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SHORT REVIEW ABOUT THE BUILDING WITH RESPECT FOR THE ENVIRONMENT OF "MOHAMMED VI GREEN CITY" IN BENGUERIR MOROCCO

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Abstract: **This paper is part of the construction with respect for the environment through particular projects of the green city Mohammed VI in Morocco; this document is a study of two practical cases of construction techniques with respect for the environment, a green city project and the first SOLAR DECATHLON AFRICA prize, in order to bring out each peculiarity these peculiarities which aims to respect the environment in terms of water consumption and energy efficiency. This paper began with a presentation by the (SADV) as responsible for everything that is construction, in particular through the projects of the green city, then a presentation of the competition and the SDA first prize.**

In order to continue with SADV's vision, the study phase included the particularity of three practical cases with regard to sustainable construction and respect for the environment by studying the Case of Villas for researchers with these particularities. Thermal insulation and its natural air conditioning system, and the case of the first SDA. Prize with its peculiarity of these building materials, water management and energy saving.

The Project was ended with a discussion about healthy construction, which consists of building in a way that respects our environment and that of future generations while offering maximum comfort to the occupants.

Keywords: **Construction, Environment, Green City Mohammed VI, Solar Decathlon Africa.**

1. INTRODUCTION

In a global context marked by growing demography and urbanization, climate change and new consumption needs, the Mohammed VI Green City (VVM6) must be a city developed according to the precepts of sustainable development. This unprecedented project in Morocco seeks to balance the environmental, economic and social needs of Benguerir and the province of Rhamna [1]. The completion of the VVM6 will set a new benchmark for environmental performance in Africa and will affirm Morocco's leadership in the fields of environment, water and energy. In this sense, the Green Planning and Development Company (SADV), a 100% subsidiary of Office Cherifien of phosphate OCP and responsible for the planning and green development of urban projects at visibilitý, in particular the Mohammed VI Green City project (VVM6), proposed to me, within the framework of this project, to deploy a construction specification that respects the environment of the first prize winner of the Solar Decathlon Africa (SDA) competition. The aim of the competition is to raise understanding and awareness of sustainable construction and to shed light on the importance of passive and active solar design strategies combined to put the world on a sustainable path to decarbonized energy systems and a clean envi-

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ronment, as well as to ensure and watch over good water consumption [2]. These specifications must comply with the implementation of the general building regulations laying down the rules for energy performance and water consumption. The energy, water, and environment issues should lead to a transition towards optimal use of energy, water and thermal insulation in the operation of buildings by using urban climatic design methods, bioclimatic architectural principles, renewable energies, water conservation and the most appropriate and energy-saving practices. SADV is responsible for the planning and development of urban projects with high visibility in the Group's strategic plan, notably through the Mohammed VI Green City and Green projects. Its primary vocation is planning, and its missions are induced by the conditions under which projects are initiated to the planning, development and management the projects. The Green City Techpark is a specialized site dedicated to non-polluting peak activities in the industries [3].

- Ideally positioned at the confluence of Universitý Mohammed VI Polytechnic, the Green Energy Park, and the Industrial Competence Centre, it will benefit from the positive impact of the existing value chain of the ecosystem, favoring the attraction of core target companies.

- An urban space dedicated to R&D, innovation, and the creation of goods and services, Techpark aims to make Green City a Worldclass R&D and technology hot spot in cutting-edge industries. However, a natural meeting place between the academic and business worlds, this project is designed to promote the transfer of knowledge and technology, encourage entrepreneurship, and create technological clusters.

Figure 1: Green City of Benguerir, A New City in the Time of COVID-19 [4].

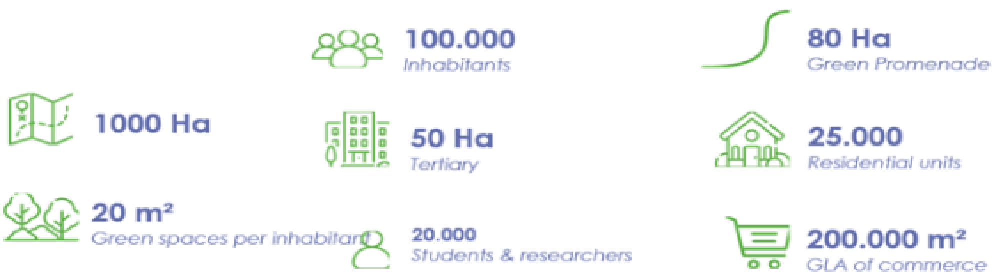

Figure 2: Green City of Benguerir statistics [5].

2. SOLAR DECATHLON AND SOLAR DECATHLON AFRICA

Solar Decathlon is an international competition that challenges collegiate teams to design, build and operate net-zero energy houses which use solar energy as the only source of energy and are equipped with all the necessary state-of-the-art building and energy technologies. During the final phase of the competition, the teams gather together; their houses are open to the general public while undergoing the ten criteria of the competition, which is why this event is called a decathlon. Solar energy houses participating in the Solar Decathlon are used as case studies [6]. The Solar Decathlon competition began in Washington DC, the USA, in 2002 and has continued to be held in the USA every two years since. The last

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American Solar Decathlon took place in Denver in October 2017. Perhaps On November 15/2016, on the sidelines of COP22 in Marrakech, Morocco, the Moroccan Ministry of Energy, Mines and Sustainable Development; the Moroccan Research Institute for Solar Energy and New Energies (RIESEN); and the U.S. the Energy Department signed a protocol agreement to collaborate on the development of Solar Decathlon AFRICA, The Solar Decathlon, like other editions around the world, highlights innovation and research at durability. Participating teams work not only to develop and build their houses but also to improve the integration of renewable energy, intelligent energy management, and knowledge generation on sustainable construction. Students from universities in Africa and worldwide must design solar-only homes that are economical, affordable, and efficient energy adapted to our African climate and location [6]. The objective of the competition is to contribute to the knowledge and dissemination of solar and sustainable housing with the following fundamental plans:

- Raising awareness among participants' students about the advantages and possibilities of renewable energies and sustainable construction and inviting them to use their creativity to develop innovative solutions that contribute to energy savings.

- Raising awareness among the general public about the responsible use of energy, renewable energies, energy efficiency, and available technologies to help reduce energy consumption.

- Promote the use of solar technologies, including the integration of the solar system into attractive architecture, and improve the use of solar technologies to replace conventional building materials in the building envelope, such as roofs, skylights, or façades. Demonstrate that high-performance solar homes can be comfortable, attractive, and affordable [6].

Figure 3: A picture of the solar decathlon AFRICA competition [7]

Figure 4: Solar Decathlon Africa, Morocco 2019 [8]

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3. MOROCCO'S ENERGY SITUATION AND THERMAL REGULATION

So far, Morocco depends on foreign energy; more than 90% of its energy consumption is imported from abroad at a high cost. Therefore, the diversification of the energy mix is a priority area for action to reduce this dependence, mainly through the development of renewable energy as an alternative to fossil fuels. The Energy Efficiency in Construction Program is a significant step forward in improving performance, energy, and sustainable development. The completion of the project was planned for 2013 [3]. Of course, its success and implementation depended on the commitment and involvement of all the players in the construction sector. The objective announced by the Moroccan government is to achieve energy savings by 2020 through the implementation of an efficiency plan for energy in the various economic sectors. Among these sectors, construction is the first energy consumer with a share of 36% of energy consumption total in the country, of which 29% is reserved for residential and the rest for tertiary. This energy consumption is expected to increase rapidly in future years for two reasons:

- The significant evolution of the building stock is due to effective programs advertised: Plan Azur of the Hotel Industry, National Education Emergency Program, 150,000 unit-per-year program, and hospital rehabilitation program.
- Significant increase in household appliance equipment due to improved living standards and lower prices (heating, air conditioning, water heating, refrigeration).

4. NATIONAL PROGRAM FOR ENERGY EFFICIENCY IN BUILDINGS:

The national program for energy efficiency in buildings is part of the government's energy policy. The National Agency implements it to Develop Renewable Energy and Energy Efficiency [9]. It will contribute to the national objective of saving 12% of fossil fuels by 2020, notably by improving the energy efficiency of buildings in Morocco. The program also aims to respond to various problems encountered in the following areas of the sector, such as rising fossil fuel prices, the lack of consideration for the energy in the design, construction, equipment, and management of buildings, or the significant increase in energy expenditure following solid expectations in terms of service quality and social comfort on the part of users.

The program is based on three main axes corresponding to the stages of design, construction, equipment, and building management:

- Urban planning, design, and construction of buildings.
- The operation of equipment (air conditioning, heating).
- Management of energy services in buildings.

In order to strengthen energy efficiency in key sectors of the national economy, means and incentives will be put in place. In addition, training, further training, vocational training, scientific research, and demonstration of techniques concerning all sectors must be implemented to promote energy efficiency and energy savings [9].

5. LAW ON ENERGY EFFICIENCY [47-09].

The Energy Efficiency Act [47-09], promulgated and published in the Official Bulletinin 2011, Includes the obligation to submit to an energy impact assessment, any urban development project or program, or any project for building construction [10]. A specific threshold for thermal or electrical energy consumption has been established by regulation. This project confirms Morocco's ambition and demonstrates its commitment to developing renewable energy, energy efficiency, and the fight against climate change. The Act aims to increase energy efficiency in the use of energy sources, avoid waste, reduce the burden of energy costs on the national economy, and contribute to sustainable development. Its implementation is mainly on the principles of energy performance, energy efficiency requirements, energy impact assessments, mandatory energy audits, and technical control [10].

The Law had provided that the draft building construction programs would be subject to a prior energy impact assessment, regardless of their use. The need to submit a construction project to an energy impact assessment is provided for in the development plans, depending on the size and nature of the project.

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 9, Issue 2, pp: (79-91), Month: April - June 2022, Available at: www.paperpublications.org

The energy impact assessment of the project shall contain the following information:

- A description of the project characteristics.
- An energy needs assessment in the project's implementation, development, and operation phase.
- Energy consumption reduction measures are envisaged.
- Measures for the development of renewable energy potentials by existing legislation.
- Training, communication, and management measures ensure its implementation, operation, and development.
- A summary notes and a simplified summary for the public.

In the first chapter of Article 1 of the Dahir, within the meaning of this Law, the following definitions shall apply:

- Energy efficiency.
- Energy audit.
- Energy performance.
- Energy service companies.

Energy efficiency: any positive action on energy consumption, regardless of the activity of the sector concerned, aimed at:

- Optimal management of energy resources.
- Control of Energy demand.
- Increasing the competitiveness of economic activity.
- Control of technology choices for an economically viable future.

6. INTRODUCE MINIMUM REQUIREMENTS THAT BUILDINGS MUST MEET

The aim is to introduce minimum requirements for new residential and tertiary buildings to optimize their heating and cooling needs while improving thermal comfort, including the following five performance requirements [11]:

- Reducing energy consumption for lighting and hot water heating, sanitary, heating, and air-conditioning of the buildings.
- Improve the thermal and visual comfort of the occupants.
- Optimize the design of energy systems.
- To encourage engineers and project managers to use design approaches to efficient building energy systems (ventilation, shading) and orientation about the sun to maximize ventilation and lighting natural).
- Helping to carry out energy diagnostics of existing buildings.

7. GREEN BUILDING - SUSTAINABLE CONSTRUCTION

The notion of green building varies according to specialists. Thus for "constructors," it is a healthy construction using natural materials. They consider that a building must first and foremost adapt to human beings, the well-being of the occupants being of paramount importance. These proponents of green building condemn the use of toxic substances in the industrial manufacture of building materials. The goal of energy conservation experts is to limit the negative environmental impacts of the human habitat through the use of state-of-the-art technologies and to reduce the energy consumption of buildings, houses, and apartments. Indeed, they recommend reinforced thermal insulation and advanced construction techniques. Eco-constructors" consider the building throughout its entire life cycle. In addition to energy savings, they are also concerned about the origin of the materials used and their management (disposal, recovery) at the end of life [12].

Green building, also known as green building or green construction, offers various possibilities to reduce the ecological impact of buildings. Green building is not a specific construction method. However, it brings together a set of techniques, materials, and technologies that, when properly integrated into a building, enhance its environmental performance. In its ideal incarnation, green construction optimizes energy efficiency, limits water consumption, makes maximum use of recycled, recyclable, and non-toxic materials, and generates the least amount of waste possible during construction as an occupation.

In green building, the processes for creating structures are environmentally friendly and use resources efficiently. This ecological practice is developing and complements the traditional concerns of designing more energy-efficient, sustainable, and comfortable buildings. The green building implies a healthy, sustainable building, designed in natural materials, consuming little energy, exploiting that renewable nature, easy to maintain, and at a reasonable cost. The green building is designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficient use of energy, water, and other resources.
- Protect the health of occupants and improve employee productivity.
- Reduce waste, pollution, and environmental degradation.

Indeed, green building can incorporate sustainable materials into its construction (reused, recycled, recyclable, or from renewable resources), Create a healthy indoor environment with minimal pollutants, and create functional landscaping that requires less water (using native plants that survive without additional watering) [12].

7.1 Natural construction

On the one hand, a natural green building must meet two complementary requirements: adapting the architecture to the landscape and its factual data. On the other hand, natural materials are renewable if possible**.** The choice of the site must be based on raw data. Indeed, topographical data have an important influence on the microclimate and thus on the characteristics of a building site. For example, in a basin where cold air is stagnant, temperatures can be up to 6°C lower than those measured on flat ground only a few hundred meters away. Architectural forms should be inspired by nature, with colors that do not look artificial. This natural construction uses materials provided by nature. When these materials replace polluting synthetic products, whose manufacture consumes a large amount of energy, their use is strongly recommended. The term "natural materials" covers above all local (renewable) raw materials, which can be used according to traditional craftsmanship or modern techniques [12].

7.2 Passive building

The term "passive building" refers to a standard of construction that can be achieved through different types of building materials. It also refers to green building construction that guarantees an indoor climate as comfortable in summer as in winter without a traditional heating system. Translated from the German term "Passivhaus," this term refers to collective and individual housing. The objective of the "Passivhaus" is to reduce the energy consumption of residential buildings by providing passive solar energy, reinforcing the insulation of buildings, using renewable energies, and heat recovery. The passive building consumes a maximum of 15 kWh/m2/year for heating and 30 kWh/m2/year for heating, hot water, and ventilation. The total consumption (including electrical appliances) must not exceed 120 kWh/m2/year in primary energy (energy taken from nature before transformation). The passive label includes specific and technical elements on windows, insulation, sealing facades, and air renewal. Very rigorous tests are carried out to obtain the passive label [13].

Single-family passive houses often have a compact appearance. It is one of the conditions to obtain a low energy consumption. In order to realize a passive building, it is necessary to go through the following points:

Excellent insulation of the whole building, the external insulation varies from 25 to 35 cm;

- Good triple-glazed windows;
- A building orientation favorable to the capture of passive solar energy and large bay windows to the south;
- A double-flow CMV (controlled mechanical ventilation) with heat recovery at a rate of at least 75%;
- Solar thermal energy for domestic hot water needs[13].

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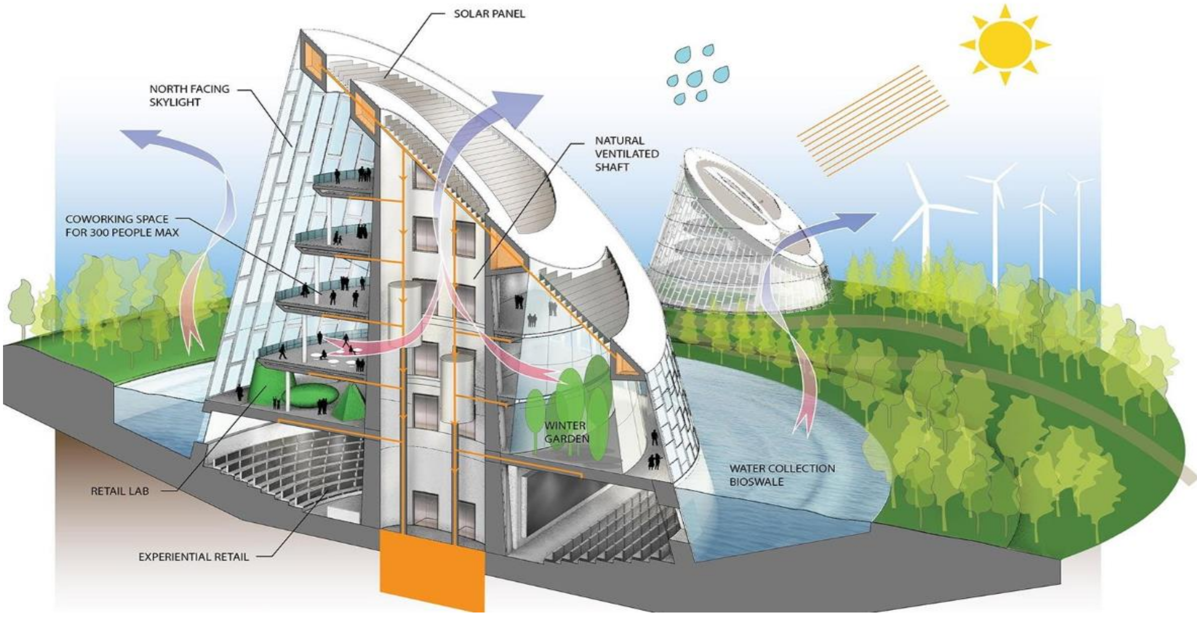

Figure 5: Sustainable Construction Overview [14]

8. ENERGY EFFICIENCY AND RENEWABLE ENERGY

Energy efficiency is a primary focus and an essential component of sustainable construction. It is even becoming the primary criterion of its success. Sustainable construction must always be equipped with solutions that enable better electrical energy management, reduce consumption and contribute to providing quality energy. This efficiency can be translated into the house by presence detectors and complete home automation equipment. These solutions can be used to control and program lighting, heating, and other consumption items to optimize their use at a lower cost. In tertiary buildings, there are many solutions to reduce energy consumption and thus promote the reduction of greenhouse gases, including lighting management, management of office equipment, emergency lighting, and measurement and monitoring of infrastructures [15]. In buildings, capacitor banks increase the installation efficiency, and network analyzers allow measurements of energy consumption and quality. Renewable energy sources have the advantage of being available in unlimited quantities. Their exploitation is a means of meeting energy needs while preserving the environment. The energy produced by photovoltaic panels is an unavoidable component of renewable energy production, which must meet the dual challenge of integration into buildings and optimized production. Heavy investments through different projects worldwide are engaged in clean energy technologies for efficiency and renewable energy to strengthen the economy, protect the environment, and reduce oil dependency [15].

8.1 Energy saving

On entend par économies d'énergie l'ensemble des actions économiquement rentables entreprises pour réduire les consommations d'énergie, par la mise en place d'équipements adaptés dans les installations électriques, par exemple.

L'objectif est aussi de consommer l'énergie de façon optimale (par exemple, la récupération de chaleur perdue dans les gaz de combustion ou la valorisation énergétique des déchets). It is important to know that energy savings are not only about electricity. The respect of simple daily gestures associated with a judicious choice of equipment also makes it possible to control the consumption of all other forms of energy (gas, fuel oil, etc.). In a green building, the search for energy savings is a priority [16].

The main measures to save energy include the following actions:

- good thermal insulation of all external parts (walls, windows, roof);
- Elimination of thermal bridges and other "energy leaks";
- Good tightness of the external envelope of the building;

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 9, Issue 2, pp: (79-91), Month: April - June 2022, Available at: www.paperpublications.org

- Reduction of heat loss due to ventilation;
- The efficiency of a reduced inertia boiler.
- Optimization of electricity management (reduction of installed power, centralized management, lighting management equipment) [16].

9. RENEWABLE ENERGY

9.1 Solar system

Solar energy is at the origin of the water and wind cycle. The plant kingdom, on which the animal kingdom depends, also uses it by transforming it into chemical energy through photosynthesis. Except for nuclear energy, geothermal energy, and tidal energy, solar energy is the source of all energy on Earth. Inexhaustible on the human time scale, solar energy is also abundant. It is estimated that the Earth receives from the sun about 10,000 times the total amount of energy consumed by all humanity. Solar energy harvesting technologies can be classified into photovoltaic solar, thermal solar, and thermodynamic solar. The use of solar energy has a prominent place in the green building [16].

Solar heating systems can be installed in all types of buildings. Using solar energy to preheat outdoor air before entering a building can significantly reduce heating costs in residential and commercial buildings. Solar heating systems are incredibly efficient for large buildings such as hospitals, hangars, schools, gymnasiums, and multi-story residential buildings.

Scientists and engineers worldwide have long been trying to develop a low-cost solar cell that is both highly efficient and easy to manufacture, with high throughput, and makes solar electricity accessible on a large scale. The vast majority of solar heating systems require the green installation of solar walls. Solar walls can be installed on new or existing buildings. Solar walls require virtually no maintenance, are liquid-free, and have no moving parts other than fans related to the ventilation system. In addition, solar walls operate on cloudy days and during the night, even though their efficiency is lower. The return on investment is two years, thanks to the energy savings they generate.

Figure 6: Green Energy park of Benguerir using the solar system [17]

10. SUSTAINABLE MANAGEMENT

10.1 Sustainable water management

Freshwater availability has become a growing concern in a context where developed and developing countries are engaged in an actual race for inexorably scarce resources. The green building must therefore be designed to make efficient use of water. Managing wastewater, irrigation water, and runoff water are essential for a sustainable approach. The use of mixer taps reduces water consumption because it is easier to regulate the temperature. Restricted-jet faucets allow less water to pass unnoticed during use. Negligent waste is to be avoided [18]. Indeed, repairing a leaking water faucet can be painful. However, dozens of water taps can save millions of cubic meters of water lost every year in Morocco alone without a proper seal. Thermostatic mixing valves (Figure 7) also provide savings. Because the water flows at the set temperature, it saves the water usually lost when setting the shower temperature. A practical and sustainable water savings strategy also relies on the knowledge or forecasting of consumption, tracking, and prevention of leaks. The replacement of unsuitable equipment and the use of "water-saving" devices, communication, and user awareness are also potential sources of water saving [18].

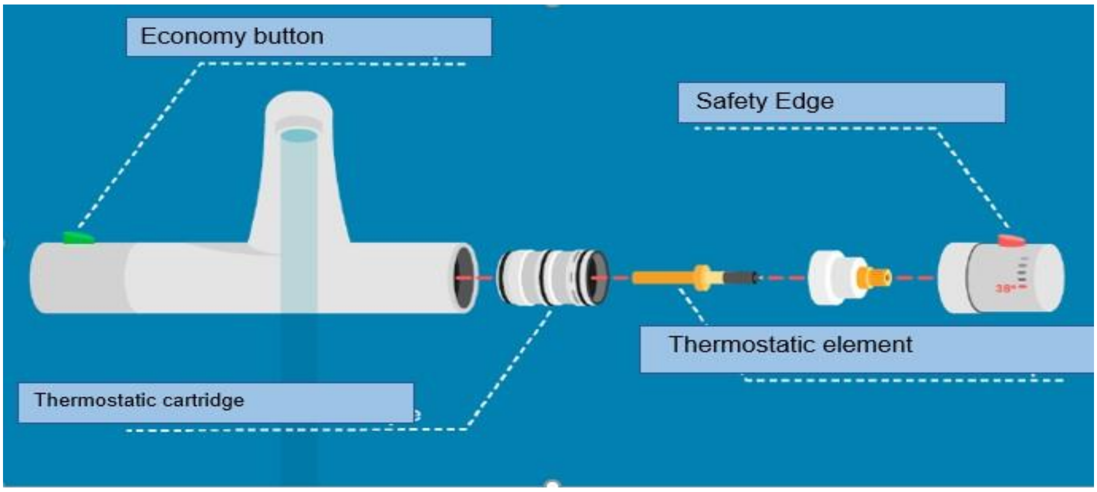

Figure 7: Faucet Thermostatic Mixing Valves [19]

11. GREEN BUILDING - ZERO-ENERGY HOUSE AND ECONOMIC ASPECTS

11.1 Zero-energy house

11.1.1 Materials

Buildings have a relatively long lifespan compared to other consumer goods. Therefore, the selection of green building methods and materials has impacted over a very long time. The choice of building materials is essential because it is necessary to choose materials with a very high thermal inertia, therefore insulating very well from cold in winter and hot in summer so that the green building installation can have a long life span. It will also be necessary to pay attention to their environmental performance [20].

An environmental approach to construction always translates into maintenance and operating cost savings. Indeed, this approach does not lead to additional initial investment costs. One of the following structural materials should be used in the construction of a green building:

- Cellular concrete (Thermo - stone): combined mineral-based carrier material and thermal insulation. It is durable, recyclable, and without toxic emissions.
- Clay brick (alveolar brick): combined load-bearing and thermal insulation material based on clay. It has high acoustic performance and is durable.
- There is over-consumption of grey energy during its manufacture.
- The wood frame: carrier material (requires the systematic addition of an insulator) and absorbs CO2. It is a renewable source and available in large quantities.

11.1.2 Energy choice

It is not a question here of total energy autonomy from the electricity supplier but of producing as much energy as the building consumes on average. This green building annually produces about as much energy as it consumes and is equipped with passive solar systems such as south-facing windows. Combined with solar collectors, these systems concentrate the sun's energy to produce electricity, heating or cooling [20].

In some countries, the solar rays captured by an average house over a year can satisfy its energy needs. It is now possible to reduce the average energy consumption of a green building to zero by using solar energy. In a green building, the reduction of energy consumption must necessarily go hand in hand with using all energy efficiency measures.

It is essential to favor renewable energies for heating, especially in new buildings. In this respect, solar, wood energy, and geothermal energy seem most suitable. With solar energy in a green building, one can offer domestic hot water and direct solar floor (DSF) for heating. Solar water heating systems are nowadays extremely efficient even if it is regrettable that the maximum output is in summer when it is least needed. This solar energy, which is unrestricted, non-polluting, and inexhaustible, can also cover part of the heating needs of the green building. We then speak of combined solar systems. They can cover 25 to 60% of the annual heating needs. The combined solar system is more challenging since domestic hot water is needed all year round, whereas heating is only needed at specific periods. Also, the temperature of the water used in the heating circuit is relatively low (between 30 °C and 50 °C), while for domestic hot water, it is much warmer (between 45 °C and 60 °C). Hydro accumulation systems have been developed to overcome these difficulties; they consist of storing the heat produced by the collectors in a volume of buffer water, from which it is drawn if necessary. The energy required for heating is dispersed throughout the building either by low-temperature radiators or underfloor heating (PSD).

Wood energy is a renewable energy that contributes to the fight against the greenhouse effect and global warming. Indeed, it recycles the carbon dioxide absorbed by the forests in the atmosphere. Moreover, it provides excellent value for the by-products and waste of the wood industry and contributes to the rational management of forests, thus maintaining the hydrological and climatic balance. Geothermal energy is also a renewable, ecological, and freely available energy principle. Geothermal heating draws heat from the earth or water, in the case of geothermal energy from groundwater, to transform it into heat that can be used in the green building, in the form of heating, via a generator. Geothermal heating offers solutions adaptable to most constructions [20].

11.2 Economic aspects of a green building

11.2.1 Costs for a green building

Usually, the ecological characteristics of a building are considered complementary. According to this vision, the construction of a green building necessarily costs more than a less environmentally friendly solution because it involves using quality materials, high-efficiency equipment, and a more complex workflow. The approach of considering that extra payment is inevitable to make a project green is beginning to give way to more holistic designs and a comprehensive view of costs and benefits.

Today, researchers, architects, and owners realize that a green building program that focuses on sustainability from the outset can lead to the discovery of techniques that will provide environmental and social benefits without additional costs. For example, simply orienting a building to make maximum use of windows and passive solar heat can allow developers and architects to create to use less energy, increase sustainability, and better daylight penetration, which can increase employee productivity without additional construction costs.

A green building can even help the owner eliminate expenses from the outset. The choice of cooling equipment is one example; for example, if heat loss in a green building project is minimized through efficient lighting and the building envelope is eco-efficient, the building will require significantly less cooling capacity [20].

12. BUILDING TECHNIQUES WITH RESPECT FOR THE ENVIRONMENT

The evolution of construction techniques has made it possible to design increasingly larger spaces, leading to the need to integrate the thermal comfort component into the entire architectural design process. Combining passive energy techniques such as convection, conduction, evaporation, and radiation, the architectural design proposes solutions to thermal regulation requirements through natural means.

Indeed, thermal comfort must be the primary objective of any architectural design by exploring the various components of the building: the shape of the envelope, the thermal properties of materials, natural light and the modes of lighting, heating, ventilation, spatial articulation, the orientation of openings [21].

All the existing potentials in the site, the spatial composition and the mode of construction must be explored intrinsically from design to realization. Therefore, the architect has a responsibilitý to protect natural environments and ecosystems

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and cannot continue to follow the classic aesthetic approach of generating fanciful forms that encourage the waste of resources. This dimension of integration of energy measures in the architectural process has been the subject of several types of research and has suscité the interest of several practicing architects. By way of example, we quote some testimonials.

In addition to these testimonials, research concerning renewable energy, especially solar energy, has been developed since the beginning of the 20th century. The concept of solar architecture has été thus introduced by the Americans by distinguishing between functional architecture (or solarized architecture) and passive architecture (or bioclimatic architecture).

For the building sector subject of this study and according to the regulations in force: "Morocco has set targets for immediate energy savings by implementing a plan of efficacitý energy in the various economic sectors. Among these sectors, the building is the first energy consumer with a significant share of the country's total energy consumption [21].

Among the objectives of urban climate design in any urban development, on the one hand, and those of bioclimatic architecture at the building scale, we can cite:

- Improving the comfort of urban spaces that also helps to improve the comfort inside the homes.
- Reducing energy consumption, including optimizing energy requirements for heating during the winter and cooling during the summer, is a critical element of the summer.
- Reducing carbon emissions.

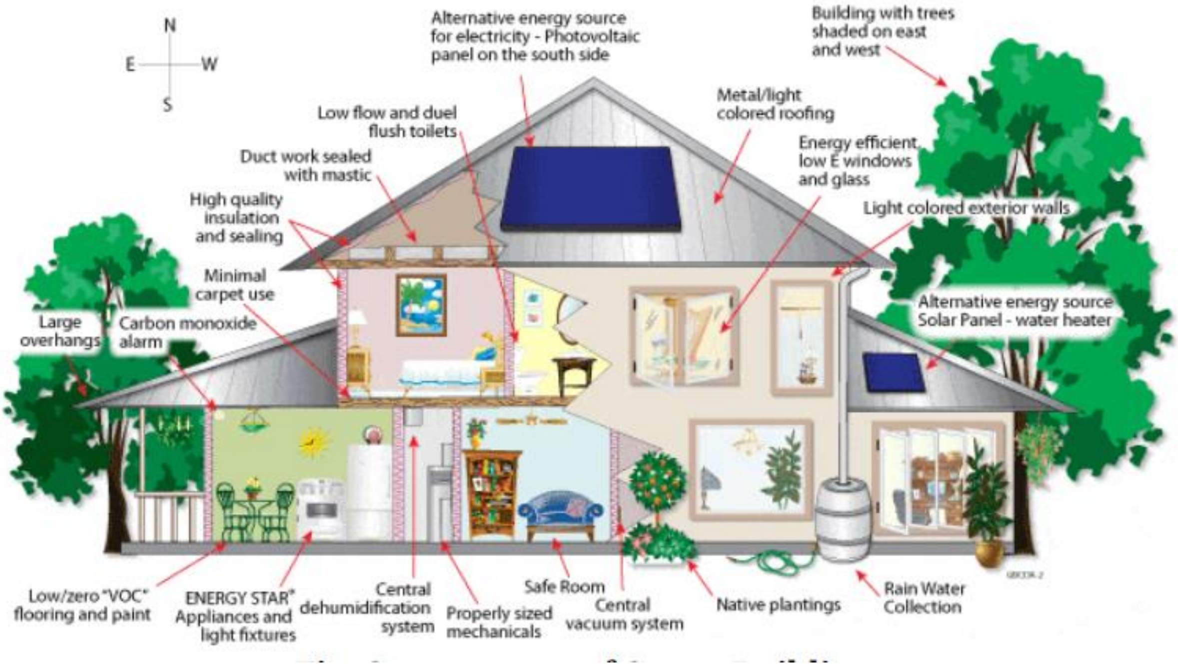

Figure 8: Example of green building with the respect for the environment [22]

13. DISCUSSION

In order to know the techniques and practices that should be used in the future project, and which is the subject of this thesis, the table below proposes a comparison between the techniques of construction in respect of the environment of three projects; the first is the standard cases in construction projects in Morocco, the second is the project of villas for researchers, which is well detailed in the previous chapter and the last is the case of INTER HOUSE which remains a significant example in terms of sustainable construction and construction in respect of the environment:

The thermal insulation in the research villas is done by hard stones or in the inter-house by stabilized earth bricks which offers immense thermal inertia. On the other hand, in practical cases in construction projects throughout Morocco, the insulation is done by synthetic insulators, mineral, plant, and animal insulators. The case of air conditioning is also different for each case; in the research villas, we saw the natural air conditioning system based on the use of the pebble bed; in the inter-house, we saw the HVAC system, in the practices of the standard cases here we talk about a ventilation device with heat recovery HRV. The same comparison was made in the case of water conservation and management of rainwater and irrigation water; almost the same thing is done in all three cases, the separation of wastewater and rainwater recovery for irrigation after treatment at the WWTP for research villas and practical cases in Morocco or by reed colonies and bacteria in the case of the inter-house. The energy-saving for the two cases studied is made by the devices used in the case of the inter-house and which are classified A+ in energy efficiency, or by the programmable air conditioning system in the case of the research villas. On the other hand, in the standard cases in Morocco, the main measures that allow energy savings include the actions mentioned in the table below.

14. CONCLUSION

The Green City of Mohammed VI is one of the first cities to implement such a model on the African continent. Its implementation plan is part of a rigorous set of specifications, in line with the highest international certification in the field, LEED-ND (Leadership in Energy and Environmental Design for Neighborhood Development), developed by the USGBC (US Green Building Council). In order to succeed in this project, in terms of architectural design, good practices in respect of water, environment, and energy, intelligent solutions have been adopted and the cases studied have shown that:

- The construction sector has significant energy-saving potential.
- The relevance of passive systems to thermal comfort is now clear: layout, building architecture, bioclimatic approach (optimal orientation, openings, solar inputs, and natural lighting, appropriate choice of materials, high-performance insulation, and use of renewable energy).
- The diversity of solutions and the range of possibilities to adapt to the specificities of local climates offer great opportunities for innovation.
- The solutions adopted by each pilot case to achieve energy savings, improve thermal comfort, and at the same time, minimize environmental impact are described in this document.
- This report is rich in lessons learned and includes feedback from concrete experiences. In Perspectives, the theme of this document and the vision of SADV address the environmental and energy challenges that Moroccan cities will face in the years to come. These challenges must be addressed at the building level and in broader territorial contexts. These new design and space management approaches aim to reduce energy consumption, reduce CO_2 emissions, improve user comfort, offer more environmentally friendly development methods, and offer sustainable solutions to urban problems.

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