Principles to achieve zero carbon buildings Implementation Barriers and Suggested Solutions

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Abstract:
When the British Government enacted a law stating that by the beginning of the year 2017 all-new residential buildings must meet zero-carbon requirements, many foundations contributed to developing engineering ideas and environmental solutions that would help in conserving energy, environment, and public health.
The fact that some communities are in greater need of such legislation is due to population growth, resource depletion, and problems caused by environmental pollution. This is consistent with the appearance of many new residential communities in Cairo and other governorates, such as the residential areas in the Suez Canal Development Center and New Cairo, which can be a nucleus for a healthy and environmentally friendly society that could then be a replicable prototype model for many areas.
The issue of energy conservation is one of the most important pillars on which low-carbon buildings depend on, so various institutions have been striving to achieve this. The entities responsible for implementing this type of building can be classified into the design of the building itself, technical systems, and devices in addition to adjusting Users' Lifestyles.
This research paper explains principles that could be applied to achieve zero-carbon buildings to encourage architects and engineers to work with them in Egypt. Then, to investigate these principles, some residential buildings that have experimented with the idea of low carbon buildings according to the British experiment are discussed. And using the inductive methodology, implementation barriers are inferred with a set of proposed actions after discussing some experiences of low-carbon buildings in Egypt, which aim to improve and raise the quality of life.

Keywords:
Zero-Carbon Buildings (ZCB), Zero Energy Buildings (ZEB), Energy Consumption, Building's outer shell.

1. Introduction
There are lots of previous researches that have discussed ZCB, whose concept with ZEB may be close to many. These researches address the economic cost, the most critical obstacles to implementation, and the necessary strategies. But, we do not find an echo for this idea in new

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national projects in Egypt for example, despite the concerted efforts made by the government with a focus on housing projects from various economic levels. Having official certificates such as LEED certification is an incentive for many designers interested in this field in the absence of certificates dedicated to ZCB. It may be very consistent with previous goals and other basic design ideas such as vernacular architecture, green architecture, and others.

The research problem arises in the absence of clear vision among designers for obtaining low or zeros carbon buildings due to their mixing with many other architectural ideas and the steps for their implementation, starting with a selection of the location and planning of the general site.

Through this research paper, the basic design principles of ZCB are discussed. Participating entities are displayed, with a focus on residential buildings as a close example for all users and for several reasons including limitations of the site area, it's the most needed building types for society, the primary funder is the owner who is the beneficiary of the idea of the project (directly or indirectly) and because it is one of the energy-consuming buildings. This will be achieved by providing some previous experiences with zero carbon buildings, as the British experience, as well as showing the closest example in Egypt. This will formulate the results and extracting the difficulties of implementation and proposing mechanisms to overcome them, developing and prioritizing the principles of applying this type of building.

2. Building Systems.

All previous experiences have proved that the way to achieve zero-carbon buildings is not to look at individual factors incrementally, but to combine them, to add other technologies and optimize the performance of a particular structure as a whole. By using this approach, a building that connects more than one factor could realize 30% to 50% energy saving, whereas the unique technology approach generally yields 1% to 5% of the whole building saving. [1]

According to Stewart Brand, a building is composed of six layers of change. [2]

1- Site: the geographical settings, the urban location.

2- Structure: the foundation and load-bearing elements.

3- Skin (envelope): the building exterior surfaces, including walls and roofs.

4- Services: including all mechanical systems like electricity, plumbing, sprinkler system, HVAC, elevators, and escalators.

5- Space Plan: the interior building parts, walls, floors, ceiling, and doors.

6- Stuff (furniture): chairs, desks, phones, pictures, appliances, …etc.

These layers can be combined in three central systems -regarding the human body- the Structural System, the Enclosure System, and the Mechanical Systems. [3] **Figure (1)**

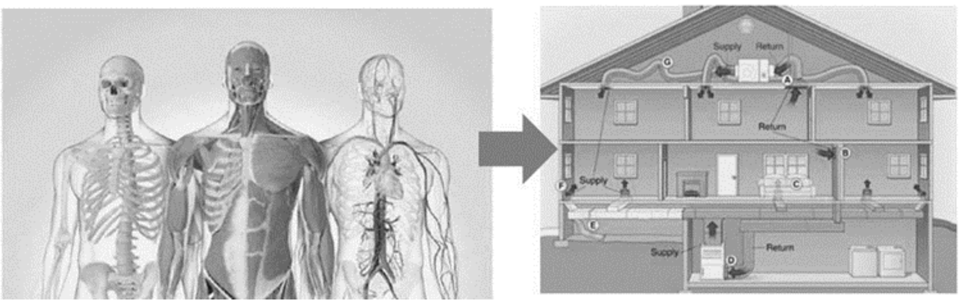

Figure (1). Building Systems. (the Researcher)

Unquestionably, many factors contribute to achieving zero-carbon buildings, which all depend on the systems mentioned above.

3. The Relation between Zero-Carbon Buildings and Energy Saving

Undoubtedly, there is a close relationship between energy-saving and achieving the zero-carbon building's target as well. Energy is the leading operator of the building and is the primary source of carbon emissions too, which is one of the greenhouse gases that affect the earth's temperature and causes increment by about 33 degrees Celsius. Currently, the world has about 40% of all CO_2 emissions caused by power stations [4]. Being a carbon-zero-emission building indicates that it is also a zero-energy building simply because all the measures are taken to reduce energy consumption fundamentally. Consequently, searching for one of them leads directly to the other. [5]

4. Principles for Achieving Zero-Carbon Buildings

With the rising cost of energy resources, technologies, production, transportation and distribution, awareness of the need to rationalize consumption and improve the efficiency of its use has increased, especially in the residential sector, which is the largest consumer of energy. To achieve the goal of rationalizing energy consumption as a prerequisite for reducing carbon emissions in the surrounding environment, it is essential to consider the building as an integrated energy system that must achieve energy conservation in its various components. Half of the cooling load in an energy-inefficient building is obtained from solar thermal gain and an inefficient lighting system.

In the same vein, proper design and implementation process of buildings and the use of green energy sources lead to improve building performance, aside from actions taken by users of these buildings and their ability to manage energy. Hence, it is an urgent necessity to find opportunities to rationalize energy consumption and improve efficiency in the building sector, which can be classified into three principles. They are all based on rationalizing energy consumption depending on the following, [6] the design of the building itself, technical systems, and adjusting users' lifestyle.

4.1 Rationalizing Energy Consumption Depending on the Design of the Building Itself.

Designing buildings following architectural design methods, which takes into account the building's adaptability to the environmental conditions, topography, surrounding climate, and changes in solar energy, make buildings environmentally friendly. This can only be achieved by decreasing carbon emissions by reducing energy consumption. Increased thermal load is a significant cause of many problems related to the environmental impacts of buildings. Identifying a building's orientation and studying all its natural surroundings are fundamentally useful for making many decisions and finding various solutions to decrease a building's thermal load. This identification can be carried out through studying the shading scheme, deciding on the size of openings (doors and windows) and their location in the facades of the building, using thermal insulation materials and appropriate materials for walls, ceilings, doors and windows, including the use of double or triple glass, and finally applying suitable colors to external walls and surfaces.

Energy-efficient buildings are classified into renovated existing buildings and newly constructed buildings. In the second type, the efficiency of building thermal insulation can be maximized to extreme limits via integrating it with all other measures that can be taken in the building starting from environmental planning (the proper preparation of the site in which the construction will be carried out) and ending with accomplishing the design of the building itself. The building design is of the utmost importance because it works on reaching the least amount of solar radiation falling on its elevations in summer and the enormous amount in winter, selecting places and dimensions of skylights and openings and delineating façades and wall types [6].

This indicates that new housing projects established by the government can be a nucleus for the widespread implementation of the previously mentioned measures. The process of raising energy efficiency is a profitable economic investment because it saves energy and reduces the consumption of devices, thus minimizing their maintenance cost. Moreover, it fulfills the requirements for comfortable living and building protection from harmful external influences and thus increasing the value of the building, as well as its lifetime.

In fact, 3-D energy design simulation tools - like HEED 4.0, Rivet, Autodesk Insight - helps in visualizing building performance with a range of design variables such as building orientation (relative to sun position), window and door type and placement, overhang depth, insulation types, values of the building elements, and airtightness. These simulations help the designers predict how the building will perform before it is built, and enable them to model the economic and financial implications on building cost-benefit analysis. [7]

4.2 Rationalizing Energy Consumption Depending on Technical Systemsand Devices.

This is achieved through the use of high-efficiency energy-saving appliances and systems in buildings, including lighting fixtures, heating equipment, and policies, air conditioning systems, water heating devices, cooling and freezing devices, washing, and drying devices, cookers, and any other electric machines. The proper selection of energy-saving appliances, along with the excellent management of using them, have proved to be highly effective in reducing energy. They can be obtained by increasing people's awareness of new energy-saving technologies and their optimal use, especially when people know that they affect each other, e.g. The effect of the lighting type on the heating load and air conditioning capacity, which are the most significant contributors to high energy burden due to high electricity consumption in most Arab countries. As such, they are searching for alternative energy as it is the ideal solution. Solar energy and wind energy are good examples of clean energy sources, in addition to other resources that need some special fittings at the layout like water energy, geothermal, biogas, in addition to wood fuel energy.

4.3 Rationalizing Energy Consumption Depending on Adjusting Users' Lifestyle.

To achieve such a goal, users should follow specific procedures to apply the concepts of rationalization and avoid excessive use of energy. This process is known as Efficient Energy Management, which subsumes calculating energy consumption and determining the sites where it is lost and taking active measures to reduce consumption costs and determine the time required for implementation. This process starts with some simple procedures such as regular equipment maintenance, air control, or water leakage, as well as shading air conditioning units from direct solar radiation without preventing the flow of air around, committing oneself to close the doors of rooms during heating or cooling. Upgrading lighting fixtures and energy-efficient equipment, using recycled materials in construction, **Figure (2)**, and, finally, changing energy sources [6].

Figure (2). Shafraaz and Serena Kaba net-zero home. By Shafraaz, Canada
Best users for fully zero energy home – using extra structure materials in stair construction
http://www.greenenergyfutures.ca/episode/episode-80-chasing-net-zero-net-zero-evolution

5. Some important factors.

There is general agreement among specialists that some factors are having much effect on saving energy than others. Applying thermal insulation in buildings is an essential economical option to reduce energy consumption because of its ability to be used in most buildings, even new or already built ones. Saving about half the amount of energy required for heating and air conditioning buildings, providing necessary thermal comfort to stay or work, and reducing energy bills, in addition to other technological tools.

5.1 Heat Insulation for Buildings' Outer Shells:

Heat transfer is caused by difference of temperature between structural elements and the surrounding environment as it moves from higher to lower parts. Buildings' thermal insulation aims to reduce heat transfer between construction parts and its external components, whether from inside the building to the outside (heat loss in the winter) or vice versa (thermal gain in the summer) to improve the nature of the internal environment. Thermal resistance, i.e., material's ability to insulate heat, depends on the thickness of the material and its conductivity; and it is known by U-Value. A building's outer shell separates the building from the outside air. Walls, ceilings, doors and windows; the type of materials the walls are made of, the roof type and the installation of its layers, along with their distribution and thickness, and the ability of these layers to isolate and store heat, as well as the type of external windows used, type of glass and tools used to reduce the impact of solar or wind radiation, such as exterior louvers, curtains and shading devices… all must work together to reduce buildings' heat transfer [8].

It is worth mentioning that the economic benefits achieved by using heat insulation materials can lead to the issuance of legislation and laws that are necessary to comply with the requirements of that insulation, improve the production of national industries, create new materials and techniques based on recycling waste, and provide new jobs for people.

5.2 Technologies for Low-Carbon Buildings

Technical systems play a fundamental role in reducing carbon emissions released from buildings. They provide a set of solutions, among which is using green energy resources or policies such as the photovoltaic systems that come in top of the list.

Photovoltaic Systems (PV):

It's one of the most popular technologies or systems. It utilizes solar cells to convert light into electricity. A traditional PV panel system could save about 1200 kg of carbon dioxide per year; that's around 30 tons over its lifetime. Using solar energy to supply power to our homes will make a real contribution to meeting the goal of producing 15% of energy from renewable sources by the year 2020 [8], . Figure (3)

Figure (3). The Solar Settlement, a sustainable housing community project in Freiburg, Germany. (Adopted from: https://en.wikipedia.org/wiki/Photovoltaics#Overview)

6. The British Experience of Achieving Zero-Carbon Homes

"Zero Carbon Hub" is a government-backed British institution interested in a zero-carbon building that has developed a set of strategies to achieve this type of building. These strategies are stated briefly as follows [9] **Figure (4)**:

(1) Reducing carbon emissions depending on the building itself, including all construction and finishing materials, as well as the design itself: this strategy starts with using hollow brick walls as a simple solution to achieve the thermal insulation of the building. The institution defined a measuring unit for the amount of energy required for cooling or heating the building (kWh/m²/year**)** and identified limits of measurements that vary according to the type of housing unit, single, twin, or any other residential building type. This strategy is known as "Fabric Energy Efficiency."

(2) Reducing carbon emissions on-site, depending on controlling the building operating issues: which is the maximum number of carbon units resulting from heating and cooling processes, such as the use of hot water, lighting units, and ventilation. It also allocated a specific group that measures the amount of carbon in kilograms per square meter per year (kg CO2 /m2/year). These values can be adjusted by using some solutions such as the use of photovoltaic (PV) panels, which are easy to apply, as a source of clean energy. This strategy is known as On-Site Low/Zero Carbon Energy. These strategies covered some points represented in **Figure (5).**

(3) Reducing carbon emissions, depending on unique solutions: these solutions include handling of the remaining carbon ratios from the previous two phases, either by improving the efficiency of the previous two stages or by resorting to new solutions. This is measured by the amount of money paid per ton of carbon within thirty years and is known as Allowable Solutions.

The institution has also developed options for implementing these strategies, including:

- Keeping Balance between strategy.

- Reliance on the first strategy.
- Reliance on the second strategy [9].

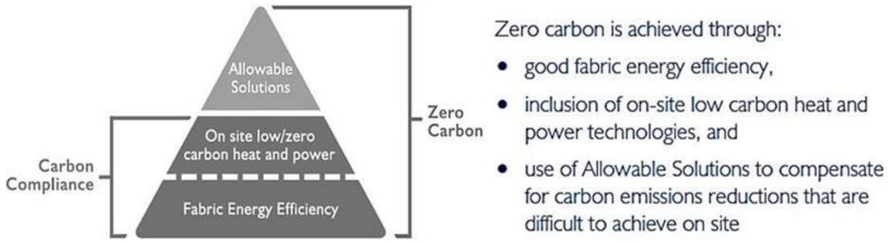

Figure (4). Zero Carbon Hub strategies. (Adopted from: Zero Carbon Strategies for Tomorrows New Homes
http://www.zerocarbonhub.org/resources/reports/zero-carbon-strategies-tomorrows-new-homes-0

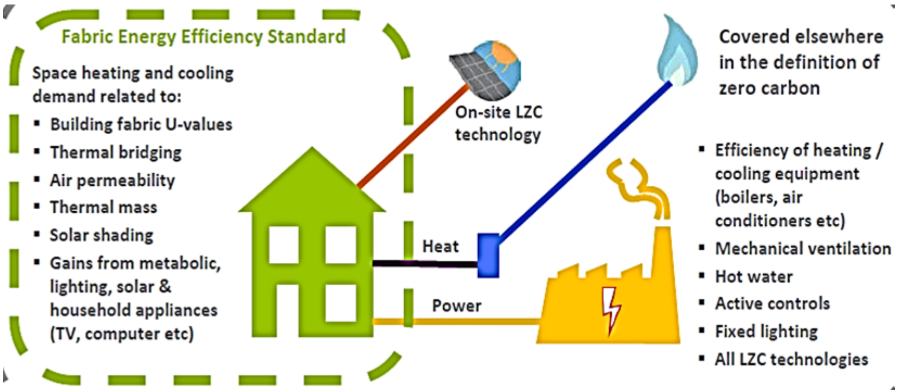

Figure (5). Points covered by the Zero Carbon Hub's strategies. (Adopted from: Defining a Fabric Energy Efficiency Standard for Zero Carbon Homes,)
http://www.zerocarbonhub.org/sites/default/files/resources/reports/Defining_a_Fabric_Energy_Efficiency.

6.1 Profiles of Building Examples

The following examples of zero-carbon buildings used the Zero Carbon Hub strategies employing different implementation options [10], Table **1**.

Table (1). Examples of Zero-Carbon buildings. (the Researcher)

Projects	Abbey Walk	Standings Court	Lovejoy Lane, Windsor
Project profile			
Overview	12 family homes in West Sussex with floor areas 80–105m2, by Greenoak Housing Association, Completed in 2010.	38 homes for rent, 12 of them certified as Passive Houses with floor areas typically 121 m^2, by Saxon Weald Homes Ltd & Osborne, Completed in 2012.	A set of various houses (semi- detached, mid-terraces and end terraces). Eight are built as zero carbon with floor areas 94-116 m^2, by Radian, Completed in 2011.

Zero Carbon strategies	**Fabric Energy Efficiency (١)**	- Timber frame construction - Airtight, heated envelope extending into the apex of the roof providing worm mezzanine. - Air cavity at walls provide a space for services (pipes and wires) without penetrating the airtight membrane. - Overall specification slightly better than the needed limits:	- Structural insulated panel system (SIPS), resulting in a very airtight, well-insulated structure with a rigorous focus on working drawings details. - Overall fabric specification to the Passive house standard:	- Structural insulated panel system (SIPS). - Overall fabric performance in excess of the needed limits:
		• External walls U value 0.15 W/m^2/K	• External walls, Roof and Floor U value 0.08 to 0.11 W/m^2/K	• External walls U value 0.18 W/m^2/K
				• Roof U value 0.10 W/m^2/K
		• Roof and Floor U value 0.10 W/m^2/K		• Floor U value 0.15 W/m^2/K
			• Windows U value 0.8 W/m^2/K (triple glazed)	• Windows U value 0.8 W/m^2/K (triple glazed)
		• Thermal bridging Y value 0.06 W/m^2/K	• Thermal bridging Y value 0.02 W/m^2/K	• Thermal bridging Y value 0.08 W/m^2/K
		• Air permeability rate typically 3.0 m^3/h/m2@50Pa	• Air permeability rate ≤0.6 m^3/h/m^2@50Pa	• Air permeability rate typically 5.0 m3/h/m^2@50Pa

Table 1. Examples of Zero-Carbon buildings. (the Researcher)

Projects		**Abbey Walk**	**Standings Court**	**Lovejoy Lane, Windsor**
Zero Carbon strategies	**(2) On-Site Low/Zero Carbon Energy**	- High-efficiency condensing gas boilers. - Solar hot water with thermal stores. -Mechanical ventilation with heat recovery. - 100% low energy lights	High-efficiency condensing gas boilers - Solar hot water with thermal stores - Mechanical ventilation with heat recovery. - 100% low energy lights -Optimized passive solar orientation. -Designing and building to the 'extreme fabric' Passive hous standard, means that the homes should be energy efficient without the need for complex space heating or cooling systems. -The use of SIPS enabled the homes to be built with the necessary attention to details and increased the speed of construction.	Significant areas of photovoltaic panels - to reach zero regulated emissions, between 3.2 and 3.8 kWp (23 to 27 m^2) of PV per home. -Some homes are heated by high-efficiency, condensing gas boilers, other by an air-to-water heat pump. - Using solar hot water systems. -House mechanical ventilation with heat recovery and 100% low energy lights.

	Allowable (٣) Solutions	Remaining CO2 Is about (10.9 kg/m^2/year) needs a simple payment into a carbon fund that will make some editing.	Remaining CO2 is about (9.9 to 10.7 kg/m^2/year)	Remaining CO2 is about (0.2 to -1.7 kg CO2/m^2/year) indicates that there is no need for any other solutions to reduce carbon emissions.
Recommendations		Keeping balance between strategies.	Keeping Balance between strategies.	Reliance on the first strategy.

6.2 Similarities between suggested principles and strategies for the British experience.

There are many similarities between the suggested principles and strategies for the British experience, despite the different names, especially in the first two essential points. About what is known as allowable solutions that are based on continuous improvement of the previous procedures that are measured by the percentage of expenses to reduce the carbon percentage during a specific period. It can be included under the item "Efficient energy management (third principle)" after combining maintenance and continuous periodic measurements, Figure **(6).**

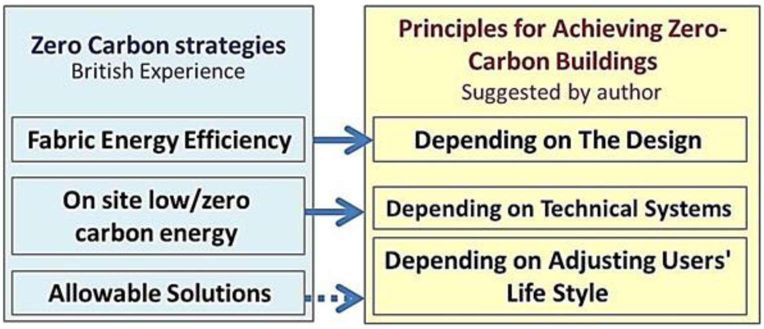

Figure (6). Similarities between suggested principles and strategies for the British experience. (the Researcher)

7. The Egyptian experience.

Many projects in Egypt are certified with LEED certificate, which refers to maintain energy levels, conserve resources, recycling ideas, etc. that makes them low-carbon buildings as well. Still, most of these buildings are public buildings. But, for residential buildings, the ideas of green architecture and vernacular architecture have the largest share, like many tourist housing buildings in El-Gouna- Hurghada, and Nuweiba, known as the eco-buildings [11], **Figure (7)**, most of the researchers studied these projects, their analysis was based on their use of natural materials in construction such as clay. Also their usage of interior courtyards and high domes, using cross-ventilation, wind catchers with strict policies for waste management, using solar water heaters and PV panels. Unfortunately, some of these issues are applicable, and others aren't for modern high rise residential buildings.


Figure (7)**. At the left, Basata eco-lodge (Nuwaeba), At the right, El-Gouna (North Hurghada)**

In general, the attempts made in Egypt to achieve low carbon buildings can be classified into the following:

First: Studies in the field of improving building evaluation codes in terms of environmental impact, as these codes are the decision-makers used to approve if the building meets the requirements of environmentally friendly buildings or low carbon buildings or not. Indeed, many types of research included recommendations for making amendments to the buildings' environmental performance assessing tools in Egypt, which indicated the necessity of separating residential buildings with special requirements and separating the codes for each country too, according to its environmental and social aspects. [12]

Second: Attempts have been realistically done to achieve low carbon buildings, but with other names that are compatible with the same goals and strategies of low carbon buildings, such as environmental, vernacular, and sustainable buildings. It has appeared strongly in the field of attracting ecotourism and preserving some special environments. In addition to attempts made in the field of developing design considerations for these environmental villages like Basata Eco-Lodge, Nuweiba - Taba Road, and Tunis in Fayoum.

Basata attempts to create a simple and unique form of tourism that has a relatively low impact on the surrounding environment and native inhabitants. Consists of several chalets, each chalet has its own distinctive design. They are constructed of mud bricks and designed in a way to stay warm in the winter and cool in the summer. To save energy, they do not provide towels, soaps, ACs, nor TVs, but instead, offer fans if needed, **Figure(8)**

Figure (8). Indoor and outdoor shots in Basata village. **https://www.basata.com**

The same ideas are repeated in most of the villages and environmental buildings, using local materials, energy conservation, natural ventilation, and renewable energy sources, as in the village of Tunis in Fayoum, **Figure (9)**. [13]

Figure (9). One of the houses in the village of Tunis in Fayoum. **https://linesmag.com/five-vernacular-buildings-in-fayoum-l-architecture/**

However, new cities plans have appeared in which special measurements of carbon emissions and types of energy consumed were taken, but they were not implemented, such as the city of Napata. Nabta Town is planned near Alexandria, Egypt. The project is in its concept phase, it is designed to be implemented gradually, three phases in 2 years. The Master Plan contains six different usage zones as shown in **Figure (10)**.

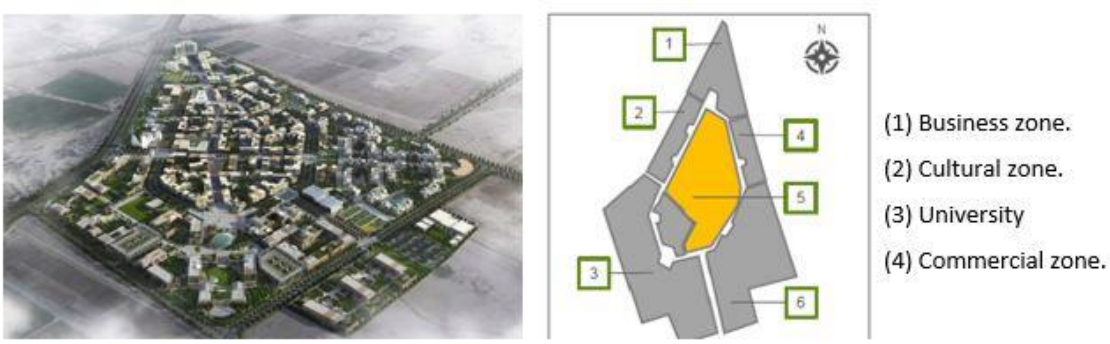

Figure (10). Nabta Town zoning and perspective (Egypt)
https://www.buildings-mena.com/info/egypt-nabta-town

Analysis has been made for different energy-affected elements for what they called Baseline situation buildings. Then, eight selected measures were studied and simulating after asking some questions, and finally, analysis has been repeated again for net-zero energy buildings as shown in Tables (2,3,4). [14,15].

Table 2. Analysis for Baseline situation (energy relevant information). https://www.buildingsmena.com/files/EGY_IKI_Report_Nabta_Upscale_final.pdf

Measure	Baseline
Roof insulation (U-Value)	3 W/m²K
Wall insulation (U-Value)	1.8 W/m²K
Floor insulation (U-Value)	3 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	Ø 21%
Shading	No
Heat supply	Reversible split unit - COP 2.5
Cold supply	Reversible split unit - COP 2.5
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	23°C/21°C

Table3. The eight measures have been studied https://www.buildingsmena.com/files/EGY_IKI_Report_Nabta_Upscale_final.pdf

No	Measure	Question	Result* A	Result* B
1	Roof insulation (U-Value)	What is the cost optimal thickness?	0.36	0.36
2	Wall insulation (U-Value)	What is the cost optimal thickness?	0.4	0.4
3	Windows (U-Value; G-Value)	What is the most energy efficient U-Value/G-Value	1.69/0.7	1.69/0.3
	Window fraction	What is the most energy efficient window fraction per orientation?	20%	
4	Shading	Should be shading measures applied?	No	Solar Glz.
5	Air tightness	What is the effect of air tightness?	min. effect	
6	Cooling supply system	What is the cost optimal efficiency for cooling? [COP]	5	5
7	RE (solar energy)	Is the installation of solar energy cost efficient?	No	Yes
8	A) Cooling B) Heating	What is the energy saving potential of an adjusted setting temperature?	Cooling 26°C Heating 20°C	

Table 4. Repeated analysis for net-zero situation.
https://www.buildingsmena.com/files/EGY_IKI_Report_Nabta_Upscale_final.pdf

Measure	nZEB
Roof insulation (U-Value)	**0.36 W/m²K**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	1.85 W/m²K
Windows (U-Value; **G-Value**)	1.69 W/m²K | **G-Value 0.3**
Window fraction	**Ø 20%**
Shading	No
Heat supply	**Split AC COP 5.0**
Cold supply	**Split AC COP 5.0**
Hot water	Electric /**Solar thermal 45%**
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	**PV**
Set temperature cooling/heating	**26°C / 20°C**

Third: Attempts in the form of studies have been conducted to try to convert existing buildings into low-carbon buildings by improving the insulation materials for walls and ceilings, as well as changing the glass type, adding renewable sources of energy, and taking measurements for the percentages of carbon and pollutants emitted before and after the modification. Other studies have reached a proposed model for a low-carbon building with special specifications and so on. [16,17,18]

Fourth: Focused attempts to obtain one of the international certificates of environmental assessment, such as LEED, BREEAM, etc., but most of them were public buildings such as banks, administrative buildings, companies, etc. These certificates represent documented evidence that the building is compatible with the environment and that it is a healthy place that achieves internal comfort for users. It has earned these buildings special fame and distinction because most of them are branches of international institutions such as Aramex Burg El-Arab- Credit Agricole Egypt Headquarters- Dar Al-Handasah New Premises in Cairo. [19]

8. Zero-Carbon Buildings Application Barriers

Although some successful models of zero-carbon buildings have been built, there are many limitations which affect implementation, at the size and quantity levels, especially with the difficulty of convincing private building owners of the importance of the idea, primarily, in the absence of laws. Barriers to the development of Zero-carbon building can be classified as follows:

Cultural Barriers:

People who have become accustomed to traditional building construction methods find it hard to understand the importance of changing building materials, energy resources, fixtures types, and, inconveniently enough, their behaviors. House builders, too, are stuck to a set of building standards, they use to implement to reduce costs. Such standards are tough to change.

Design &Technical Barriers:
Unfortunately, for many designers, there is no clear definition of zero-carbon buildings or how to obtain them. They have no idea about the requirements of application, specifications, or measurements. Add to this the absence of organization between team members involved in the construction and operation of the building.

Another primary issue related to the construction of zero-carbon homes is technical requirements like the integration of renewable energy. Mainly when applied to small scale buildings like homes, as it is widely perceived that such technologies are currently unreliable and cost too much, compared to their prices.

Financial Barriers:
Several studies and previous surveys proved that the lack of defining the accurate costs of constructing zero-carbon buildings, both in terms of design and implementation and technical processors used, is one of the main obstacles to implement and develop zero-carbon structures. The most compelling evidence of this is the actual rise in the cost of environmentally friendly buildings, especially in the field of modern technologies. [8]

Legislative Barriers:
Incomplete Government's policies that give attention to the need for zero-carbon buildings and enforce designers, engineers, and builders to apply such policies constitute a barrier to the application of Zero-carbon buildings [12].

9. Overcoming Barriers and Taking a Step Forward Toward Zero-Carbon Buildings

Overcoming previous barriers needs a group of actions which vary according to those who are taking them, provided that they ensure that all members of the design and construction team, will be responsible for achieving zero-carbon buildings successfully, throughout the project lifetime. **Figure (11).**

Accordingly, the project owner (person or organization) should establish a set of organized steps to develop a zero-carbon building; these steps are:

1- Setting the vision: People must set a clear goal to reach, i.e., reducing carbon emissions; reducing energy consumption.

2- Forming the working team and assigning responsibilities: Once the vision is set, a worklist has to be compiled, maybe in a schedule that defines tasks each member of the team has to perform. Commissioned participants have to learn continuously about zero-carbon building strategies and prior successful and unsuccessful experiences in the field. A working team includes an architect, a technical engineer, a project manager, a representative of the owner, facility-building engineer (HVAC, fire, lighting…etc.), and a cost consultant.

3- Applying green options: through following zero-carbon building strategies. With respect to this step, the financial aspect is a significant barrier.

4- Green Operation: users of a building can reduce energy, save money, and preserve the environment by buying "green" equipment and rationalize the use of energy.

5- Communication: effective communication among team members is a good indicator of consistent success.
6- Continuous Improvement: it can be facilitated by continuous maintenance and monitoring.

By getting benefit from previous experiences, whether the British experience or the studies that were conducted to establish the city of Napata, the legislation on low-carbon buildings will not be complied unless the government obliges engineers, contractors and company owners to implement these type of buildings, through extensive and expanded campaigns that include governmental and private audio-visual media, as happened, for example, in the government's initiatives calling for converting cars to run on natural gas in order to conserve energy and protect the environment, or as campaigns that have been successfully conducted in the field of health, facing the Corona virus or treating chronic diseases... and other initiatives, i.e. Clearly and directly, when the change is obligatory (connected with building permits and approvals) not optional, the application will begin.

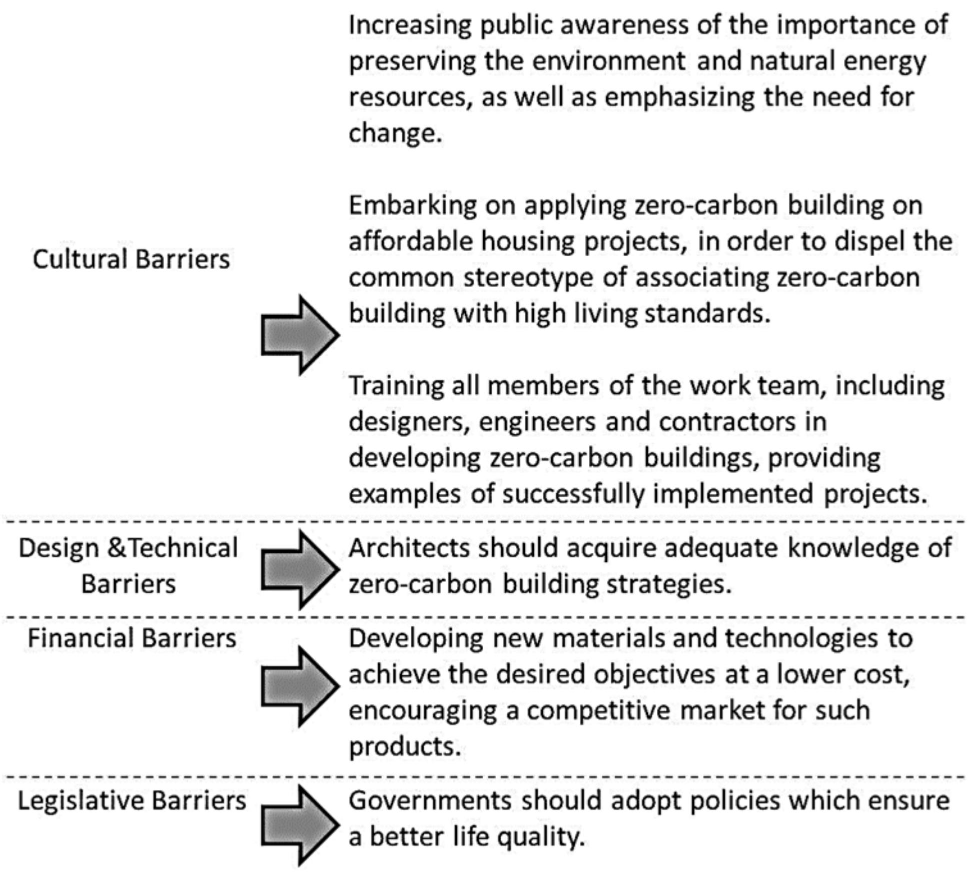

Figure (11). Zero-Carbon Buildings Barriers & Proposed Actions. (the Researcher)

10. Recommendations

- Many existing buildings generate carbon emissions. Therefore, reducing the emissions caused by the building industry should not be limited to future buildings but should include buildings that are now in use, too.
- New building codes and certification systems—regarding buildings'CO2 emissions, energy efficiency, and other environmental policies in Egypt—must be stricter. Policies should obligate

designers, contractors, and owners to take steps toward improving the quality of people's life by saving energy.

- There is a gap between what the architects need and how they meet them. This is due to a lack of work-team coordination and consistency. Some factors of achieving zero-carbon building require reliance on the participation of specialists who can take charge of technical systems and devices, like using renewable sources of energy, high-efficient air conditioning systems, …etc. So teamwork is a must.

11. Conclusion

The more zero-carbon building can enhance our lives through the renovation of existing buildings and erecting new ones by applying modern design concepts, like passive building standards, sustainable principles, and through encouraging building users to make the energy-efficient factor a priority, while purchasing. It can be concluded from the examples of existing zero-carbon building that reliance on Fabric Energy Efficiency, especially heat insulation for the building's outer shell, is the main factor that addresses energy efficiency requirements, as well as architectural design elements provided by the passive solar design.

One of the important things which architects gain more excellent knowledge about is incorporating various energy reduction techniques in existing buildings since reconstruction based on sustainable goals is expensive, time-consuming, labor-intensive, and energy-consuming.

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