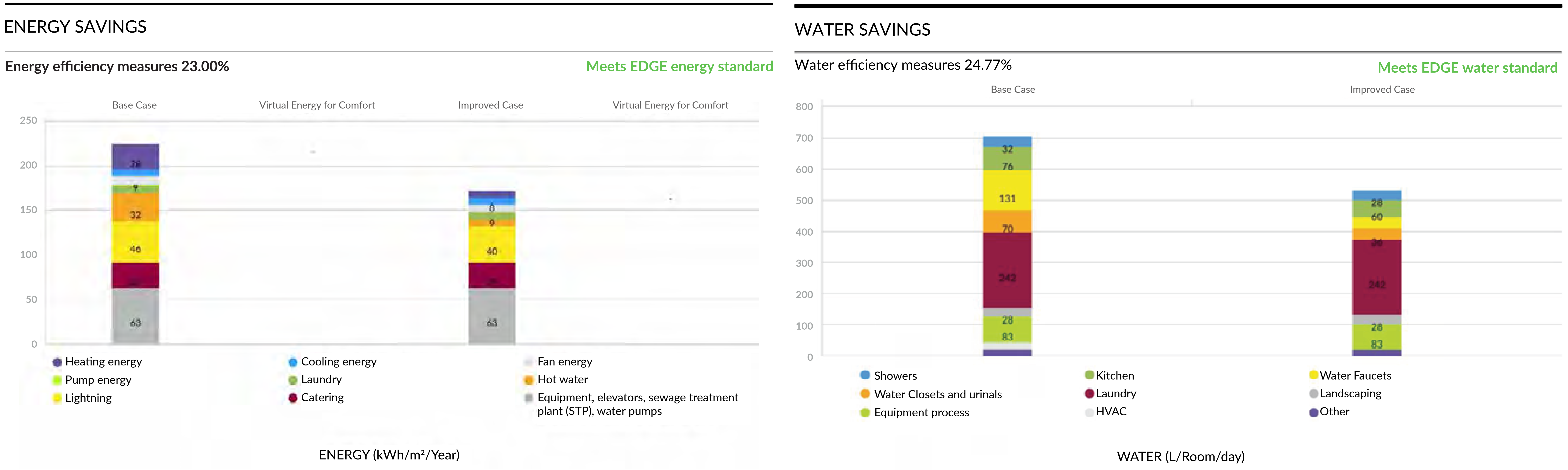
With them, the minimum standard of 20% was exceeded.

Water: Likewise, the minimum measures were adopted initially, and the minimum saving was exceeded without changing the flows and flushes.

- Low-flow showerheads: 7 liters/min.
- Low-flow bathroom washbasins: 2 liters/min.
- Water closets dual flush: 3 liters and 6 liters per flush.
- Water efficient urinals in all bathrooms: 2 liters per flush.
- Kitchen faucets with efficient water use: 6liters/min.

Appendix 6 shows the summary of measures chosen for the 9 simulations of this case.

Figure 36. Simulation i results summary for BAA-PH case.



Tips

The low E-coated glass and the high thermal performance glass behave similarly as regards energy saving. However, it is more cost-effective to use low E-coated glass because it has a lower incremental cost*.

The use of solar panels provides a significant saving in energy at an incremental cost of just over USD 60,000. By implementing this measure, the payback period is reduced by 18 months.

Including sensible heat recovery from exhaust with 60% efficiency significantly raises the incremental cost and increases the saving by only around 2%.

To optimize the incremental cost, a combination of measures can be used, such as energy-saving light bulbs for external spaces and solar hot water collectors. However, if the aim of the project is to reduce the monthly cost of utilities, energy-saving light bulbs for internal spaces should be used. This measure raises the incremental cost of the projects but reduces the monthly cost.

The air conditioning with water cooled chiller does not generate a significant increase in the efficiency (around 0.2%). However, it does generate an incremental cost of almost USD 100.000.

Using speed variable units in pumps is not significant regarding energy saving or incremental cost.

In this kind of existing buildings, it is necessary to implement efficient lighting measures and to specify the cooling system to be used to reach the energy saving standard.

Grey water recycling is more cost-effective than rainwater recycling, from an investment standpoint.

Using solar photovoltaic panels represents a significant incremental cost, as well as an increase in efficiency.

The minimum water measures suggested by EDGE are enough to reach the standard, without having to change the flows or flushes.

* It should be taken into account that Buenos Aires climate has 4 very different seasons. If the project is located mainly in cold or warm climates, the results may change.

11. Results for the existing hospital simulations: savings

The results of the simulations were compared to check trends and relations between the different strategies.

11.1 Energy

All simulations reach the standard of 20% saving in energy. Sa, Sb, Sc and Sd are focused on passive strategies, and Se, Sf, Sg and Sh are focused on active ones, including generating on site renewable energy.

Sd presents the lowest energy saving, mainly because of the use of air-cooled chiller. This system is significantly less efficient when compared to a variable refrigerant flow (VRF).

Sg shows the highest energy saving because it considers the following: High thermal performance glass, VRF type HVAC system, variable speed in the air handlings and in the pumps, heat recovery and renewable energy, both solar thermal with collectors as well as photovoltaic.

11.2 Water

Similarly to what happened with energy, all simulations reached the standard of 20% saving required by EDGE. When the grey water treatment and recycling system was used, savings higher than 30% were achieved.

Figure 37. Energy savings PH simulations.

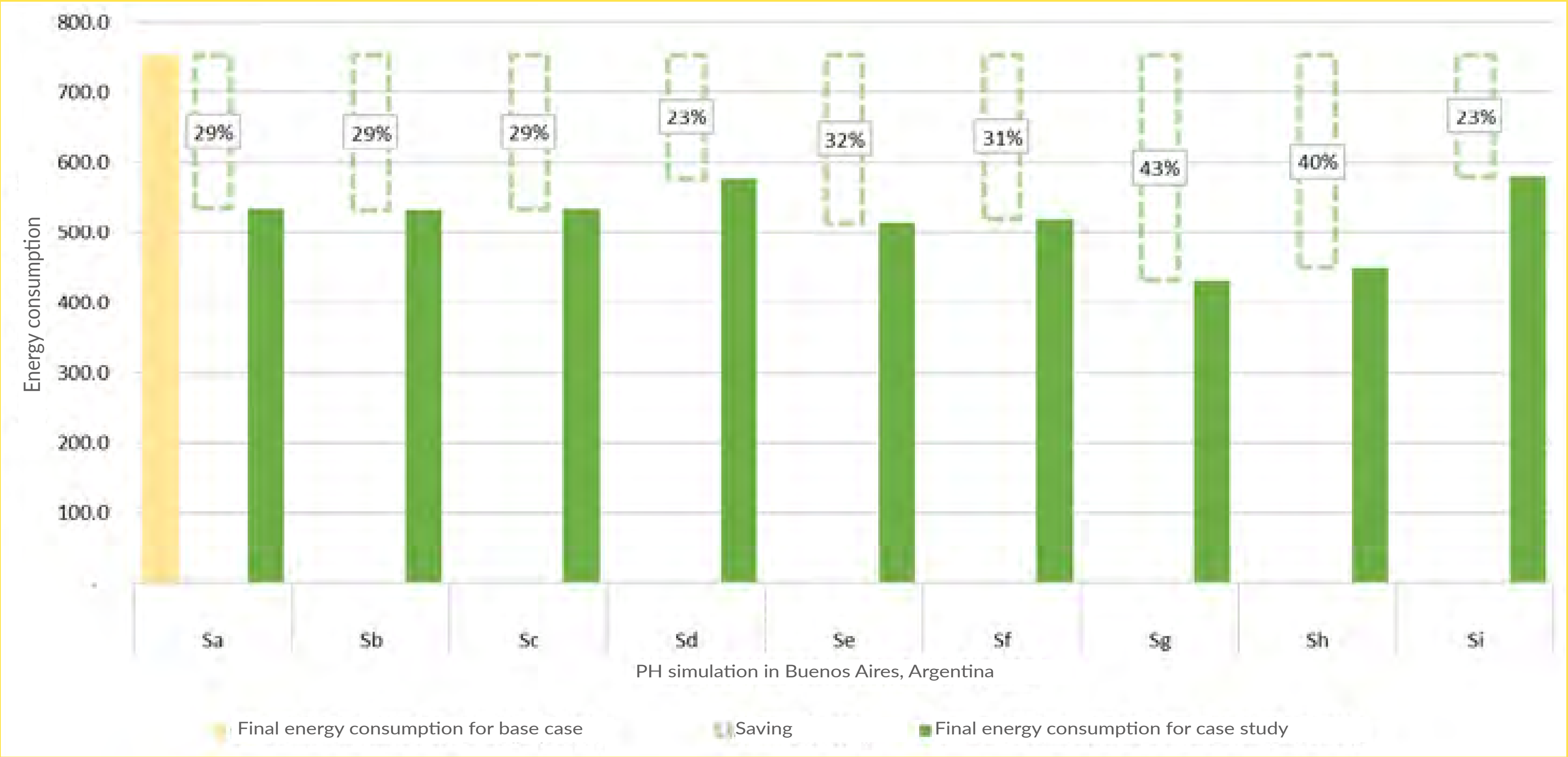
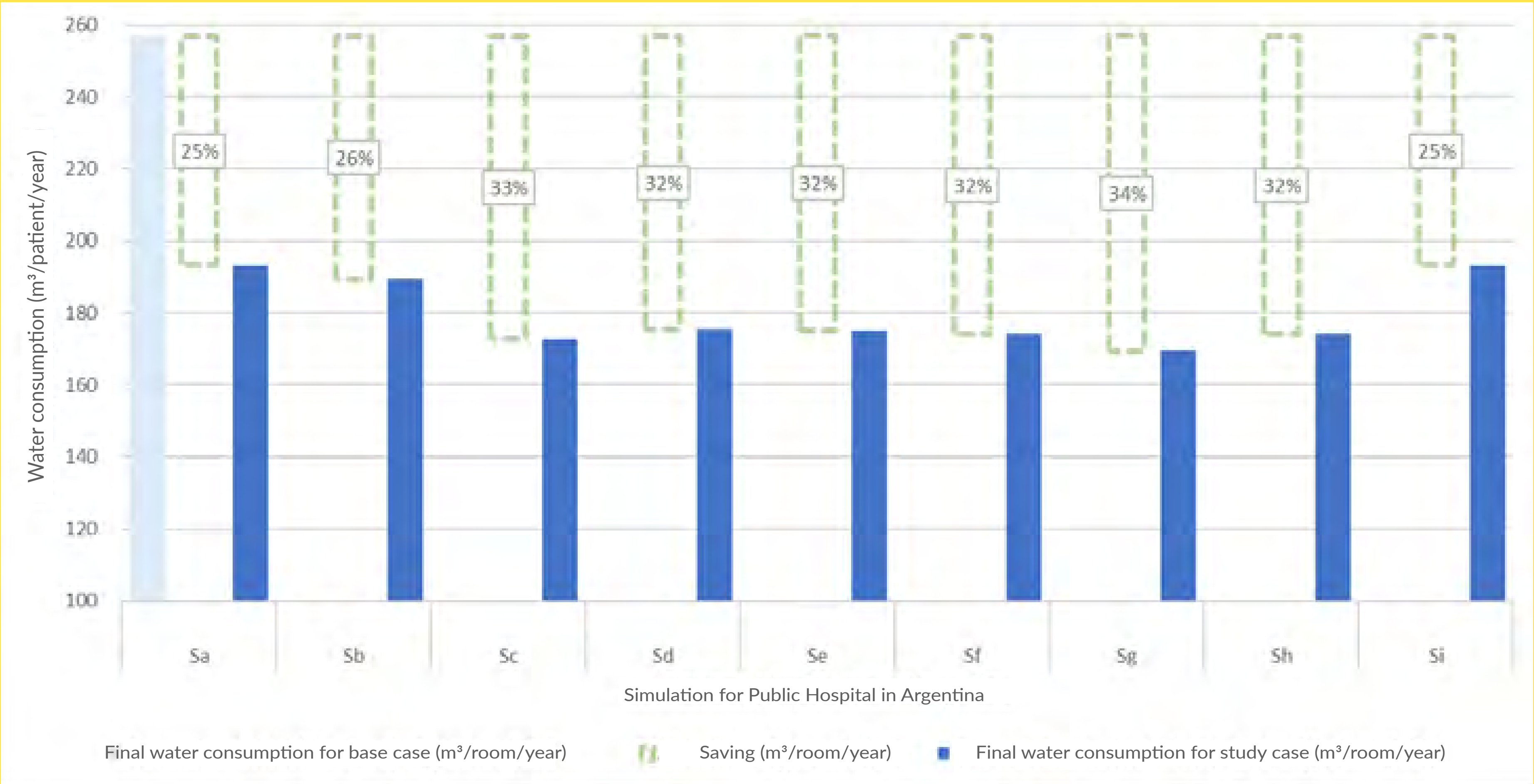


Figure 38. Water savings PH simulations.



12. Financial analysis of the existing hospital

12.1 Incremental cost and savings

The first step to carry out a financial analysis is to determine the **incremental cost** of each alternative, together with the potential **savings of utilities tariffs**.

Sa, Sb and Sc show that with an incremental investment close to USD 1.2 million, the EDGE standard could be reached and estimate savings in utilities of around USD 150,000 per year could be obtained. The amount invested represents approximately USD 30/m², and a saving of USD 3.75/m² with a PP of 8 years could be reached. Sg and Sh show a PP similar to the previous ones, but higher incremental cost and saving.

In Se and Sf the saving is similar, but the PP is higher because of the cost of the incremental investment.

Lastly, Si shows that with an investment of USD 530,000 (USD 13.25/m²) the standard EDGE saving is reached. Besides, the PP is 4.3 years, the lowest of all the alternatives. Therefore, from a financial standpoint this is the most favorable simulation.

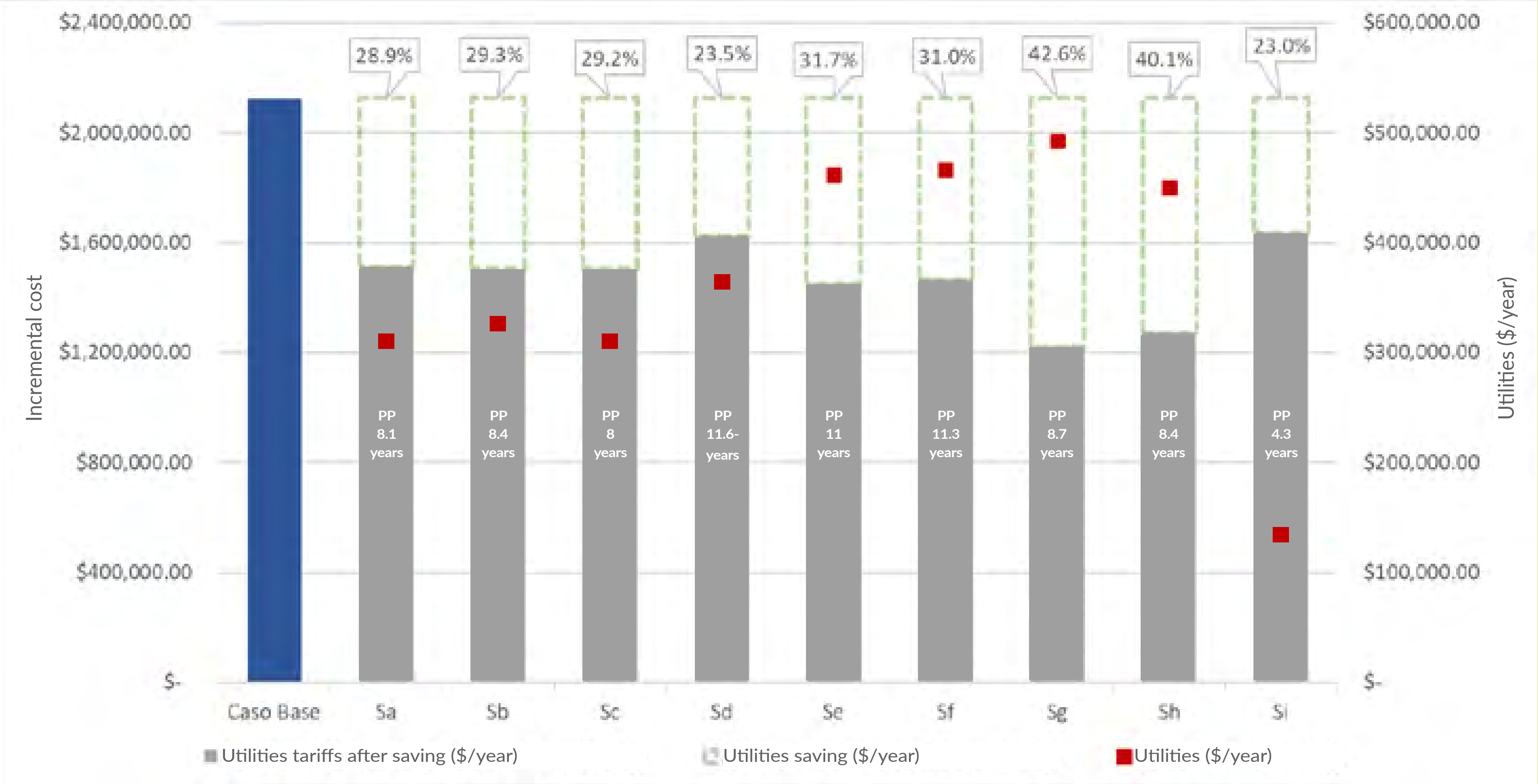
12.2 Financial indicators

To analyze the financial viability, the following are calculated: The internal rate of return (IRR) of the investment project, the net present value (NPV) and the payback period of the investment.

In this case, the project's financial viability was calculated using an IRR of 10%. Under these conditions, all simulations show an economically attractive result.

By observing the Figure below, it is possible to assert that financially speaking Si is the most favorable alternative. This is because the IRR is 21.8% with a positive NPV calculated with a 10% discount rate.

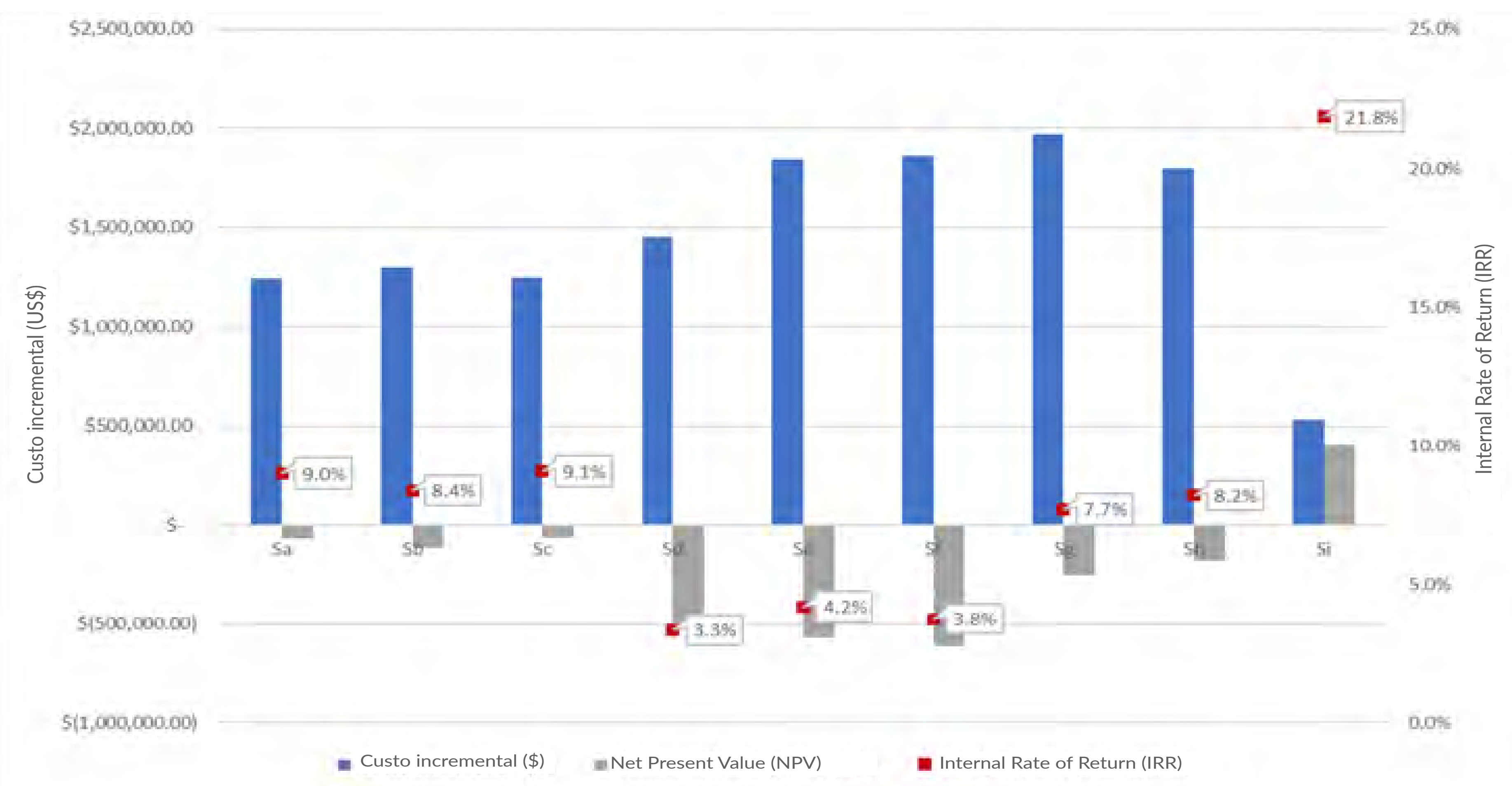
Figure 39. PH incremental cost and annual savings.



As previously stated, alternatives Sa, Sb and Sc have similar results and are validated with the previous Figure which shows that the IRR is around 9% and the NPV is below zero. Although the IRR is not over 10%, it is close and can be considered feasible if resources saving is prioritized over financial profitability.

Sd, Se, Sf and Sg show very low IRR (below 10%) and negative NPV. In other words, the project's future flows at present value with a discount rate of 10% do not justify the investment.

Figure 40. Financial indicators of different PH scenarios.



HOW MUCH ENERGY AND WATER CAN WE SAVE IN AN EXISTING HOSPITAL?

ENERGY

On average, 72 kWh per construction square meter.

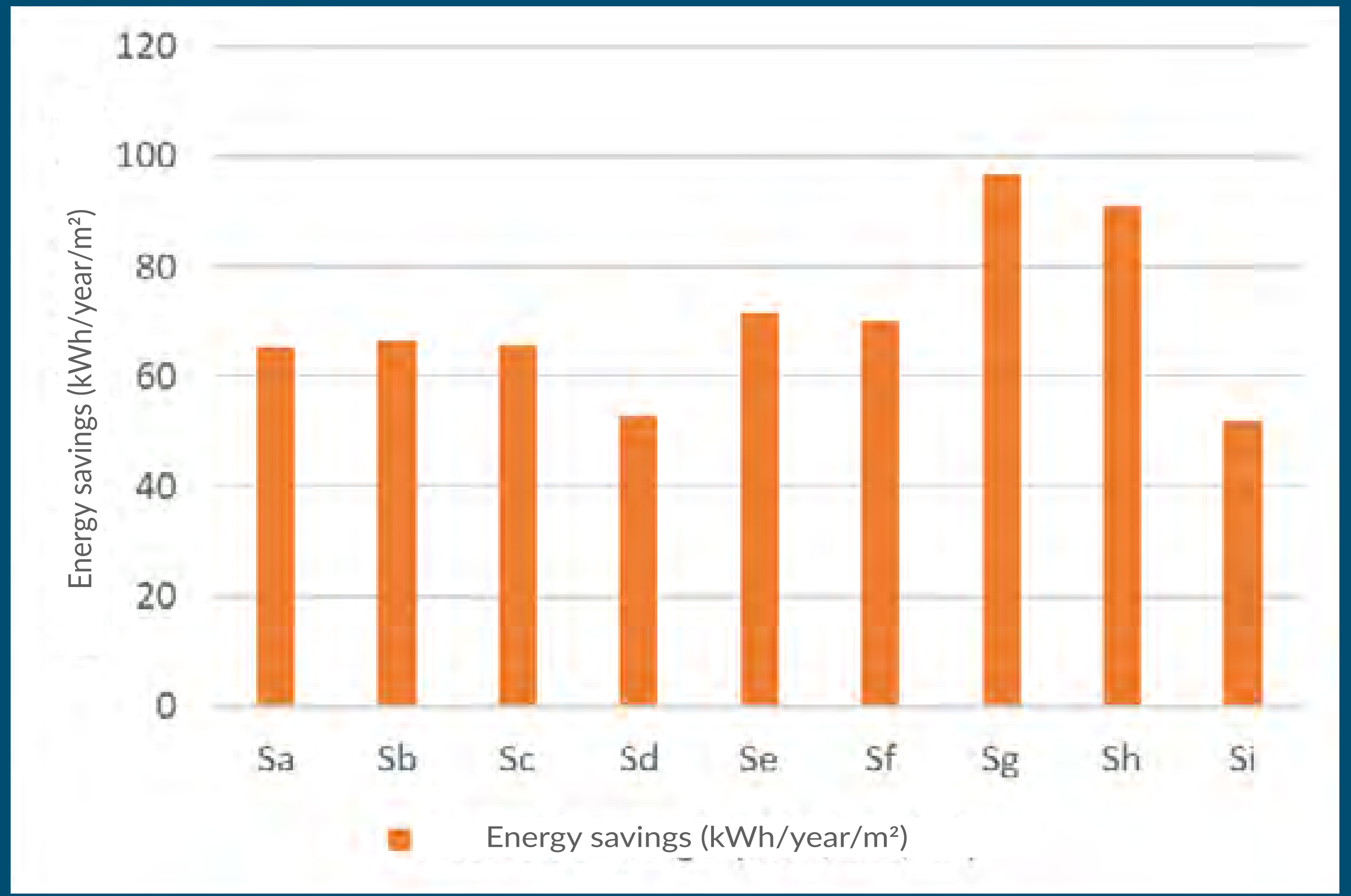


Figure 41. Annual Energy savings per PH m².

WATER

On average, 0.86 m3 of water per construction square meter.

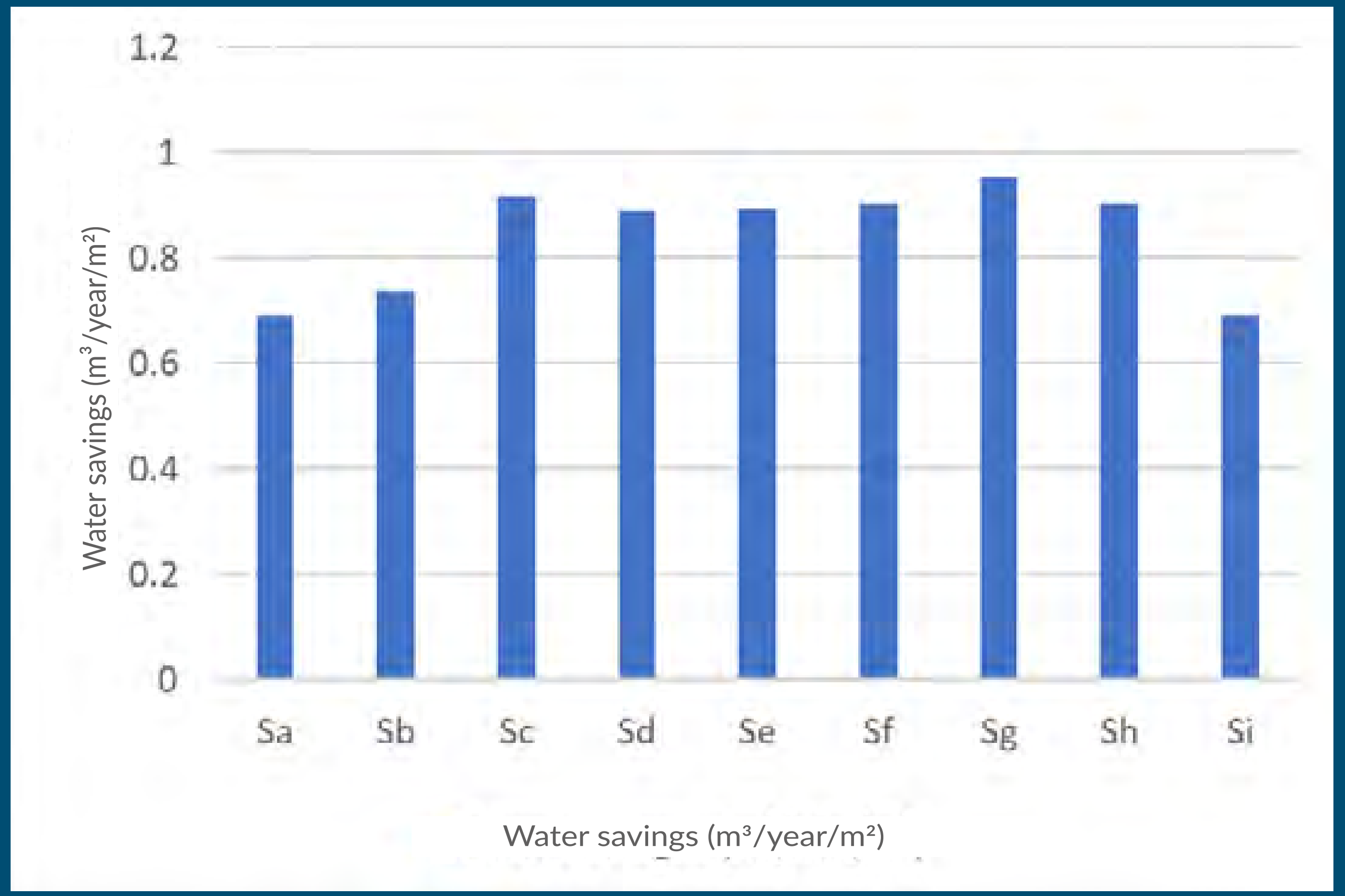


Figure 42. Annual water savings per PH m².

13. Findings and recommendations

CONSUMPTION SAVINGS

- For new health care buildings, the annual savings could be of **109 kWh, 0.9 m³ in water, 0.6 GJ** in embodied energy in the materials and **0.044 tCO_2 per construction square meter**, with an average incremental cost that does not exceed **USD 20/m²**.

- For existing hospital buildings, an annual saving of **72 kWh and 0.86 m³ in water per construction square meter could be obtained**, with an average incremental cost that does not exceed **USD 49/m²**. Depending on the implemented measures, that cost could fall to **USD 13.25/m²**.

FINANCIAL SAVINGS

- The analysis carried out showed that, although there are many options with different initial investment costs, these investments can be profitable within a reasonable term (less than 7 years) if the savings in the utilities during the operation stage are taken into account.

- Favorable results were obtained after doing the financial analysis, both with the utilities costs of EDGE and with a specific research of current tariffs. Whatever the case, EDGE recommends confirming the value of utilities costs with the local companies if a more precise financial analysis is needed.

ENERGY

- Using energy-saving light bulbs is key, both in cold and warm climates. LED bulbs are recommended. However, if that is not possible, compact fluorescent lamps (CFL), T5 or other kinds that reach 90 lm/W or more can be used.

- VRF cooling system with a COP of 3.5 always turned out to be positive due to its low incremental cost compared to its saving level, especially in higher scale projects such as hospitals. Other systems, like the air conditioning with air- or water-cooled chillers, were not as effective and the incremental costs were higher.

- Reflective paints for surface and walls have a low impact on savings and increase the incremental cost, although their effectiveness is higher in warm climates. The key is the type of surface and walls chosen, and the type of insulation, especially in the case of cold climates. However, the use of these paints has better results on concrete and brick walls.

- In low-complexity buildings and in hot climates, passive strategies have better efficiency than active ones. Natural ventilation for internal corridors is determinant for these results. Nevertheless, possible requirements for space tightness or specific regulations that do not allow the use of natural ventilation in certain areas should be considered.

- In a large-scale building and in hot climates, it is not enough to use passive design measures. To reach the standard it is necessary to add a VRF cooling system with a minimum COP of 3.5.

- Using external shading devices in windows to limit direct solar radiation is a more cost-effective measure than the high thermal performance glass, because its efficiency is lower than 1.5%, and it significantly raises the incremental cost. This conclusion was verified both in hot and cold climates, although it is necessary to consider other factors such as the window and wall ratio, and the building orientation.

- Heating is the main energy consumption in cold climates or in climates with low-temperature seasons. For these cases, high-efficiency equipment must be used to reduce energy consumption.

WATER

- Regarding water consumption, health care buildings can be divided into two categories: Those that do not have beds, kitchen and laundry; and those that have these services. Final water consumption in the projects is highly incremented by services related to laundry and catering.

- If the minimum flows and flushes suggested by EDGE are used, a minimum 20% reduction in water consumption can be achieved, and it is even possible to exceed it.

- It is always recommended to implement saving technologies that match the flows suggested by EDGE or to implement other ones that improve water consumption savings.

- The largest water demand is in the laundry service. Reusing water from these services means a high incremental cost and more treatment.

- No matter the rainfall level in a city, investing in rainwater harvesting systems has never proven to be effective. Nevertheless, grey water treatment and recycling systems do present a low incremental cost and high water saving.

- The projects that have green and landscaping areas should include efficient irrigation systems and consider native species to avoid excessive use of water.

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MATERIALS

- Regardless of the measures suggested by EDGE, the selection of materials should always comply with local regulations. These regulations generally define minimum thickness and insulation levels.
- The 3-D wire panel with 'shot-crete' both sides and expanded polystyrene proved to have a good energy performance and a reasonable incremental cost, both in warm and cold climates.
- If the curtain wall (opaque element) is used in cold climates, the incremental cost increases considerably, without generating a significant reduction in the embodied energy. For this kind of climate, façades with a higher window to wall ratio (WWR) are recommended, although this will also be determined by the orientation and the type of glass used.
- In turn, in warm climates, curtain walls avoid reaching the standard. The 50% ratio between wall and window in the 4 façades should not be exceeded.
- If the curtain wall is desired, a design that integrates passive and active measures should be created for its optimal implementation.
- In situ reinforced concrete slabs have a positive impact if they are specified with a thickness lower than 350 mm and 35 kg of reinforced steel. It is important to comply with each city's local regulations.
- Unplastic PVC and aluminum present a very similar incremental cost, although the former has a higher impact in the embodied energy saving.

14. Limitations and final considerations

This analysis does not intend to be thorough and the results depend on EDGE parameters and default list of measures. The results herein do not offer definite conclusions or unique solutions, they just provide an initial guideline for project teams and decision-makers to identify the measures that allow energy and water savings, less investment costs and shorter payback periods.

The simulations were run in September 2019, with EDGE Version 2.1.5. If the user carries out simulations after this date, the version can be a different one, therefore the results may not be the same. Every 3 years, approximately, EDGE updates the baseline for each country, including the utilities tariffs. At the same time, the IFC is permanently adjusting the platform to improve its information and accuracy.

Reducing energy consumption, compared to the baselines, does not necessarily maximize the building comfort. EDGE is, first of all, a model to perform financial directional comparisons. For comfort results, additional, more detailed studies are needed. Those studies should incorporate the use of a software aimed at assessing the building thermal comfort.

15. References

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Appendix

Appendix 1. Detailed description of the cities considered

1. Hermosillo, México. (HMX)

Hermosillo is in the state of Sonora, in the northwest of Mexico and 210 meters above sea level (masl). It has desert climate and during the year there is virtually no rainfall. The mean annual temperature is 20.7 °C and the average annual rainfall is 1,504.70 mm. The climate is classified as BWh according to the Köppen-Geiger system.

Figure 43. Atmospheric and geographical conditions in Hermosillo /Mexico.

Hermosillo/México

Month	Average temperature (°C)
January	13
February	14
March	17
April	21
May	25
June	28
July	28
August	26
September	25
October	22
November	16
December	13
Max. Temp.	28
Min. Temp.	13
Annual average	20.7
Average annual rainfall	26.7
Latitude	29

Figure 44. Atmospheric and geographical conditions in Cartago/Costa Rica.

Cartago/Costa Rica

Month	Average temperature (°C)
January	17.6
February	18.1
March	18.7
April	19.7
May	20.5
June	20.3
July	19.8
August	20.1
September	20.4
October	20.1
November	19
December	18.1
Max. Temp.	20.5
Min. Temp.	17.6
Annual average	19.4
Average annual rainfall	1504.7
Latitude	10

2. Cartago, Costa Rica (CCR)

Cartago southeast of Costa Rica's capital city, at an altitude of 1,435 masl. Its climate is temperate and warm. During summer there is a good amount of rainfall, whereas in winter there is very little. The average temperature is 19.4 °C and the average annual rainfall is 1,504.70 mm. Köppen and Geiger classify this location as Af.

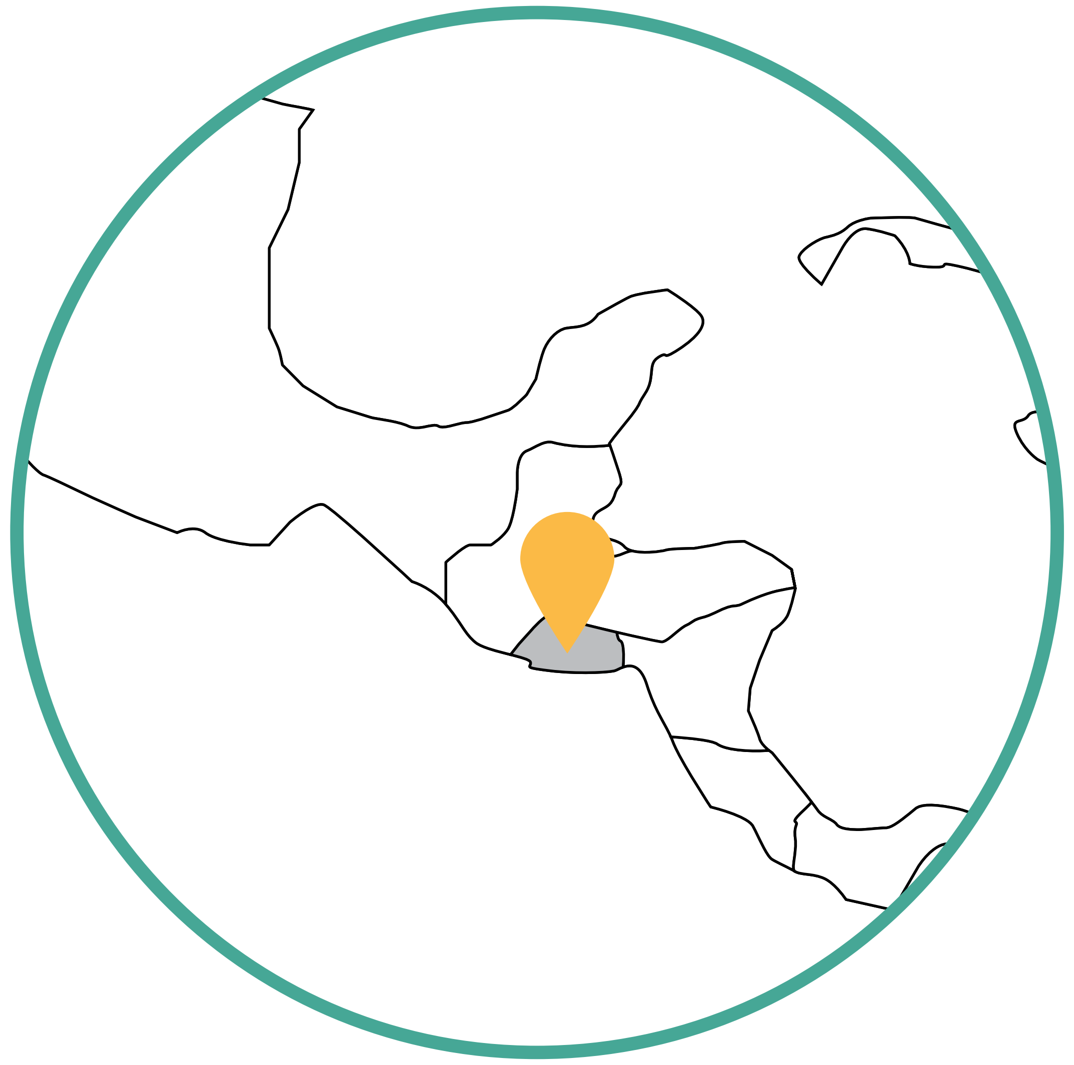
3. San Salvador, El Salvador (SEL)

San Salvador is the capital city of El Salvador and it is around 670 masl and 25 km from the pacific coast. The climate in San Salvador is classified as tropical where summers are rainier than winters.

The average annual temperature is 24.2 °C and the average annual rainfall is 979 mm. The Köppen-Geiger climate classification is Aw.

Figure 45. Atmospheric and geographical conditions in San Salvador/El Salvador.

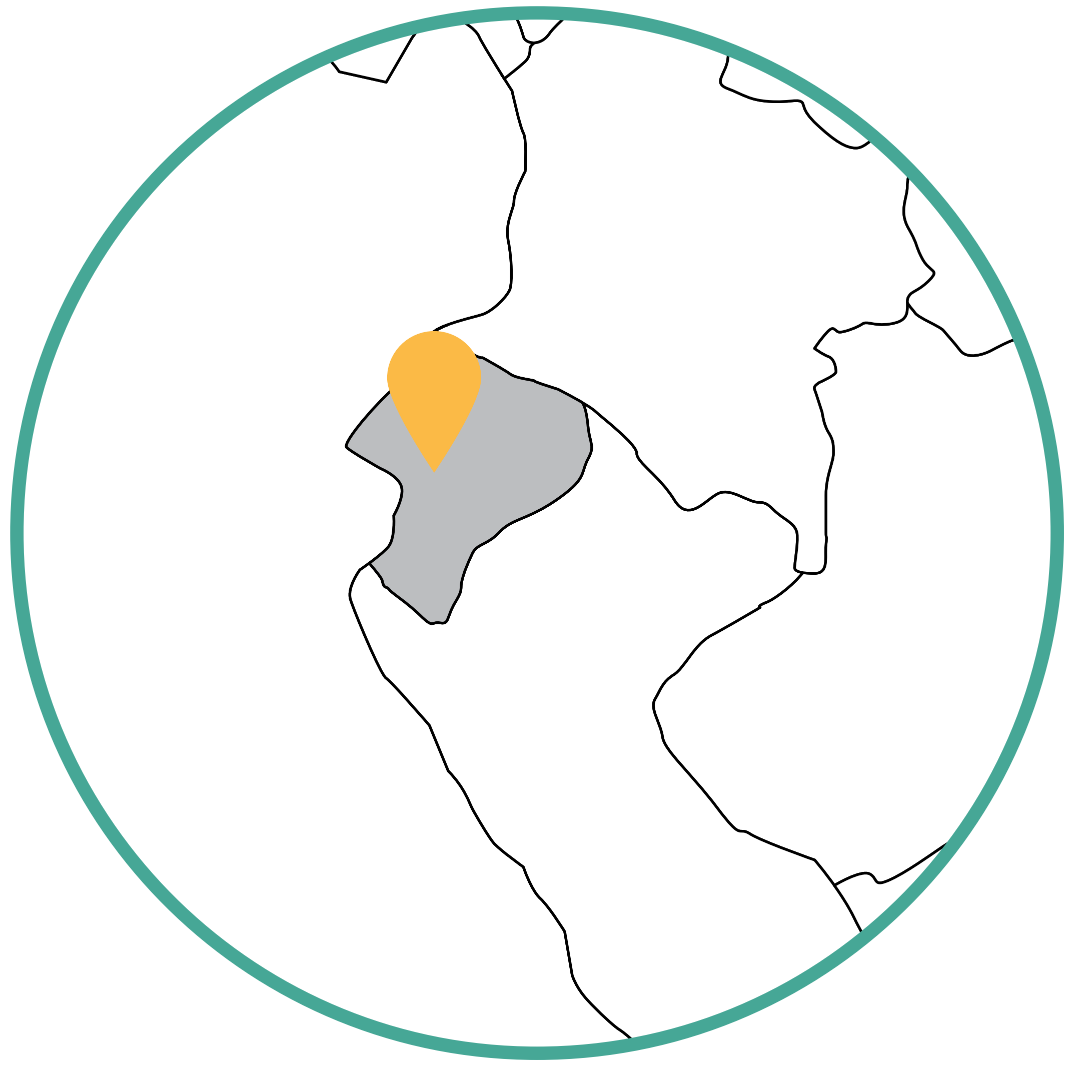
San Salvador/ El Salvador



Month	Average temperature (°C)
January	23
February	24
March	25
April	26
May	25
June	24
July	24
August	24
September	24
October	24
November	24
December	23
Max. Temp.	26
Min. Temp.	23
Annual average	24.2
Average annual rainfall	979
Latitude	13.7

Figure 46. Atmospheric and geographical conditions in Quito/Ecuador.

Quito/Ecuator



Month	Average temperature (°C)
January	14
February	14
March	14
April	14
May	14
June	14
July	14
August	14
September	14
October	14
November	14
December	14
Max. Temp.	14
Min. Temp.	14
Annual average	14
Average annual rainfall	2743
Latitude	0.13

4. Quito, Ecuador (QEC)

Quito, the capital city of Ecuador, is between mountains at 2,850 masl. The climate is temperate and warm, with great amounts of rainfall, even in the driest month. According to Köppen and Geiger the climate is Cfb with a mean annual temperature of 14 °C and the average rainfall is 2,743 mm per year.

5. Santa Marta, Colombia (SMC)

Santa Marta is in Colombia, next to the Caribbean Sea, at 15 masl. In Santa Marta the climate is local steppe and there is little rainfall throughout the year. The mean annual temperature is 25.8 °C and the rainfall is 1,777 mm. According to Köppen-Geiger classification, this climate is classified as BSh.

Figure 47. Atmospheric and geographical conditions in Santa Marta/Colombia.

Santa Marta/Colombia

Month	Average temperature (°C)
January	25
February	25
March	26
April	26
May	26
June	26
July	26
August	26
September	26
October	26
November	26
December	25
Max. Temp.	26
Min. Temp.	25
Annual average	25.8
Average annual rainfall	1777
Latitude	11.3

Figure 48. Atmospheric and geographical conditions in La Paz/Bolivia.

La Paz/Bolivia

Month	Average temperature (°C)
January	8
February	8
March	8
April	8
May	6
June	5
July	4
August	6
September	7
October	8
November	9
December	9
Max. Temp.	9
Min. Temp.	4
Annual average	7.2
Average annual rainfall	561
Latitude	16.5

6. La Paz, Bolivia (LPB)

La Paz, in Bolivia, is 3,625 masl. The climate is warm and temperate. During summer there is a good amount of rainfall, whereas in winter there is very little. According to Köppen and Geiger the climate is classified as Cwb with an average temperature of 7.2°C. Besides, the average rainfall is 561 mm per year.

7. Manaus, Brazil (MBR)

Manaus is the capital city of the state of Amazonas in Brazil, it is 92 masl. The climate in Manaus is tropical and most months are characterized by significant rainfall with a short dry season of low impact. The climate here is classified as Am by the Köppen-Geiger system, with a mean annual temperature of 27.3 °C and average annual rainfall of 1,811 mm.

Figure 49. Atmospheric and geographical conditions in Manaus/Brazil.

Manaus/Brazil

Month	Average temperature (°C)
January	27
February	26
March	27
April	27
May	27
June	27
July	27
August	28
September	28
October	28
November	28
December	27
Max. Temp.	28
Min. Temp.	26
Annual average	27.3
Average annual rainfall	1811
Latitude	3.1

Figure 50. Atmospheric and geographical conditions in Puerto Santa Cruz/Argentina.

Puerto Santa Cruz/Argentina

Month	Average temperature (°C)
January	24
February	22
March	19
April	15
May	11
June	8
July	8
August	9
September	12
October	16
November	19
December	22
Max. Temp.	24
Min. Temp.	8
Annual average	15.4
Average annual rainfall	135
Latitude	50

8. Puerto Santa Cruz, Argentina (SCA)

Puerto Santa Cruz is a small city in the province of Santa Cruz, Argentina. It is on the river which has its same name, less than 20 kilometers away from the Argentine Sea. Its altitude is 0 masl. The climate in Puerto Santa Cruz is local steppe with little rainfall during the year. The mean annual temperature is 15.4°C and the average annual rainfall is 135 mm. According to Köppen-Geiger classification, this climate is BSk.

Appendix 2. Detailed description of the buildings considered

1. Outpatient Clinic 1 (CPA1)

The proposal is a 300 m² service building for outpatients, similar to a health station or a low-complexity health care center without emergency service. It does not have accommodation, or laundry and kitchen services.

Default information provided by EDGE was used for the distribution of internal areas, main orientation, floor plan depth, and baseline assumptions.

It was assumed that the building will have air conditioning and heating system.

Table 13. Parameters and information for the Outpatient Clinic 1 (300 m²).

Outpatient Clinic 1		
General information	Area (m²)	300
	Floors	1
	Landscaping area (outdoors, m²)	60
	Average occupancy rate	70%
	Floor to floor height (m)	4
Details	Type of space	Área (m²)
	Consultation rooms	207
	Diagnostic services	24
	Offices	45
	Mechanical and electrical rooms	0
	Bathrooms/Storage	7
	Waiting rooms	17
Building lengths (m)	North	8.7
	South	8.7
	East	8.7
	West	8.7
	Northeast	8.7
	Northwest	8.7
	Southeast	8.7
	Southwest	8.7

2. Outpatient Clinic (CPA2)

The proposal is an outpatient service building of 1,500 m², similar to a low-complexity health care center without emergency service. It does not have accommodation, or laundry and kitchen services.

Default information provided by EDGE was used for the distribution of internal areas, main orientation, floor plan depth, and baseline assumptions.

It was assumed that the building will have air conditioning and heating system.

Table 14. Parameters and information for the Outpatient Clinic 2 (1,500 m²).

Outpatient Clinic 2		
General information	Area (m²)	1500
	Floors	1
	Landscaping area (outdoors, m²)	300
	Average occupancy rate	70%
	Floor to floor height (m)	4
Details	Type of space	Área (m²)
	Consultation rooms	1034
	Diagnostic services	121
	Offices	224
	Mechanical and electrical rooms	0
	Bathrooms/ Storage	34
	Waiting rooms	86
Building lengths (m	North	19.4
	South	19.4
	East	19.4
	West	19.4
	Northeast	19.4
	Northwest	19.4
	Southeast	19.4
	Southwest	19.4

3. Diagnostic Center (DC)

The proposal is an outpatient building whose main function is to provide diagnostic services. It has a built surface of 5000 m² distributed in two floors. It does not have accommodation, or laundry and kitchen services; but it does have an indoors parking area.

Default information provided by EDGE was used for the distribution of internal areas, main orientation, floor plan depth, and baseline assumptions.

It was assumed that the building will have air conditioning and heating system.

4. Multi-Specialty Hospital (MSH)

The proposal is a hospital building with an approximate surface of 12,000 m². It has surgery areas, 122 inpatient beds, laundry and kitchen services, and indoors parking area.

Default information provided by EDGE was used for the distribution of internal areas, main orientation, floor plan depth, and baseline assumptions.

It was assumed that the building will have air conditioning and heating system.

Table 15. Parameters and information for the Diagnostic Center.

Diagnostic Center		
General information	Area (m²)	5000
	Floors	2
	Landscaping area (outdoors, m²)	400
	Average occupancy rate	70%
	Floor to floor height (m)	4
Details	Type of space	Área (m²)
	Diagnostic services	3158
	Offices	421
	Corridors	421
	Mechanical and electrical rooms	0
	Bathrooms/Storage	105
	Indoor Car Parking	526
	Waiting rooms	368
Building lengths (m)	North	25
	South	25
	East	25
	West	25
	Northeast	25
	Northwest	25
	Southeast	25
	Southwest	25

Table 16. Parameters and information for the Multi-Specialty Hospital.

Multi-Specialty Hospital		
General information	Area (m²)	12034
	Floors	3
	Landscaping area (outdoors, m²)	1200
	Average occupancy rate	70%
	Floor to floor height (m)	4
	Beds	122
	With kitchen and laundry	
Hospital de Múltiplas Especialidades		
Details	Type of space	Área (m²)
	Patient Areas - General	5490
	Intensive Care Units (ICUs)	488
	Pre- & Post-Operating Rooms	244
	Operating Rooms	488
	Consultation Rooms	854
	Therapy rooms	488
	Diagnostic services	732
	Offices	244
	Corridors	976
	Central Sterile Supply Department	244
	Mechanical and electrical rooms	200
	Bathrooms/Storage	122
	Kitchen & Food Preparation	488
	Laundry	122
	Indoor Car Parking	732
	Waiting areas	122
Building lengths (m)	North	31.7
	South	31.7
	East	31.7
	West	31.7
	Northeast	31.7
	Northwest	31.7
	Southeast	31.7
	Southwest	31.7

5. Teaching Hospital (TH)

The proposal is a hospital building of around 20.000 m² distributed in 6 floors, including all the corresponding services and 227 inpatient beds.

Default information provided by EDGE was used for the distribution of internal areas, main orientation, floor plan depth, and baseline assumptions.

It was assumed that the building has air conditioning and heating system.

6. Nursing Home (NH)

The proposal is a nursing home, with 24 h accommodation, a surface of 3,000 m2 and two floors. The building has laundry and kitchen areas.

Default information provided by EDGE was used for the distribution of internal areas, main orientation, floor plan depth, and baseline assumptions.

It was assumed that the building will have air conditioning and heating system.

Table 17. Parameters and information for the Teaching Hospital.

Teaching Hospital		
General information	Area (m²)	20017
	Floors	6
	Landscaping area (outdoors, m²)	1500
	Average occupancy rate	70%
	Floor to floor height (m)	4
	Beds	227
	With kitchen and laundry	
Teaching Hospital		
Details	Type of space	Área (m²)
	Patient Areas - General	8172
	Patient areas – specialty wards	1022
	Intensive Care Units (ICUs)	817
	Pre- & Post-Operating Rooms	409
	Operating Rooms	817
	Consultation Rooms	2043
	Diagnostic services	1022
	Offices	409
	Corridors	1634
	Central Sterile Supply Department	409
	Mechanical and electrical rooms	200
	Bathrooms/Storage	204
	Kitchen & Food Preparation	817
	Laundry	204
	Indoor Car Parking	613
	Waiting areas	409
	Auditorium	817
Building lengths (m)	North	26.7
	South	26.7
	East	26.7
	West	26.7
	Northeast	26.7
	Northwest	26.7
	Southeast	26.7
	Southwest	26.7

Table 18. Parameters and information for the Nursing Home.

Nursing Home		
General information	Area (m²)	3000
	Floors	2
	Landscaping area (outdoors, m²)	300
	Average occupancy rate	70%
	Floor to floor height (m)	4
	With kitchen and laundry	
Nursing Home		
Details	Type of space	Área (m²)
	Patient Areas - General	1140
	Patient areas – specialty wards	684
	Consultation Rooms	143
	Offices	86
	Corridors	86
	Kitchen & Food Preparation	285
	Dining	285
	Waiting area	57
	Mechanical & Electrical Rooms	115
	Laundry	150
Building lengths (m)	North	19.4
	South	19.4
	East	19.4
	West	19.4
	Northeast	19.4
	Northwest	19.4
	Southeast	19.4
	Southwest	19.4

Appendix 3. Codes used during the study

Table 19. Cities.

City	Code
Cártago - Costa Rica	CCR
Hermosillo – México	HMX
La Paz – Bolivia	LPB
Manaus – Brazil	MBR
Quito – Ecuador	QEC
Puerto Santa Cruz – Argentina	SCA
San Salvador – El Salvador	SEL
Santa Marta – Colombia	SMC
Buenos Aires – Argentina	BAA

Table 20. Types of buildings.

Type	Code
Outpatient Clinic I	OC1
Outpatient Clinic II	OC2
Diagnostic Center	DC
Multi-Specialty Hospital (MSH)	MSH
Teaching Hospital (TH)	TH
Nursing House (NH)	NH
Existing Public Hospital	PH

Table 21. Energy Saving Measures.

Measure	Code
Reduced window to wall ratio in the exterior façade	*HSE01
Reflective paint/tiles for roof: solar reflectivity (albedo) 0.7	HSE02
Reflective paint/tiles for external walls: solar reflectivity (albedo) 0.7	HSE03
External shading devices - Annual average shading factor (ASSF) 0.61	HSE04
Insulation of roof surfaces - U-value: 0.297	*HSE05
Thermal insulation of external walls - U value: 0.289	*HSE06
Low-E coated glass - U-value: 3 W/m².K and SHGC: 0.45	HSE07
Higher thermal performance glass - U-value: 1.95 W/m².K and SHGC: 0.28	HSE08
Natural ventilation – Corridors	HSE09
Natural ventilation - Lobby, waiting and consultation areas	HSE10
Natural ventilation – Patient rooms	HSE11
Variable refrigerant volume (VRV) cooling system COP of 3.5	*HSE13
Air conditioning with air cooled chiller - COP of 3.3	*HSE14
Air conditioning with water cooled chiller - COP of 5.2	*HSE15
Variable speed drives in AHU	HSE20
Variable speed drives pumps	HSE21
Sensible heat recovery from exhaust air 60% efficiency	HSE22
Energy – saving light bulbs – Internal spaces (except OT)	HSE29
Energy – saving light bulbs – External spaces	HSE30
Lighting controls for corridors	HSE32
Occupancy sensors in bathrooms	HSE33
Solar hot water collectors - 60% of hot water demand	HSE35
Solar photovoltaics - 10% of total energy demand	HSE36

Table 22. Water saving measures.

Measure	Code
Low-flow showerheads - 7 liters/min	*HSW01
Low-flow faucets in all bathrooms. 2 liters/min.	*HSW02
Dual flush for water closets. 6 liters/the first flush, 3 liters/the second flush	*HSW03
Water efficient urinals in all bathrooms - 2 liters per flush	*HSW04
Water efficient kitchen faucets- 6 liters/min	*HSW07
Water efficient landscaping - 4 liters/m2/day	HSW09
Grey water treatment and recycling system	HSW12

Table 23. Materials efficiency measures.

Measure	Code
Floor slabs	*HSM01
Roof construction	*HSM02
External walls	*HSM03
Internal walls	*HSM04
Flooring	*HSM05
Window frames	*HSM06
Walls insulation	HSM07
Roof insulation	HSM08

Appendix 4. Summary of the measures simulated

Table 24. Summary of measures in the Outpatient Clinics 1 (OC1).

Energy	CCR S1	CCR S2	HMX S1	HMX S2	LPB S1	LPB S2	MBR S1	MBR S2	QEC S1	QEC S2	SCA S1	SCA S2	SEL S1	SEL S2	SMC S1	SMC S2
HSE01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE02																
HSE03																
HSE04	■		■		■		■		■		■		■		■	
HSE05*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE06*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE07	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE08																
HSE09	■		■		■		■		■		■		■		■	
HSE10	■		■		■		■		■		■		■		■	
HSE11	■		■		■		■		■		■		■		■	
HSE13		■		■		■		■		■		■		■		■
HSE14																
HSE15																
HSE20																
HSE21		■		■		■		■		■		■		■		■
HSE22																
HSE29	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE30	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE32																
HSE33	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE35		■		■		■		■		■		■		■		■
HSE36		■		■		■		■		■		■		■		■

Water	CCR S1	CCR S2	HMX S1	HMX S2	LPB S1	LPB S2	MBR S1	MBR S2	QEC S1	QEC S2	SCA S1	SCA S2	SEL S1	SEL S2	SMC S1	SMC S2
HSW01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW07*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW09																
HSW12		■		■		■		■		■		■		■		■

Materials	CCR S1	CCR S2	HMX S1	HMX S2	LPB S1	LPB S2	MBR S1	MBR S2	QEC S1	QEC S2	SCA S1	SCA S2	SEL S1	SEL S2	SMC S1	SMC S2
HSM01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM05*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM06*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM07	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM08	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 25. Summary of measures in the Outpatient Clinics 2 (OC2).

Energy	CCR S1	CCR S2	HMX S1	HMX S2	LPB S1	LPB S2	MBR S1	MBR S2	QEC S1	QEC S2	SCA S1	SCA S2	SEL S1	SEL S2	SMC S1	SMC S2
HSE01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE02																
HSE03																
HSE04	■		■		■		■		■		■		■		■	
HSE05*	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
HSE06*	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
HSE07																
HSE08																
HSE09	■		■		■		■		■		■		■		■	
HSE10	■		■		■		■		■		■		■		■	
HSE11	■		■		■		■		■		■		■		■	
HSE13		■		■		■		■		■		■		■		■
HSE14																
HSE15																
HSE20									■							
HSE21		■		■		■		■		■		■		■		■
HSE22																
HSE29	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE30	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE32																
HSE33	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE35		■		■	■	■		■	■	■	■	■		■		■
HSE36		■		■		■		■		■		■		■		■

Water	CCR S1	CCR S2	HMX S1	HMX S2	LPB S1	LPB S2	MBR S1	MBR S2	QEC S1	QEC S2	SCA S1	SCA S2	SEL S1	SEL S2	SMC S1	SMC S2
HSW01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW07*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW09																
HSW12	■	■		■		■		■		■		■		■		■

Materials	CCR S1	CCR S2	HMX S1	HMX S2	LPB S1	LPB S2	MBR S1	MBR S2	QEC S1	QEC S2	SCA S1	SCA S2	SEL S1	SEL S2	SMC S1	SMC S2
HSM01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM05*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM06*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM07	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM08	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 26. Summary of measures in the Diagnostic Center (DC).

Energy	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSE01*																
HSE02																
HSE03																
HSE04																
HSE05*																
HSE06*																
HSE07																
HSE08																
HSE09																
HSE10																
HSE11																
HSE13																
HSE14																
HSE15																
HSE20																
HSE21																
HSE22																
HSE29																
HSE30																
HSE32																
HSE33																
HSE35																
HSE36																

Water	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSW01*																
HSW02*																
HSW03*																
HSW04*																
HSW07*																
HSW09																
HSW12																

Materials	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSM01*																
HSM02*																
HSM03*																
HSM04*																
HSM05*																
HSM06*																
HSM07																
HSM08																

Table 27. Summary of measures in the Multi-Specialty Hospital (MSH).

Energy	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSE01*																
HSE02																
HSE03																
HSE04																
HSE05*																
HSE06*																
HSE07																
HSE08																
HSE09																
HSE10																
HSE11																
HSE13																
HSE14																
HSE15																
HSE20																
HSE21																
HSE22																
HSE29																
HSE30																
HSE32																
HSE33																
HSE35																
HSE36																

Water	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSW01*																
HSW02*																
HSW03*																
HSW04*																
HSW07*																
HSW09																
HSW12																

Materials	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSM01*																
HSM02*																
HSM03*																
HSM04*																
HSM05*																
HSM06*																
HSM07																
HSM08																

Table 28. Summary of measures in the Teaching Hospital (TH).

Energy	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSE01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE02																
HSE03																
HSE04	■		■		■		■		■		■		■		■	
HSE05*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE06*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE07																
HSE08																
HSE09	■		■		■		■		■		■		■		■	
HSE10	■		■		■		■		■		■		■		■	
HSE11	■		■		■		■		■		■		■		■	
HSE13	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE14																
HSE15																
HSE20																
HSE21																
HSE22																
HSE29	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE30	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE32	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE33	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE35	■	■		■		■		■		■		■		■		■
HSE36		■		■		■		■		■		■		■		■

Water	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSW01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW07*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW09		■		■		■		■		■		■		■		■
HSW12		■		■		■		■		■		■		■		■

Materials	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSM01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM05*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM06*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM07	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM08	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 29. Summary of measures in the Nursing Home (NH).

Energy	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSE01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE02																
HSE03																
HSE04	■		■		■		■		■		■		■		■	
HSE05*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE06*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE07																
HSE08																
HSE09	■		■		■		■		■		■		■		■	
HSE10	■		■		■		■		■		■		■		■	
HSE11	■		■		■		■		■		■		■		■	
HSE13	■	■		■	■	■		■	■	■	■	■		■		■
HSE14																
HSE15																
HSE20																
HSE21																
HSE22																
HSE29		■		■		■		■		■		■		■		■
HSE30	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE32	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE33	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSE35	■	■		■		■		■		■		■		■		■
HSE36		■		■		■		■		■		■		■		■

Water	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSW01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW07*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSW09																
HSW12	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Materials	CCR		HMX		LPB		MBR		QEC		SCA		SEL		SMC	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
HSM01*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM02*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM03*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM04*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM05*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM06*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM07	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HSM08	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Appendix 5. Detailed description of the existing hospital

1. Buenos Aires, Argentina (BAA)

In Buenos Aires the climate is temperate and warm, with great amounts of rainfall, even in the driest months. The annual mean temperature is 17.4°C and the average annual rainfall is 950 mm. According to Köppen-Geiger climate classification, this climate is humid subtropical (Cfa).

The proposal is a public hospital built in 2000, of around 40,000 m² distributed in 10 floors and a basement. It has all the corresponding services and 429 inpatient beds.

Default information provided by EDGE was used for the distribution of internal areas, main orientation, floor plan depth, and baseline assumptions.

It was assumed that the building will have air conditioning and heating system, and a landscaped area of 2,000 m².

Figure 51. Atmospheric and geographical conditions in Buenos Aires/Argentina.

Buenos Aires/Argentina

Month	Average temperature (°C)
January	25
February	23
March	21
April	18
May	14
June	11
July	11
August	12
September	14
October	17
November	20
December	23
Max. Temp.	25
Min. Temp.	11
Annual average	17.4
Average annual rainfall (mm)	950
Latitude (Deg)	34.6

Table 30. Parameters and information for the Existing Hospital.

Existing Public Hospital		
General information	Area (m²)	40032
	Floors	10
	Landscaping area (outdoors, m²)	2000
	Average occupancy rate	70%
	Floor to floor height (m)	4
	Beds	429
	With kitchen and laundry	
Existing Public Hospital		
Details	Type of space	Área (m²)
	Patient Areas - General	14264
	Patient areas – specialty wards	4076
	Intensive Care Units (ICUs)	1630
	Pre- & Post-Operating Rooms	815
	Operating Rooms	1630
	Consultation Rooms	2856
	Therapy Rooms	1630
	Diagnostic services	2445
	Offices	815
	Corridors	3260
	Central Sterile Supply Department	815
	Mechanical and electrical rooms	500
	Bathrooms/Storage	408
	Kitchen & Food Preparation	1630
	Laundry	408
	Indoor Car Parking	2445
	Waiting areas	408
Building lengths (m)	North	28.9
	South	28.9
	East	28.9
	West	28.9
	Northeast	28.9
	Northwest	28.9
	Southeast	28.9
	Southwest	28.9

Appendix 6. Simulations summary for the existing hospital

Table 31. Summary chart of the strategies used in each simulation.

Energy	Sa	Sb	Sc	Sd	Se	Sf	Sg	Sh	Si
HSE01*	■	■	■	■	■	■	■	■	■
HSE02		■				■	■		
HSE03		■				■	■		
HSE04	■	■		■					
HSE05*	■	■	■	■	■	■	■	■	■
HSE06*	■	■	■	■	■	■	■	■	■
HSE07				■					
HSE08		■					■	■	
HSE09	■	■	■						
HSE10	■	■	■						
HSE11	■	■	■						
HSE13	■	■	■				■	■	■
HSE14				■		■			
HSE15					■				
HSE20			■		■		■		
HSE21			■		■		■		
HSE22							■		
HSE29	■	■	■	■	■	■	■	■	■
HSE30	■	■	■	■	■	■	■	■	■
HSE32	■	■	■	■	■	■	■	■	■
HSE33	■	■	■	■	■	■	■	■	■
HSE35				■	■	■	■	■	■
HSE36					■	■	■	■	

Water	Sa	Sb	Sc	Sd	Se	Sf	Sg	Sh	Si
HSW01*	■	■	■	■	■	■	■	■	■
HSW02*	■	■	■	■	■	■	■	■	■
HSW03*	■	■	■	■	■	■	■	■	■
HSW04*	■	■	■	■	■	■	■	■	■
HSW07*	■	■	■	■	■	■	■	■	■
HSW09					■	■	■	■	
HSW12			■	■	■	■	■	■	

Appendix 7. Utilities costs according to current tariffs

Table 32. Electricity costs according to current tariffs (Oct-2019).

City/Country	Electricity cost ($/kWh)[1]	Company	Year
Hermosillo/México	$ 0.17	Web site: Federal Electricity Commission (Comisión Federal de Electicidad, CFE)[2]	2019
Cartago/Costa Rica	$ 0.1847	ICE[3]	2019
San Salvador/ El Salvador	$ 0.1102	Statistics of the electric sub-sector of the countries within the Central American Integration System (SICA, by its Spanish acronym), 2016. Economic Commission for Latin America and the Caribbean (ECLAC). CAESS[4]	2016
Quito/Equador	$ 0.081	Electricity Regulation and Control Agency of Ecuador (Comisión Federal de Electicidad)[5]	2019
Santa Marta/ Colômbia	$ 0.15	Web site: Caribbean Electric Company (Electrificadora del Caribe). Electricaribe[6]	2019
La Paz/Bolívia	$ 0.11832	Web site: Electricity Distribution Company of La Paz (Distribuidora Eléctrica de La Paz)	2019
Manaus/Brazil	$ 0.17	Global Petrol Prices.com[7]	2019
Puerto Santa Cruz – Argentina	$ 0.095	(Ente Nacional Regulador de la Electricidad de Argentina)[8]	2019
Buenos Aires/ Argentina	$ 0.095	National Electricity Regulation Body of Argentina (Ente Nacional Regulador de la Electricidad de Argentina)	2019

1. All of them in USD according to XE currency exchange (https://www.xe.com/), when applied.
2. https://app.cfe.mx/Aplicaciones/CCFE/Tarifas/TarifasCRENegocio/Negocio.aspx
3. https://www.grupoice.com/wps/portal/ICE/Electricidad/servicios-empresariales
4. https://www.cepal.org/es/publicaciones/42720-estadisticas-subsector-electrico-paises-sistema-la-integracion-centroamericana
5. https://www.regulacionelectrica.gob.ec/resoluciones-pliegos-tarifarios/
6. http://www.electricaribe.co/tu-energia/
7. https://www.globalpetrolprices.com/electricity_prices/
8. https://www.argentina.gob.ar/enre/tarifas

Table 33. Water costs according to current tariffs (Oct-2019).

City/Country	Utility cost $/m³ [9]	Company	Year
Hermosillo/México	$ 2.958	Town Hall of Hermosillo[10]	2019
Cartago/Costa Rica	$ 2.97	Costa Rica's Institute of Aqueducts and Sewing (Instituto Costarricense de Acueductos y Alcantarillados)[11]	2019
San Salvador/ El Salvador	$ 1.822	National Administration of Aqueducts and Sewing (Administración Nacional de Acueductos y Alcantarillados)[12]	2019
Quito/Ecuador	$ 0.98	EPMAPS Quito Water (Agua de Quito)[13]	2019
Santa Marta/Colombia	$ 1.54	Santa Marta Utilities Company (Empresa de Servicios Públicos de Santa Marta - Essmar E.S.P.)[14]	2019
La Paz/Bolivia	$ 1.76	Drinking Water and Basic Sanitizing Audit and Social Control Authority (Autoridad de Fiscalización y Control Social de Agua Potable y Saneamiento Básico)[15]	2010
Manaus/Brazil	$ 3.9	Manaus Water (Agua de Manaus)[16]	2019
Santa Cruz/Argentina	$ 0.4475	AYASA[17]	2019
Buenos Aires/Argentina	$ 0.4475	AYASA[1]	2019

9. All of them in USD according to XE currency exchange (https://www.xe.com/), when applied.
10. http://aguadehermosillo.gob.mx/aguah/tarifas/
11. https://www.aya.go.cr/servicioCliente/SitePages/estimacionImporte.aspx
12. http://www.anda.gob.sv/pliego-tarifario/calculo-de-tarifa/
13. https://www.aguaquito.gob.ec
14. https://www.hoydiariodelmagdalena.com.co/archivos/229102
15. http://www.aaps.gob.bo/Figures/DER/EPSAS.pdf
16. http://www.aguasdemanaus.com.br/legislacao-e-tarifas/
17. https://www.aysa.com.ar/usuarios/Conoce-tu-factura

Social Infrastructure

GREEN BUILDINGS

FOR THE HEALTH CARE SECTOR

Cost-effective measures for sustainable design

Eric Fischel – Wilhelm Dalaison – Esperanza González-Mahecha
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