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Energy Renovation for Zero-Carbon Buildings in Cameroon: Methodology

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Abstract:- This article presents an effective methodology for renovating buildings in Cameroon towards achieving net-zero carbon emissions. It emphasises two critical conformity assessment approaches: prescriptive and performance-based. The article specifies some building envelope and systems requirements and develops the EDGE energy software's methodology. That software is accessible and facilitates evaluation of energy saving measures during the renovation process. The core of the article focuses on a multi-step building energy and resource optimisation methodology. This comprehensive process commences with a site survey to gather data on location, environment and climate. Following this, detailed building inventories on structure, functionality and aesthetic levels are developed to establish a baseline understanding of energy consumption patterns and potential inefficiencies. With this information in hand, the methodology guides through renovation planning, encompassing the identification of optimal upgrade strategies and the creation of a prioritized renovation roadmap. The design phase incorporates modelling techniques to visualise the project and evaluate the predicted energy performance of the renovated building. Additionally, the methodology incorporates quantity surveying to estimate the resources required for the renovation, providing with an understanding of the project's cost implications. Finally, the methodology emphasises the importance of rigorous impact assessments to quantify the environmental, economic, social and cultural benefits achieved through the renovation. By implementing this comprehensive methodology, stakeholders and building owners in Cameroon can gain a roadmap for transforming their existing buildings into sustainable spaces. This paves the way for a more sustainable built environment in Cameroon, contributing to the country's transition towards a net-zero carbon future.

Keywords:- *Methodology, Building, Energy Renovation, EDGE Energy Simulation, Cameroon*

I. INTRODUCTION

Cameroon faces a major challenge in terms of reducing greenhouse gas emissions and access to energy [1]. The building sector accounts for 38% of total energy-related CO2 emissions worldwide, if emissions from the construction sector are included [2]. These findings call for particular attention to be paid to resource efficiency [3]. Today, as well as designing more environmentally-friendly buildings, it is important to improve the performance and minimise the carbon footprint of existing ones. The aim of this article is to facilitate the renovation process by providing a detailed description of the stages involved.

II. CONFORMITY ASSESSMENT METHODOLOGY AND REQUIREMENTS

Ivorian interministerial order no. 134/MPEER/MCLU of 18 November 2020 introduces approaches for expressing minimum technical specifications for the energy performance of buildings [4].

A. Building Envelope Requirements

Table 1: Building Envelope Values

Climatic zone	Maximum U-value (W/m².°C)				Maximum Solar Factor	Maximum ROM (%)	
	Roof	Exterior Walls	Glass walls (windows, doors or patio doors)				
			Single glazing	Double glazing		Medium	South, East and West
0A	1.1	1.1	6.8	6.8	0.82	19	25
1A	1.1	1.8	6.8	6.8		20	25
2A	1.1	1.8	6.8	6.8		20	25
3A	1.1	1.8	6.8	6.8		20	25

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Table 2: Values to be Respected By Glass Walls

Maximum U-value of bare glazing (W/m².°C)				
Glazing Type	**Air Gap Thickness (mm)**	**Nature of the Joinery**	**Vertical wall**	**Horizontal Wall**
Single glazing	-	Wood	5	6.2
		Metal	5.8	6.8
Double glazing with air gap	5 to 7	Wood	3.3	3.5
	5 to 7	Metal	4	4.3
	8 to 9	Wood	3.1	3.3
	8 to 9	Metal	3.9	4.2
	10 to 11	Wood	3.0	3.2
	10 to 11	Metal	3.8	4.1
	12 to 13	Wood	2.9	3.1
	12 to 13	Metal	3.7	4
Double window	More than 30 mm	Wood	2.6	2.7
	More than 30 mm	Metal	3.0	3.2

➢ *Remarks:*

- The U-value of a window and its SF are given by the manufacturer;
- The ROM of a window is calculated by dividing the fenestration area of a façade by the total area of the same façade;
- The average ROM corresponds to the ratio of the glazed areas of all the façades divided by the total area of all the same external walls;
- A facade is considered to face north if it faces north plus or minus 45°, and the same principle is applied for each orientation;
- A maximum average ROM must be respected, as well as a maximum ROM for facades to the south, east and west;
- A building using skylights is not eligible for the prescriptive approach.

B. Requirements for Air-Conditioning Systems

For air-conditioning systems, the calculation of the thermal loads of the premises must be carried out in accordance with the requirements of standard ISO 1185-4, which sets out the design, sizing, installation and control of cooling systems.

Table 3: Minimum Performance of Air Conditioning Units

System Type	Cooling capacity (kW)	Minimum Energy Efficiency Ratio (EER)
Split unit	< 4.5	2.7
	≥ 4.5 and < 7.1	2.8
	≥ 7.1	2.9
Window Unit	Any Capacity	2.7
Cupboard	Any Capacity	2.8
Power plant	Any Capacity	2.7

C. Performance Approach

This approach is used to design, using simulation software, a model building that achieves a specific level of performance. It is therefore appropriate to present the software used, the calculation conditions and the performance to be achieved.

➢ *Considerations*

The aim is to produce an improved scenario that incorporates different efficiency strategies. The choice of these strategies is guided by the following considerations:

- Accessibility of the product/technology;
- Affordability of the product/technology;
- Achievement of at least 40% energy savings, 20% water savings and 20% grey energy savings in materials to achieve the zero-carbon perspective.

➢ *EDGE Energy Simulation Software*

EDGE is proposed for its accessibility [3]. The EDGE application loads by default on the Houses building type page. The user can select a different type from the sidebar on the left as shown in fig. 1, or from the drop-down menu in the first panel. From the options at the top right of the screen, the user can view their dashboard, change the version and language, and register.

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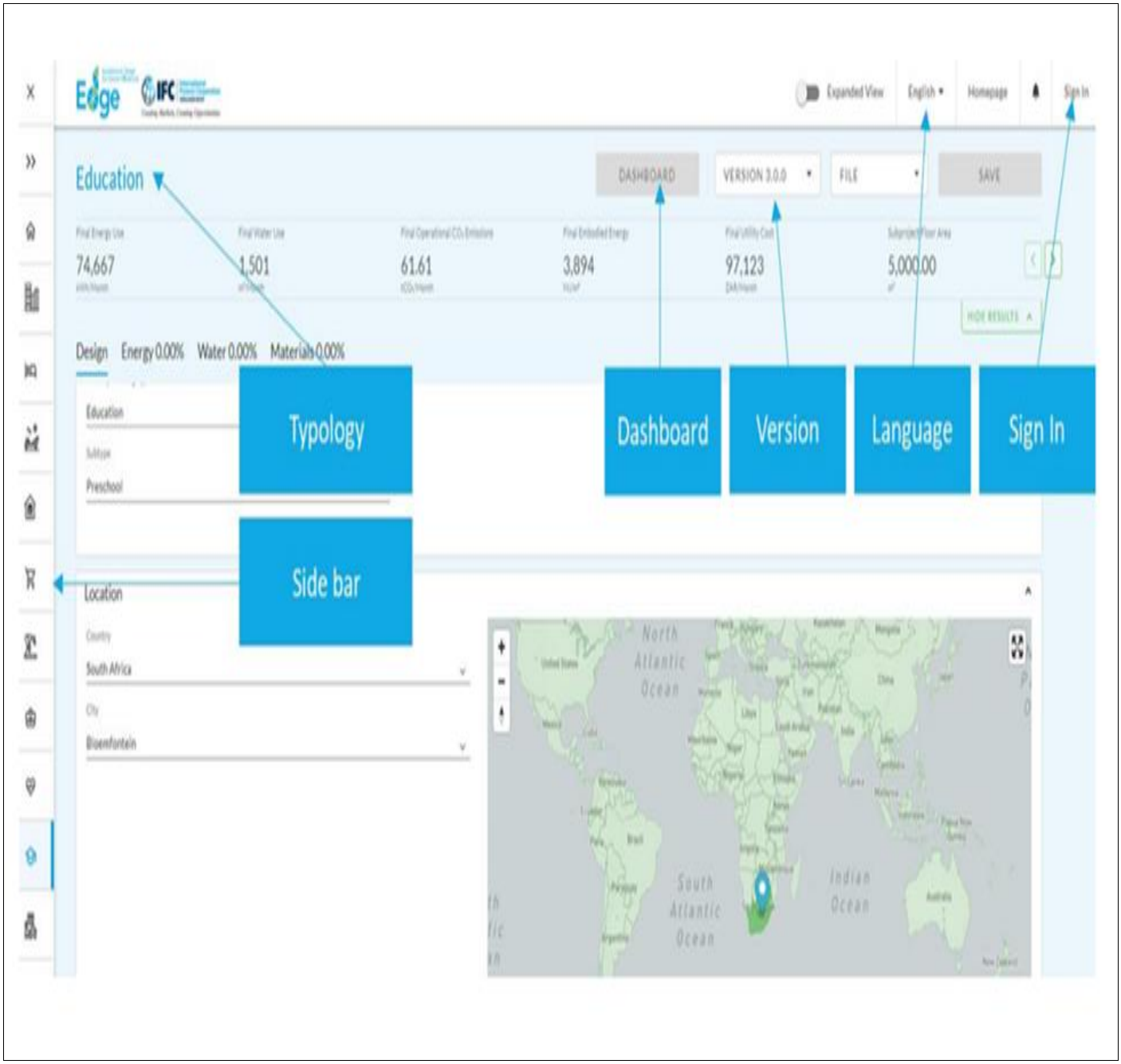

Fig 1: Screenshot Showing the Layout of the EDGE Main Page

Fig. 2 shows the main tabs - Design, Energy, Water and Materials. Above the tabs is the Results bar. Some panels of the Design tab and all Measurements have an Options menu.

The Options menu may contain several functions depending on the panel, such as Detailed Entries, Calculators or Document Download.

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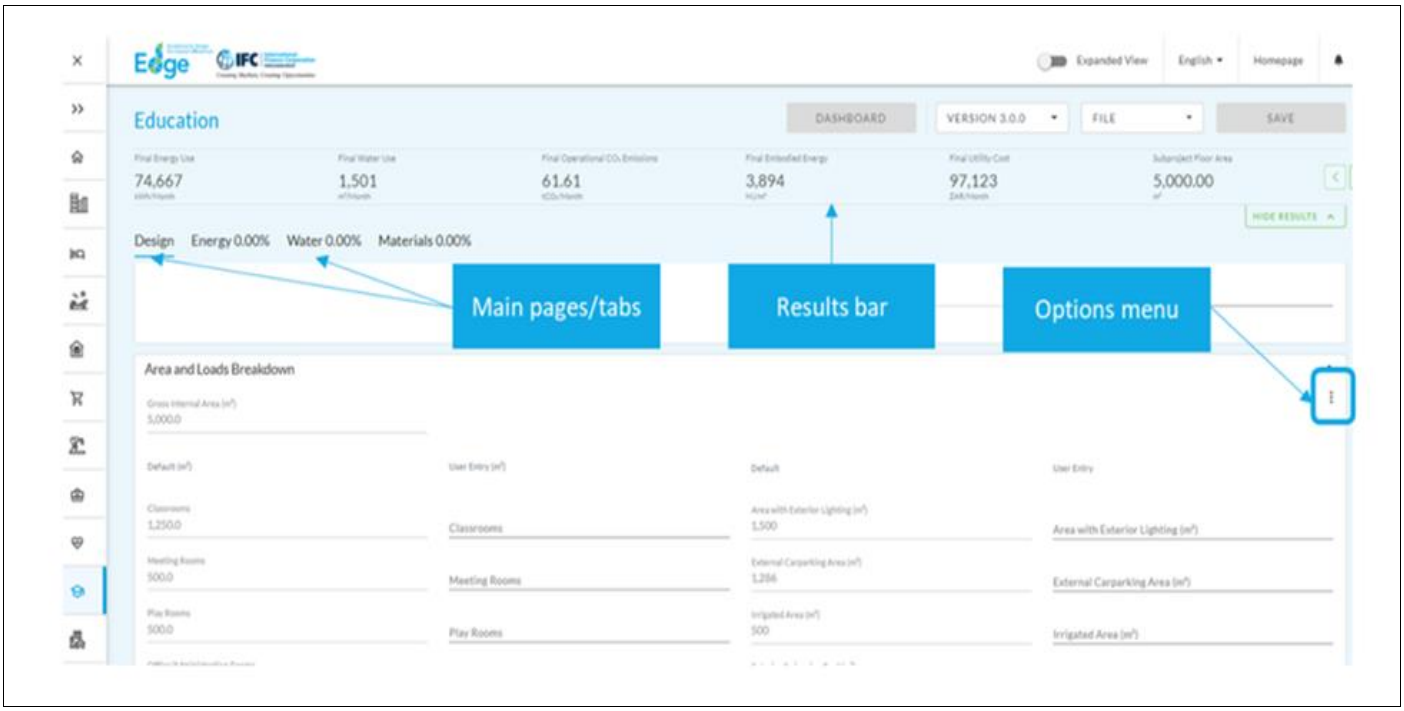

Fig 2: Screenshot of the EDGE Application Showing the Main Features - Main Pages or Tabs, Results bar and Options Menu

The EDGE application is designed with default values entered in all fields, so that users can model buildings with as little data entry as possible. However, users should note that the EDGE application will use the default values if the user does not change them. Therefore, attention should be paid to the default values, particularly during the certification process, to confirm that the assumptions reflect the actual building.

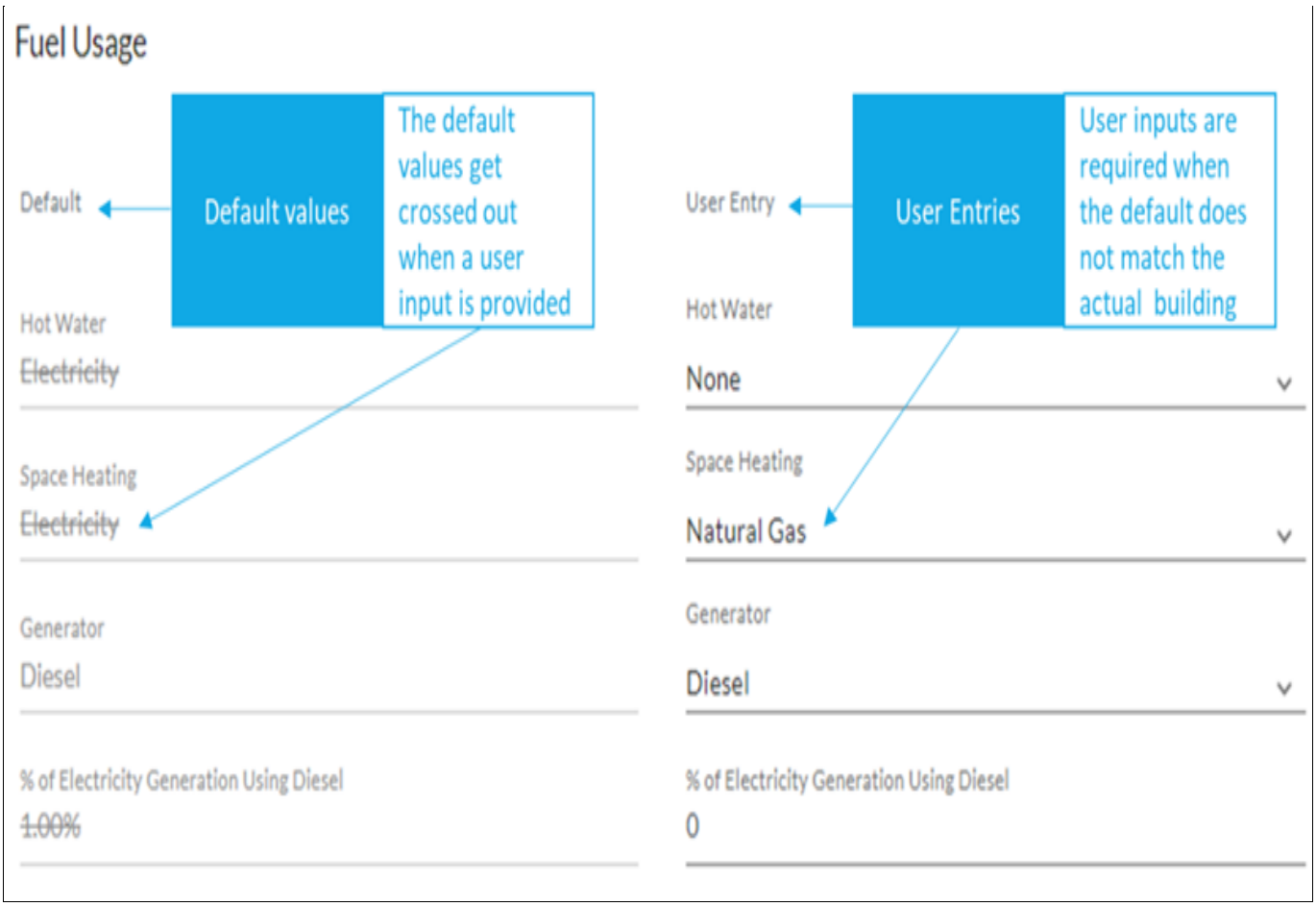

Fig 3: Example of Default Values and user Input in the EDGE Application

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➢ *The Results Bar in EDGE is a Summary of the Key Performance Indicators Calculated by EDGE Which are:*

- Final energy consumption (in kWh/month) ;
- Final water consumption - water consumption (m3/month) ;
- Final CO2 emissions resulting from use ;
- Final embodied energy (in MJ/m2) ;
- Final water and energy costs (in dollars or national currency per month) ;
- Sub-project floor area ;
- Energy savings ;
- Water savings ;
- CO2 savings per use ;
- Grey energy savings ;
- Water and energy cost savings (in dollars and in national currency in some countries) ;
- Basic EPI (Energy Performance Index) ;
- Improved EPI (Energy Performance Index) ;
- Total building construction ;
- Marginal cost - Additional cost of implementing selected efficiency measures (in dollars or national currency in some countries);
- Cost increase (%);
- Return on investment in years ;
- Number of people affected ;
- Reference scenario - Global warming potential of the refrigerant ;
- Improved scenario - Global warming potential of the refrigerant.
- The EDGE software offers various measures of energy and resource efficiency.

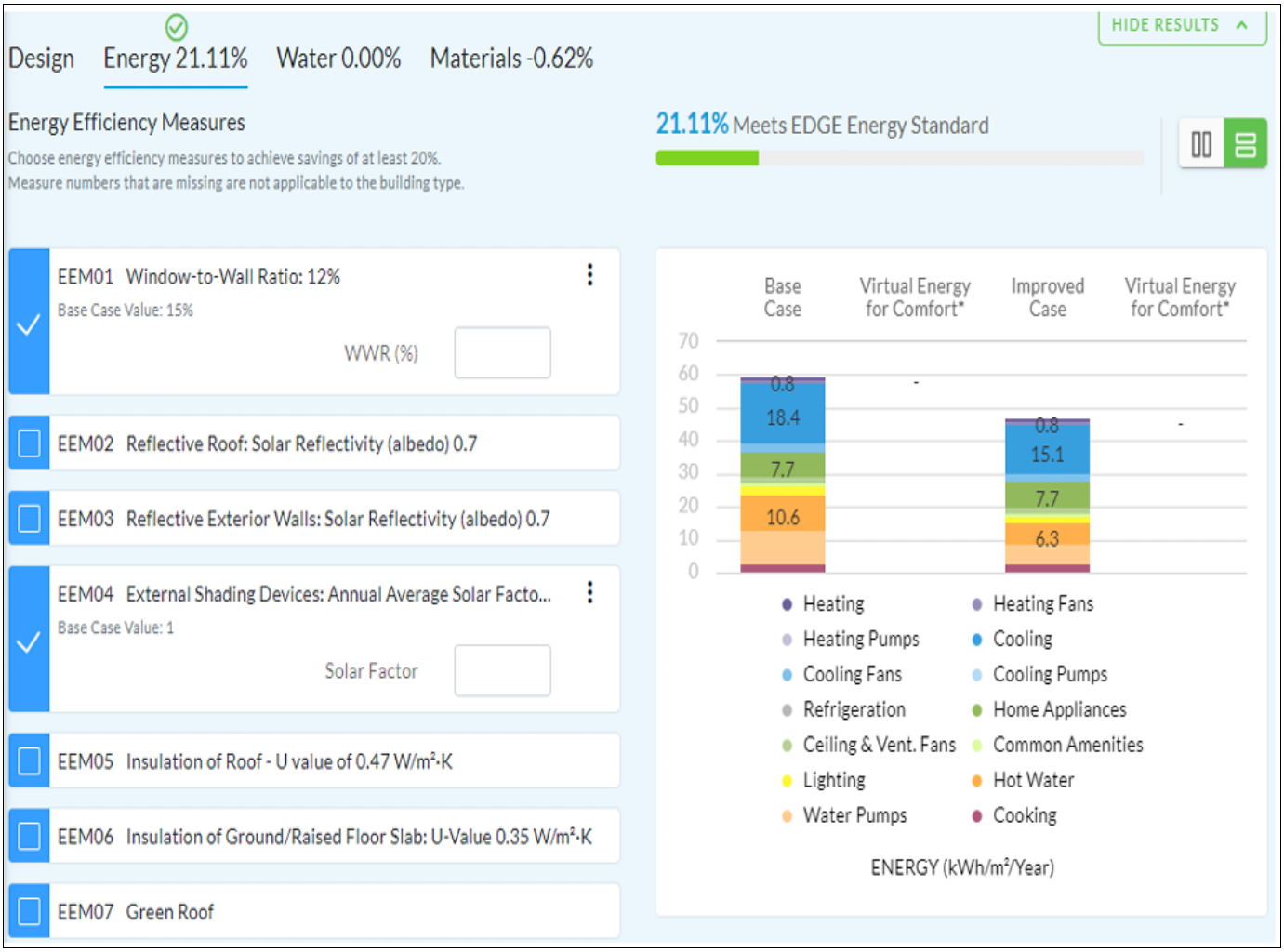

Fig 4: Screenshot of Recommended Energy-Saving Measures for a Building Type (Housing) in the EDGE Application

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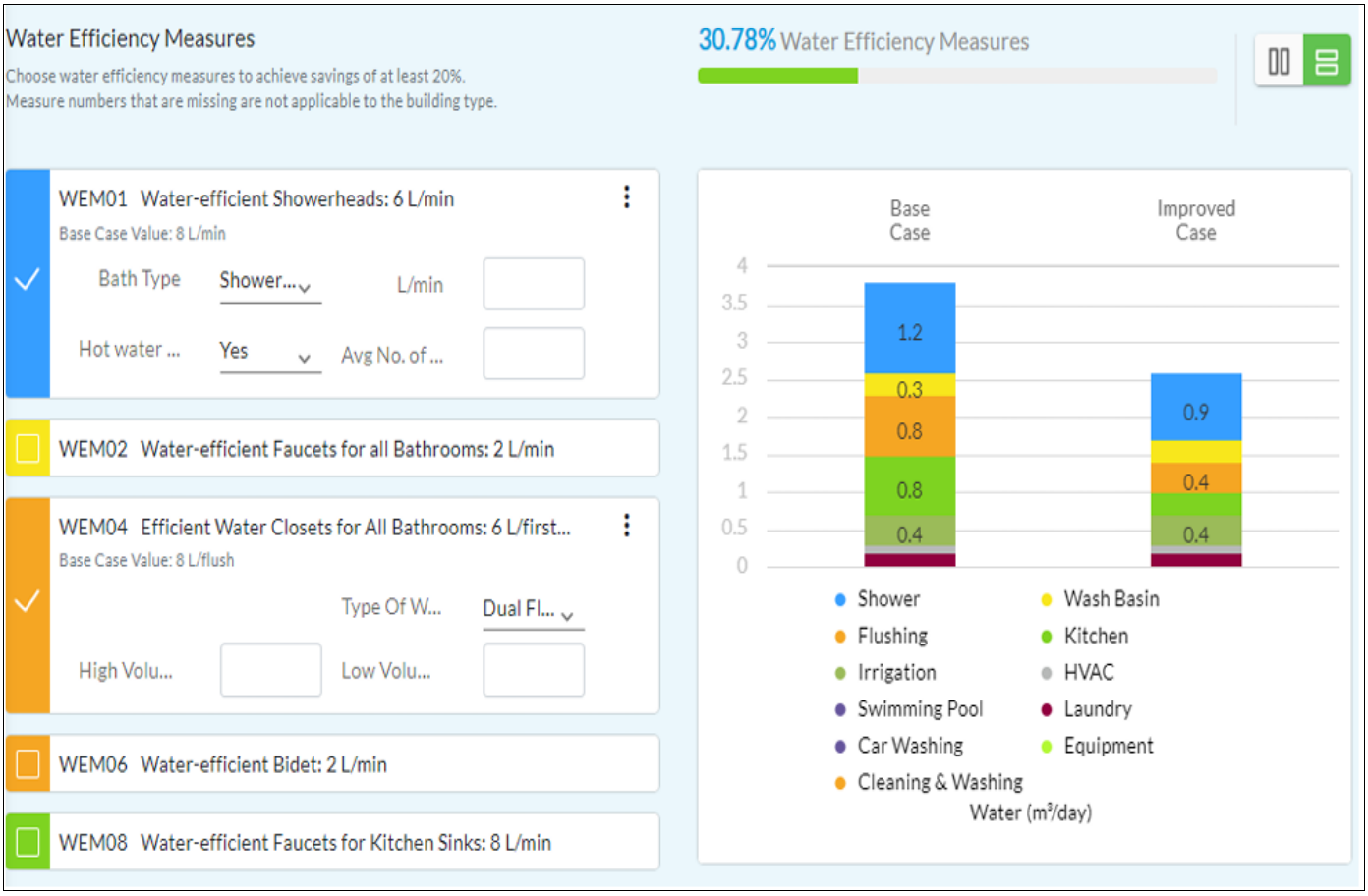

Fig 5: Screenshot of Recommended Water-Saving Measures for a Building Type (Housing) in the EDGE Application

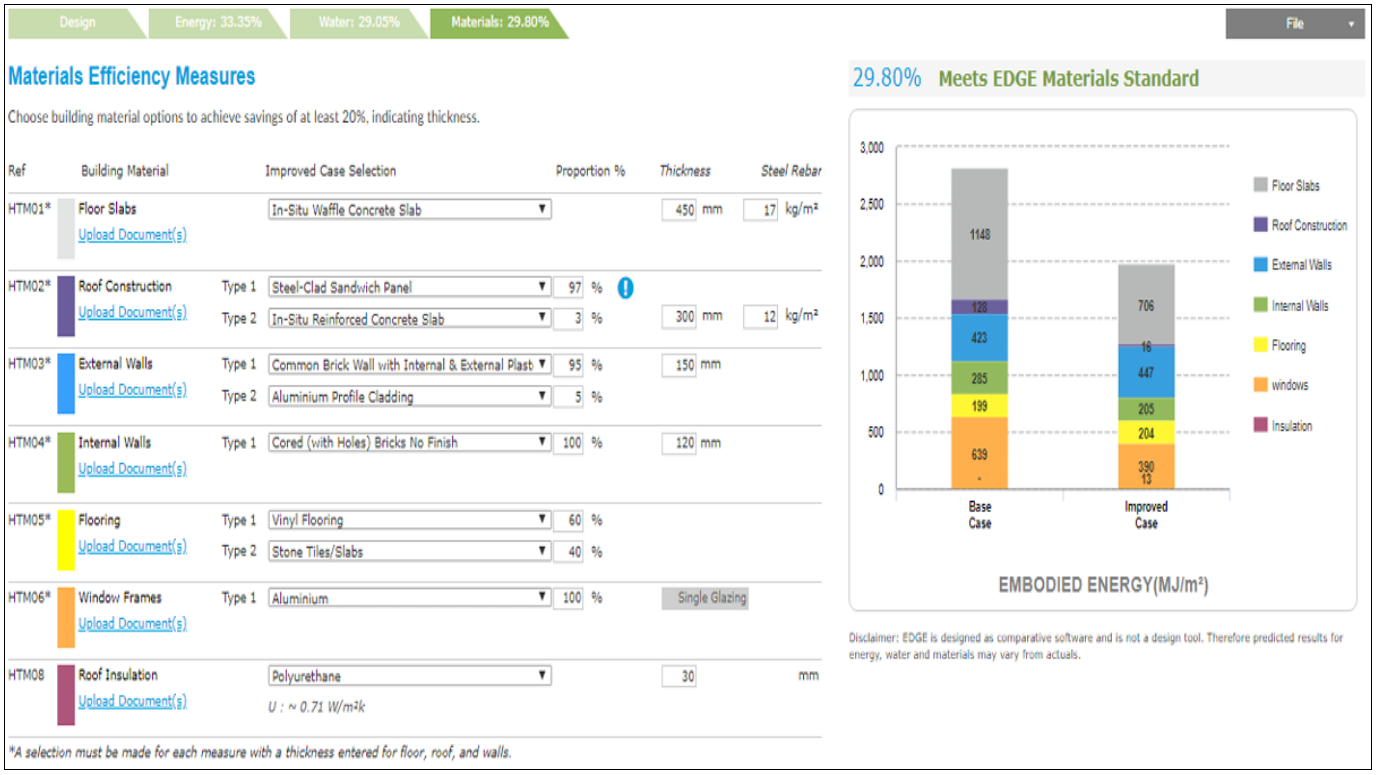

Fig 6: Screenshot of Material Efficiency Measures in EDGE for Hotels

In EDGE, an asterisk (*) next to a measure indicates that the project team is 'required' to enter the actual specifications of the measure in EDGE, if this measure is present in the project.

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III. BUILDING ENERGY AND RESOURCE OPTIMISATION METHODOLOGY

A. Site Survey

The purpose of the site survey is to define the main characteristics of the site on which the building is to be located, i.e. its location, environment, topography and climate - climate zone, precipitation, temperature and relative humidity. Useful softwares for this operation:

- Google Maps: This is an online mapping service that lets you consult maps from all over the world. Its features include searching for places and pinpointing their precise location.
- Climate Consultant: This is an easy-to-use computer programme that helps you understand your local climate. It uses annual climate data in EPW format made available free of charge by the Department of Energy for thousands of weather stations around the world.

B. Inventory of the Building

➢ *The Inventory of Fixtures Involves a Visit to the Site. A Number of Items of Equipment are Used, Including:*

- Personal protection equipment, decametre, notepad, pen, and camera: These are used to collect the data needed to create the existing building. This data includes sketches of the layout, facades and surroundings of the building. This is an opportunity to obtain clear information on the characteristics of the building, such as its dimensions, the number of storeys above ground level, the number of basement storeys, storey height, roof area and total number of rooms.
- Questionnaire: used to list the other questions required to assess the building. It is sent to the person responsible for the building and to any other person in possession of the information requested. Questions may relate to the year the building was built, the function of the building, details of technology packages, water and electricity consumption and materials, particularly those that are not visible or explicit. Certain operational details are also important, such as working days, opening hours and occupancy rates.
- Autocad, Archicad, Revit, Twinmotion, Lumion: CAD and visualization software used to clean up all the information collected.

➢ *Building Structure*

- *Foundation*

As far as possible, it is important to determine the type, quantity and size of foundations.

✓ Surface foundations: Continuous footings under walls; Insulated footings under pillars; Pedestals and sills.
✓ Foundation by general slab: Used when the admissible stress of the ground cannot support the structure.
✓ Deep foundations: Piles; Bars; Micro piles

The site survey consists of inspecting the general condition of the foundation and, if necessary, locating and identifying any problems that could affect the structure and safety of the building.

✓ Examination of the exterior of the foundation: Check for cracks, rot or other signs of damage to masonry walls and concrete foundations.
✓ Check drainage and gutters: Problems with excessive or inadequate drainage can cause major damage to the foundation and the building. Ensure that gutters and downpipes are working properly and that water is draining away from the building's foundation.
✓ Check soils and slopes: A poor slope or subsidence of the ground can cause foundation problems. Inspect the soils and slopes around the foundation for problem areas.

- *Columns and Beams*

It is important to determine as far as possible the type of column and beam, the quantity and their dimensions.

✓ Types of column based on cross-sectional shape: Round; Square; I-column; T- or L-shaped column; H-shaped column
✓ Beam types based on loads and support: Simply supported beam; Fixed beam; Overhanging beam; Continuous beam; Cantilever beam; Truss beam
✓ Based on the construction method, a distinction must be made with the prestressed beam.

The site survey consists of inspecting the general condition of the columns and, if necessary, locating and identifying any problems that could affect the structure and safety of the building.

✓ Structural integrity: Check the columns and beams for signs of cracks, splinters, rust or deformation.
✓ Wear: Inspect surfaces for wear caused by exposure to water, sun or other climatic elements.
✓ Joints and connections: Examine the joints and connections between the building's structural elements.
✓ Alignment: If columns and beams are not perfectly aligned, this could lead to uneven weight distribution throughout the building, causing structural stress.

- *Walls and Floors*

It is important to determine as far as possible the specifics of walls and floors, including their dimensions.

✓ Wall types based on materials: Concrete walls; Masonry walls; Wooden walls, Steel walls
✓ Floor types based on materials: Reinforced concrete floor Hollow beam flooring Honeycomb concrete flooring Wooden floors Mixed and collaborative floors

The site survey consists of inspecting the general condition of the walls and floors and, if necessary, locating and identifying any problems that could affect the structure and safety of the building.

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- Settlement: Walls should be checked for settlement, deteriorated joints or cracks that could compromise the structural condition of the building. In the case of floors, this can occur if they are too heavy or do not rest properly on the supports.
- Mould: Mould can indicate moisture or waterproofing problems that can cause significant damage over time. Walls and floors should be checked for mould and its cause.
- Spalling or cracking: Walls and floors should be checked for spalling or cracking which could indicate more serious structural problems.
- Gaps: Gaps in building materials, such as bricks, blocks or concrete, may indicate problems with the building's foundation or drainage.

➢ *Roofing*

- It is important to determine as far as possible the type of roof and its dimensions.
- Roof types: In situ reinforced concrete slab; Clay roof tiles on steel or wooden crossbeams; Micro-concrete roof tiles on steel or wooden cross-beams; Steel sheets (zinc or galvanised iron) on steel or wooden cross-beams; Aluminium sheets on steel or wooden cross-beams; Copper sheet on steel or wooden cross-beams; Asphalt shingles on steel or wooden cross-beams; Aluminium or steel lined sandwich panels.

The assessment involves inspecting the general condition of the roof and, if necessary, locating and identifying any problems that could affect the structure and safety of the building.

- Cracks or damage to materials: Erosion or extreme weather conditions can cause cracks or damage to roofing materials such as shingles, tiles or sheet metal.
- Water infiltration: Water leaks or infiltration can cause serious damage to the building's internal structures and insulation.
- Waterproofing problems: A leaky roof can allow rainwater or run-off to enter.
- Insulation problems: A poorly insulated roof can lead to over-consumption of air conditioning.
- Ventilation problems: An unventilated or poorly ventilated roof can lead to the formation of mould and condensation, which can cause health and comfort problems.
- Structural problems: Structural problems such as rotten beams, inadequate framing or broken supports can compromise the integrity and safety of the roof.
- Debris and dirt: Leaves, branches and other types of debris can accumulate on the roof and cause clogging of gutters and water pipes.

➢ *Floor Coverings*

- As far as possible, it is important to determine the nature of the wall and floor coverings and their characteristics.
- Some types of wall and floor coverings: Paint Mosaic Wooden flooring Tiles Polished concrete Carpet Wall fabric
- Some things to bear in mind when assessing the condition of a building's floor coverings:
- Cracks and breaks are indicative of poor condition and possible weakening of the structure;
- Dampness and mould, which can be caused by waterproofing or ventilation problems;
- Peeling or flaking of the topcoat indicates the need to repaint or plaster these surfaces;
- Chips or damage caused by wear and tear, which can make surfaces less attractive and more likely to develop more serious problems:
- Losses and perforations that may have been caused by rodents, insects or extreme weather conditions;
- Rust and corrosion, which can have an impact on the functionality and durability of metal components such as gutters and door and window frames;

➢ *Water Infiltration;*

- Changes in colour or texture which may indicate poor quality materials or poor application;
- Maintenance considerations as the upkeep and repair of cladding can have a significant impact on its condition and lifespan.

➢ *Airtightness:*

- Airtightness: Poorly insulated walls and ceilings, and windows and doors that are not properly sealed, can let air through and cause heat loss and excessive energy consumption. Leaking pipes and ducts can also reduce indoor air quality and cause health problems.
- Water tightness: Water tightness problems can include water infiltration, which can leave traces of damp or mould and cause damage to the building's structure and finishes; condensation, which can lead to the formation of mould and other moisture-related problems; a deteriorated or poorly maintained roof can have waterproofing problems, causing water to seep into the building; Water tightness problems around the foundation of a building can be caused by poor management of the finish or structural problems such as drainage leaks or problems with the slope of the land.

➢ *Joinery*

- It is essential to make an inventory of the wood and metal joinery and glazing present in the building.
- Here are a few points to bear in mind when assessing the condition of a building's wood and metal joinery:
- Quality, in particular whether any parts are rusty, rotten or cracked;

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- Whether window frames fit and seal properly, and whether handles work properly;
- Gutters and pipes to ensure that they carry water correctly and do not damage the joinery;
- Ironmongery, such as hinges and bolts, to ensure that they work properly.
- Whether wood or metal surfaces are properly protected against the weather to prevent corrosion or rotting.
- Some factors to consider when assessing the condition of a building's glazing:
- Energy efficiency: determine the thermal performance of the glazing.
- Cracks and scratches: determine the extent of deterioration and whether immediate repair is necessary.
- Condensation and mould: persistent condensation may indicate a waterproofing or moisture problem, which could degrade the glazing and impair its performance.

➢ *Roads and other Networks*

- Access to the building: assess whether the building is easily accessible and whether access is sufficiently wide and well lit;
- Access for people with reduced mobility: assess whether the building is easily accessible for people with reduced mobility;
- Road conditions: assess the streets and note any damage such as potholes, corrosion of infrastructure, landslides or flooding;
- Water and electricity supply networks: Typically, the water network starts with a large water pipe that supplies the building from the public water system. Water pipes are then distributed to different levels and areas of the building to supply water to toilets, kitchens and sanitary facilities; the electrical network uses power cables to transmit energy directly from the public power supplier to the building. These cables branch off to a main distribution board or main circuit breaker, which then distributes the electrical energy to the various transmission zones;
- Telecommunications: determine the quality and coverage of the Wi-Fi signal throughout the building; check the location and number of Wi-Fi access points; measure 4G, 4G+ and 5G reception, speed and quality of the mobile connection in the building;
- Water drainage: check the operation of plumbing and water pressure in toilets, baths and showers; inspect drains, gutters, downpipes and sewers;
- Waste management: describe how the building manages its solid waste; liquid waste is normally disposed of in the septic tank.
- Fire protection: fire extinguishers and water points; smoke and heat detectors; automatic sprinkler system and fire alarm; emergency lighting and escape routes;
- Surveillance and security: surveillance cameras and intrusion sensors; alarm and access control systems; remote control and guard posts.

➢ *Functionality*

- *Floor Area Program*

For an existing building, this program lists and describes the different areas and spaces allocated to each function and activity planned in the building. It must be ensured that the minimum dimensions are respected.

- *Functional Organization Chart*

This is a visual representation of how the different areas of a building interact and function together. It is used to improve the efficiency and productivity of day-to-day operations by optimizing the flow of people.

- *Opening to the Sun*

This involves determining the building's wall opening ratio (WOR) and checking that it complies with the requirements based on the zone in which the building is located.

- *Environmental Conditions*

This involves describing the environment in each room of the building and checking whether it is properly equipped for its function.

- *Technological Packages*

Plumbing and sanitation: It is essential to make an inventory of the sanitary equipment in the building, including toilets, sinks, baths, showers and dishwashers.

➢ *Here are a Few Points to Bear in Mind When Assessing their Condition:*

- Check the condition of sanitary installations;
- Assess the water-saving performance of plumbing equipment;
- Check visible pipes and plumbing installations for leaks, blockages, corrosion or other anomalies;
- Assess the performance of the domestic hot water system;
- Electrical: It is essential to make an inventory of the electrical installations in the building.

➢ *Here are a Few Points to Bear in Mind when Assessing their Condition:*

- Checking the main equipment: Examine the condition of the electrical panel, including circuit breakers, fuses and earth leakage switches, and make sure that all components are secure and working properly;
- Inspection of cables and conductors: Check the condition of all cables and conductors throughout the building and look for any that may be damaged, cut or deteriorated;
- Check sockets and switches: Ensure that all sockets and switches are working properly and that the wires are connected correctly, and replace or repair any damaged parts;

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- Testing lighting and light fittings: Switching on lights and light fittings to ensure that they are working properly and checking all bulbs and other parts of the fittings for any problems;
- Energy efficiency: determine the energy performance of lighting fixtures.

➢ *Air Conditioning and Ventilation: It is Essential to Draw up an Inventory of the Air Conditioning and Ventilation Equipment in the Building*

- Type of air conditioning system: Packaged air conditioning; Split system air conditioning; Multi-split air conditioning; VRF system (Variable Refrigerant Flow); Central air conditioner; Water-cooled air conditioner.
- Some things to consider when assessing their condition:
- Check used air-conditioning or ventilation filters and the operation of air-handling units;
- Inspect pipes and ducts for leaks, deformation and other anomalies;
- Determine the performance of the air conditioning and ventilation system.

➢ *Aesthetics*

The aesthetic analysis of a building is a process that enables its visual and artistic quality to be understood and assessed. It can involve the following stages:

- Understanding the historical context in which the building was constructed and the artistic and architectural influences;
- Identifying the artistic style to which the building belongs. For example, gothic, baroque, modern, contemporary;
- Evaluation of the building according to a set of aesthetic criteria which may include proportion, harmony, symmetry, composition, material, colour;

C. Planning The Renovation

Once the existing building has been studied, it is possible to decide on the type of renovation to be carried out in order to increase the value of the building and achieve the planned performance levels. There are three main types of renovation [6]:

- Heavy renovation: These include elements such as: insulation, electricity, walls, roofing, and flooring. These renovations are often more complex and require the intervention of qualified professionals.
- Light renovation: This concerns areas such as the kitchen and bathroom, and involves minor modifications to the electrical and/or plumbing systems, as well as some carpentry work.
- Refurbishment: This work is lighter and less costly. It includes tasks such as painting, floor and wall coverings, and aims to modernise the interior.

D. Designing

➢ *Definition of the Architectural Approach*

The design approach is the backbone of the project, the guiding idea behind the architectural design. It is used to describe the principles and ideas that are to have effect during the design process. This may cover the choice of materials, colours, shapes and other specific design elements.

➢ *Project Description*

A project description is a general outline of the work planned to be undertaken to improve, rehabilitate or transform the existing building. It explains the changes to be made and the improvements expected.

E. Modelling

The presentation of the project involves producing sketches and all the graphic and descriptive documents for the project. To achieve this, we will use CAD (Computer Aided Design) tools.

F. Quantities and Estimates

It details the quantities required to complete the project and the costs associated with the work. There are several ways of finding out the prices of the planned work:

- Contacting several suppliers and comparing their offers.
- Consult price databases such as [7].
- Use your own experience and old invoices to estimate prices.
- Seek professional advice from an architect, engineer or contractor.

It is advisable to take delivery costs into account and allow a safety margin for unforeseen circumstances.

G. Impact Assessment

This is essential to ensure that the project makes a positive and sustainable contribution to its environment and community. Impact assessment can include several components, such as environmental, social, cultural and economic impacts.

IV. CONCLUSION

Ultimately, energy renovation begins with an assessment of the building by comparing its characteristics with the standard. This assessment takes stock of the building's structure, functionality and aesthetics. Then, using energy simulation software such as EDGE, the improved building is modelled, incorporating efficiency strategies. Lastly, it is necessary to produce an estimate of the work planned and analyse the environmental, social, cultural and economic impact of the project as a whole.

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