MSA UNIVERSITY ENGINEERING JOURNAL

MSA UNIVERSITY جامعة أكتوبر للعلوم الحديثة والآداب

UNIVERSITY of GREENWICH

Redesigning Buildings With Sustainable Architecture Principles In Smart Village Egypt

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Abstract

Since ancient prehistoric generations, renewable resources have been utilized in buildings to work with building needs like light, ventilation, and thermal comfort. The need for shade in summer and sunshine in winter is required for the architecture of the past. Bioclimatic architecture is the concept of designing or redesigning buildings depending on the country's climate, for the purpose of improving thermal comfort using local environmental resources and benefits of the local climate.

Converting academic buildings into sustainable buildings has been vital in the research and policy focus for years, with the focus on the united nations sustainable development goals (SDGs) of Education for Sustainable Development. Building design and practices play an important role in converting universities into places of sustainable learning, behavior, and space. Previous research has mentioned the concept of sustainable buildings tremendously. The parts of the paper use a case study approach that focuses on Redesign Existing university in Smart village Giza, Arab Academy for Science Technology & Maritime Transport (AASTMT) which is located in smart village Cairo-Alexandria desert road, one of the most famous information technology

ENGINEERING JOURNAL Volume # Issue #
Received Date Month Year
Accepted Date Month Year
Published Date Month Year
Online at https://engj.org/
DOI:10.4186/ej.20xx.xx.x.xx

DOI:10.4186/ej.2009.VOL.ISSUE.pp

industry places located in the western urban area of Greater Cairo. This paper consists of three sections: A, B, and C. The first section mentions the climatic data analysis of the academic building, the Second section evaluates the academic building, and finally, the third section gives ideas to redesign it with the help of sustainable Architecture techniques, in addition, gives an opportunity to adapt to climate constraints combined with ideas of passive design and green building concepts.

Keywords: Bioclimatic architecture, redesign existing building, sustainable architecture, passive design, green building concepts

1. Introduction

Redesigning buildings into environmental buildings is a very complex process. Since ancient civilizations, energy has been employed in buildings to work with light, ventilation, and thermal comfort. The energy consumption of a building is at a higher rate and it will keep increasing till the energy produced in the buildings themselves can make up for their growing energy needs. The educational building sectors can reduce their energy consumption by incorporating energy-efficient strategies through redesign using the passive technology implemented in existing buildings. The passive building concept will increase energy efficiency levels in existing educational buildings by designing the buildings to meet all of their environmental requirements using low-cost, locally available, low-emission, renewable energy sources. The energy consumption of a building is at a higher rate and it will go on increasing till the energy produced in the buildings themselves can make up for their growing energy needs.

There are two ways for measuring environmental or bioclimatic design; Passive design and Active design. Passive design principles have several techniques aimed at minimizing the energy demand of the building. Active design techniques use energy (such as oil, natural gas, and electricity) to maintain buildings comfortably. These techniques included components of the mechanical system such as heat recovery ventilators, air-conditioning, radiant heating, heat pumps, and electric lighting. Furthermore, Active strategies include systems that produce energy such as wind turbines, geothermal energy exchangers, solar thermal panels, and solar electric.

The difference between passive cooling systems and mechanical systems is that passive cooling systems depend on natural heat sinks in order to extract heat from a building. By definition, they derive cooling from radiation, convection, and evaporation directly without using intermediate electrical drivers or devices. Some low-energy or passive-hybrid cooling systems use motors or pumps. However, the ratio of cooling to electric power consumption is much higher than that for more mechanically dependent cooling systems. Passive cooling suggests that, when possible, unnecessary heat should be minimized before it enters the facility. In addition, the building envelope [1], itself, should be used to speed the transfer of excess heat into the outdoor environment.

Redesigning buildings into environmental buildings is a very complex process. The educational building sectors can reduce their energy consumption by incorporating energy-efficient strategies by redesigning using the passive technique implemented in existing buildings. The passive building concept will increase energy efficiency in existing educational buildings by designing the buildings to meet all of their environmental requirements using low-cost, locally available, low-pollution, and renewable energy sources and local materials.

2. Sustainable Building Goals

The 17th Sustainable Development Goals (SDGs) are the world's optimum best plan to enhance our world for people's lives and Transform our planet by 2030 with 169 targets that all 191 UN Member States have agreed to try achievement goals by the year 2030. These

17th SDGs create a challenge for humanity to decouple economic growth from climate change, poverty, and inequality.

There are 9 SDGs belong to provide the foundation for meeting sustainable building goals. These are: "good health and well-being" goal, "affordable and clean energy" goal, "decent work and economic growth" goal, "industry innovation and infrastructure" goal, ""responsible consumption and production" goal, sustainable cities and communities" goal, "life on land "goal, "climate action" goal, and "partnerships for the goals" goal. In table 1, the goals associated with sustainable building concepts have been collected according to their benefits. Each goal and its benefits on design and redesigning have been shown in the table.

Table 1. UN Sustainable Development(SDG) Goals Related to Sustainable Building Design

UN SDG No.	**SDG name**	**SDG benefits on sustainable building concepts**
3	good health and well-being	Sustainable buildings could enhance people’s health and well-being.
7	affordable and clean energy	The sustainable building could use renewable energy, making it cheaper to run
8	decent work and economic growth	The sustainable building could develop careers and raise the economy.
9	industry innovation and infrastructure	Sustainable building could support innovation and contribute to climate infrastructure
11	sustainable cities and communities	Sustainable buildings are the fabric of sustainable cities
12	responsible consumption and production	Sustainable building use recycle system, where resources are not wasted
13	climate action	Sustainable buildings produce fewer emissions, helping to minimize climate change
15	life on land	Sustainable buildings could save water resources and protect greenery.
17	partnerships for the goals	Sustainable building creates strong and global partnerships.

3. Data Collection

Several techniques and strategies can be employed in sustainable building design. The passive design technique is about taking advantage of natural energy flows to maintain thermal comfort. It depends on using the appropriate building orientation, building materials, and landscaping [2]. Passive building design aims for three main goals heat protection, heat collection from the Sun, and heat rejection according to the seasons of the year, the direction of the building elevation, and the type of building climatic zone properties. Building heat protection depends on building insulation methods and building solar control methods like shading [3]. Building heat collection from the sun depends on heat direct solar collection or indirect solar collection to the building. Building heat rejection depends on natural ventilation and building cooling.

3.1. Building Form And Orientation

Building form and orientation are the first choices in the design process. They are the most critical issues because of their impact on thermal, visual comfort, and energy consumption. Figure 1 explains the optimal orientation of passive building design. Form and orientation are two of the most important passive design strategies to reduce energy consumption and improve thermal comfort for the building's occupants. Further, Buildings should be oriented with their longer axis (north-south) aligned perpendicular to the prevailing winds to facilitate maximum airflow and cross ventilation through the building. Buildings can be directed to an angle between 0° to 30° toward the prevailing wind direction [4].

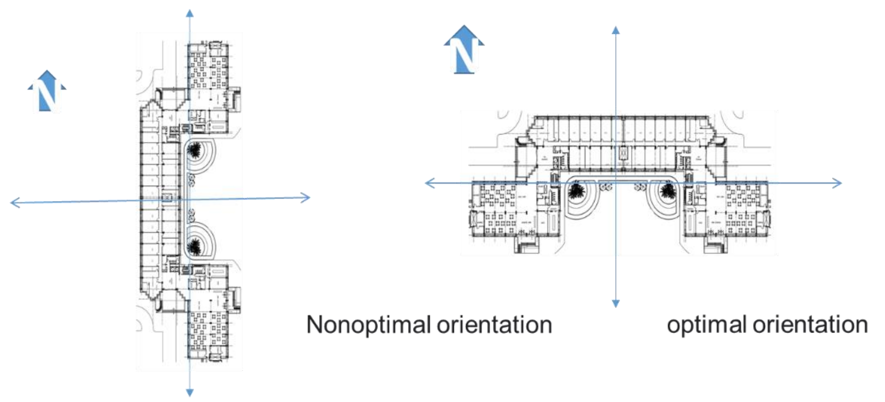

Figure 1: Form and orientation of passive building design.

3.2. Building Heat Protection By Shading

Orientation is a major factor in determining the shading type. Horizontal screening louvers exclude direct sunlight on the south side with little visual interference. Permanent building elements such as cantilevers function as seasonal solar screening [5] [6]. On east and west façades, movable vertical louvers are preferable because the sun strikes at low altitudes [7].

3.3. Vegetation

Vegetation is a flexible regulator of solar and wind penetration in buildings. It reduces direct sun from striking and heating building surfaces and lowers the outside air temperature which in turn affects the heat transfers from outside to the building envelope and interior [7]. It can also be used as an internal shading element. Using such plants increases the shading factor, a measure of the effectiveness of shading devices [8], without affecting the outside view. Plants also grow toward sunlight and growth varies with the seasons, so when used taking into account seasonal variations in the building's location, they can be inexpensive, flexible shading elements.

3.4. Building Heat Rejection By Natural Ventilation

Ventilation is the most common heat rejection strategy, using external air as a heat reservoir to lower indoor temperatures. Horizontal placement of openings and internal partitions can alter the direction and spread of the air stream. Ideally [9], openings must be placed on opposite walls, and diagonally but not directly opposite to each other. When placed in walls perpendicular to each other, the inlets and outlets should be at the farthest corners of the walls as shown in Figure 2.

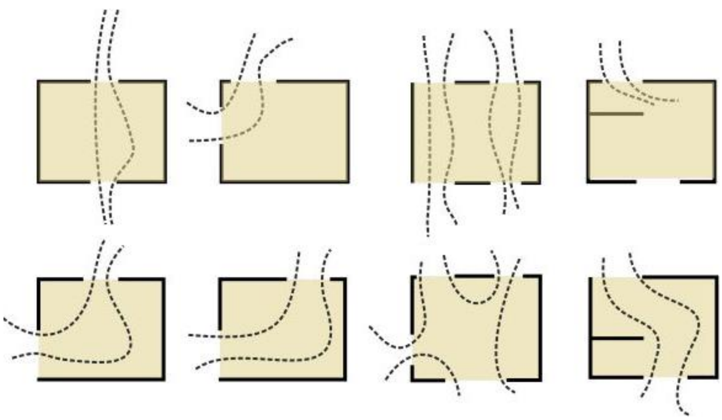

Figure 2: layout explains the right airflow of natural indoor ventilation [10]

3.5. Building heat protection by Fenestration

Fenestrations, such as skylights, windows, and any other openings in a building, etc, allow daylight and the prevailing wind inside the building when needed [11]. There are some methods used for reducing heat gain through windows. These methods are; Orientation and size, Glazing, Internal shading devices (blinds, curtains), and External shading devices.

3.6. Building heat rejection by evaporative cooling

Over the years, people have approved the idea of a water source for instance a pond, lake, or fountain to provide a cooling effect to the area surrounding [12]. Passive cooling means using design choices to minimize heat gain and maximize heat loss. Evaporative cooling minimizes the air temperature indoors thus minimizing the cost of energy needed for air conditioning in buildings. Reducing energy load meets the passive design goals, however, evaporative cooling is the most effective parameter in a dry and hot climate where the humidity is low.

3.7. Building heat collection by passive heating

Passive solar design is the process of using specific building systems to help regulate internal temperature by using the Sun's energy [13]selectively and beneficially in an attempt to improve energy efficiency. In simple terms, passive heating collects heat as the sun shines through south-facing windows and retains it in materials that store heat [14]. Thermal mass is the process of storing, material absorbing, and releasing heat.

3.8. Thermal comfort

Thermal comfort is considered to be an assessment of the thermal condition of the area surroundings. ISO 7730 states define thermal comfort as "That condition of mind that expresses satisfaction with the thermal environment" [15]. People may feel that their surroundings are cold, warm, or simply comfortable depending on the thermal state of the area surroundings, and, equally importantly, physiological and psychological factors. Lack of comfort due to the last factors cannot be alleviated by cooling or heating a building, but thermal conditions can be changed for the better as shown in Figure 3.

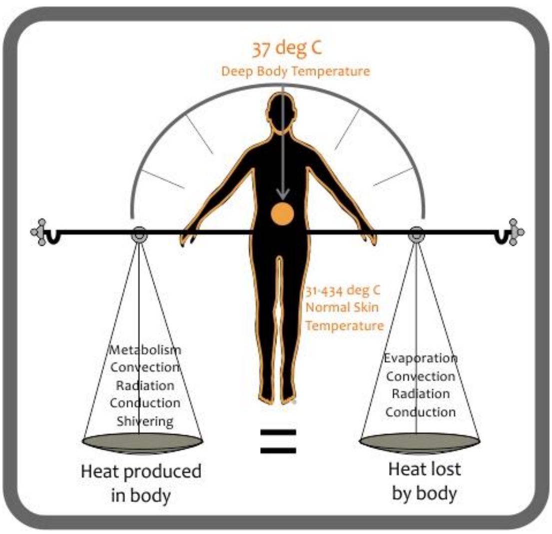

Figure 3: human thermal comfort [16].

3.9. Heat protection by Building insulated materials

To reduce the energy demand, the building envelope should prevent, or at least minimize, heat flow due to temperature differences. material with a high thermal resistance that opposes heat transfer between areas with temperature differences is considered an insulator.

4. Problem Statement

In the present study, the climatic data analysis of the case study area was chosen to be:

- Air temperature
- Solar radiation
- Wind speed and direction
- Bioclimatic chart

4.1. Climatic Zone Analysis

Egypt rightfully advertises itself to the world as the 'Land of the Sun'. On average, the temperature varies between 27 and 32 °C in the summer and up to 42 °C on the Red Sea coast. Winters are moderate, as temperatures vary between eight degrees and 21 °C. During the winter, the northern coast receives substantial rainfall, as much as 410 millimeters. South of Cairo annual rainfall does not exceed five millimeters.

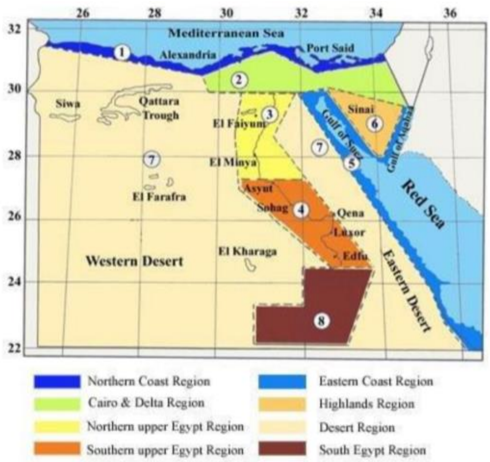

Figure 4: Major physical features of Egypt, as well as information about the climate zones. [16]

During spring, usually in April, a strong wind blows dust and sand from the south accompanied by fluctuations in temperature for some fifty days, hence the name of the wind, khamsin, the Arabic word for ‘fifty’.

AASTMT is used as an educational building operated by the Arab Academy for Science, Technology and Maritime Transport, Smart Village campus, Giza. The number of students per day: 2000 to 2500 daily. The total area is 4737 m^2. Solar radiation in Egypt varies between 5.4 to 7.1 KWh/m^2 from north to south elevations.

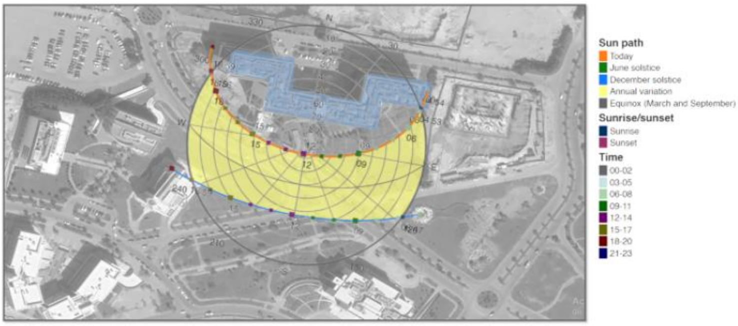

Figure 5: AASTMT has a delta and Cairo region zone.

Other climatic data according to the housing and building research centers’ information are:

•Average daylight in October: 11.4h The month with the longest days is June (Average daylight: 14.1h). The month with the shortest days is December (Average daylight: 10.2h).
•Average sunshine in October: 9.4h The month with the most sunshine is June (Average sunshine: 11.9h). The month with the least sunshine is December (Average sunshine: 6.4h).
•Average humidity in October: 60% Months with the highest relative humidity are August, November, and December (61%). The month with the lowest relative humidity is May (46%).
•Average high temperature in October: 29.2°C The warmest month (with the highest average high temperature) is July (34.7°C). The month with the lowest average high temperature is January (18.9°C).
•Average low temperature in October: 17.4°C The month with the highest average low temperature is August (22.1°C). The coldest month (with the lowest average low temperature) is January (9°C).

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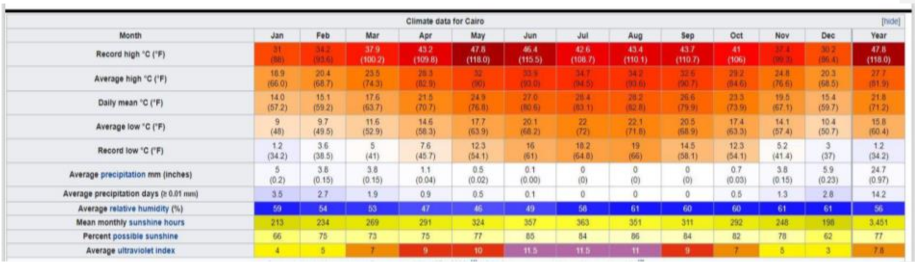

Climate data for Cairo													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	31 (88)	34.2 (93.6)	37.9 (100.2)	43.2 (109.8)	47.8 (118.0)	46.4 (115.5)	42.6 (108.7)	43.4 (110.1)	43.7 (110.7)	41 (106)	37.4 (99.3)	30.2 (86.4)	47.8 (118.0)
Average high °C (°F)	18.9 (66.0)	20.4 (68.7)	23.5 (74.3)	28.3 (82.9)	32 (90)	33.9 (93.0)	34.7 (94.5)	34.2 (93.6)	32.6 (90.7)	29.2 (84.6)	24.8 (76.6)	20.3 (68.5)	27.7 (81.9)
Daily mean °C (°F)	14.0 (57.2)	15.1 (59.2)	17.6 (63.7)	21.5 (70.7)	24.9 (76.8)	27.0 (80.6)	28.4 (83.1)	28.2 (82.8)	26.6 (79.9)	23.3 (73.9)	19.5 (67.1)	15.4 (59.7)	21.8 (71.2)
Average low °C (°F)	9 (48)	9.7 (49.5)	11.6 (52.9)	14.6 (58.3)	17.7 (63.9)	20.1 (68.2)	22 (72)	22.1 (71.8)	20.5 (68.9)	17.4 (63.3)	14.1 (57.4)	10.4 (50.7)	15.8 (60.4)
Record low °C (°F)	1.2 (34.2)	3.6 (38.5)	5 (41)	7.6 (45.7)	12.3 (54.1)	16 (61)	18.2 (64.8)	19 (66)	14.5 (58.1)	12.3 (54.1)	5.2 (41.4)	3 (37)	1.2 (34.2)
Average precipitation mm (inches)	5 (0.2)	3.8 (0.15)	3.8 (0.15)	1.1 (0.04)	0.5 (0.02)	0.1 (0.00)	0 (0)	0 (0)	0 (0)	0.7 (0.03)	3.8 (0.15)	5.9 (0.23)	24.7 (0.97)
Average precipitation days (≥ 0.01 mm)	3.5	2.7	1.9	0.9	0.5	0.1	0	0	0	0.5	1.3	2.8	14.2
Average relative humidity (%)	59	54	53	47	46	49	58	61	60	60	61	61	56
Mean monthly sunshine hours	213	234	269	291	324	357	363	351	311	292	248	198	3,451
Percent possible sunshine	66	75	73	75	77	85	84	86	84	82	78	62	77
Average ultraviolet index	4	5	7	9	10	11.5	11.5	11	9	7	5	3	7.8

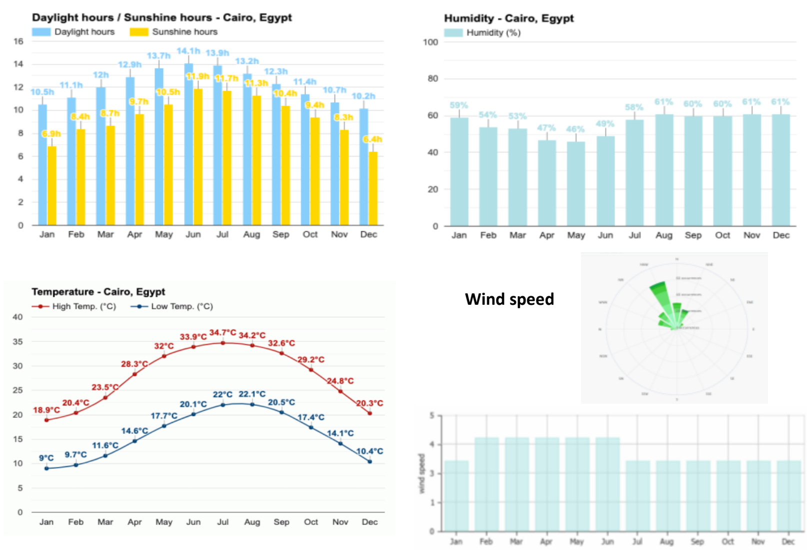

Figure 6: climate data for Cairo [16]

4.2. Assessment of Case Study Building Related to Climatic Building Design Items

In this study the climatic design strategies could be assessed according to the following parameters:

- SITE ANALYSIS

Egypt is mostly desert, so it has hot, dry summers. They get rain in the winter. The north gets more rainfall than the south

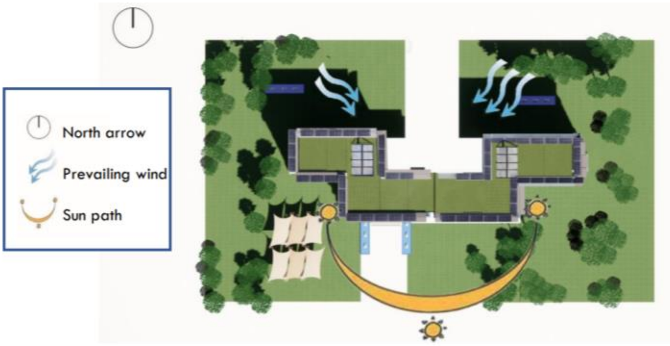

Figure 7: AASTMT ‘s site analysis.

- FORM AND ORIENTATION

The Building court is oriented towards the north with the building perpendicular to the prevailing winds. The building consists of two basements with a total area of 8000 m^2, and six typical floors of an area of 2000 m^2 each and 27 m in height. The total area is 20,000 m^2.

Figure 8. AASTMT ‘s form and Orientation.

- LANDSCAPE

The type of trees used was not deciduous and are not suitable for providing enough shade or protection against direct solar heat.

Figure 9: AASTMT ‘s landscape.

- MATERIALS

The building has a reinforced concrete structure (Skelton system), elevations are mainly tinted double glass, and the ground floor is shaded in all elevations.

• External Walls: Brick walls of 20 cm thickness, 2 cm interior and exterior plaster with a total U-value(the rate of transfer of heat) of 2.04 W/m2K are used without any insulation.
• Roof: Reinforced concrete roof of 20 cm thickness is used, and the interior paint and insulation material has a U-value of 0.57 W/m^2K. Mechanical System Auditing
• HVAC system: The building is fully air-conditioned, the HVAC system is the “Package Direct Expansion Unit,” and an air handling unit is on the top of the building.
• Electrical system: Is traditional linear fluorescent 500 Lux.

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- VENTILATION AND COOLING SYSTEM

• The building has central heating, cooling, and ventilation systems to acclimatize indoor air quality.
• The cooling system is used mainly during the summer using an air-cooled liquid chiller (package direct expansion unit) with heat recovery systems that run on electricity.
• The comfort temperature ranges from 20 °C for circulation spaces to 22 °C in offices. The two basement floors are mechanically ventilated.

- BUILDING ENVELOPE

Building envelopes can play a significant role in controlling energy consumption, especially in hot regions because of the wide variety of envelope materials

• Using curtain walls for maintaining adequate lighting in public buildings could lead to higher energy consumption because of the continuous exposure to the sun in hot regions.

4.3. Building sustainable technique assessment

Elements of the environmental assessment are According to UN sustainable development goals. In Table 2, the large number of environmental assessment elements that discussing the valuation level for each element and the reasons causing that.

Table 2. Illustrate valuation levels for each environmental element

Elements of environmental assessment	Valuation Levels				Notes
	Very Good (A)	Good (B)	Average (C)	Poor (D)	
Integrative thinking			x		No involvement of users in design decisions
Energy				x	The building did not provide solutions for energy saving. As all the building is screen walls so more heat enters the building so, more ac is used to make the temperature better for the users.
Water				x	Non-efficient use of water in the building
Waste				x	The hierarchy of waste management and utilization of recycling was not cared about
Materials			x		Traditional Materials
Location & transportation		x			Good selection of the site where it is put between companies and buildings aiming for a more technological future as well as having easy access by various transportation means.

Sustainable site		x	Not considerate of sustainability in origin
Health & human experience		x	Not considering the humanitarian needs in the design
Regional impacts	x		Buildings influenced by surroundings
Innovation		x	No innovations for sustainable solutions
Global, Regional, and Local		x	Not Affected

5. Case Study Redesign Methods

Well-designed passive buildings Strategy maintains the best environment for human habitation while minimizing the cost of energy. The objectives of this study are to improve the comfort levels of the occupants and reduce energy use (electricity, natural gas, etc) for heating, cooling, and lighting in educational buildings in Egypt. According to Hyde [17], passive building design is important in a hot climate because of the limitations of conventional energy a source in terms of both cost and availability. The following design strategies are considered for application in a hot dry climate that can bring about energy efficiency and improvement of thermal comfort in redesigning educational buildings in Egypt:

1. Heat Protection >Insulation >Solar control >Fixed shading devices>Horizontal louvers.
2. Heat collection from the sun > Triple-glazed windows
3. Heat Rejection >Natural Ventilation>Evaporative cooling.

It is known that heat enters and leaves a home through the roof, walls, windows, and floor. Heat distribution within a home is affected by internal walls, doors, and room arrangements. These elements are collectively referred to as the building envelope. The envelope design is the integrated design of building form and materials as a total system to achieve optimum comfort and energy savings. Good envelope design responds to climate and site conditions to optimize thermal performance. It improves comfort and lifestyle and minimizes environmental impact. Table 3 illustrates the strategy used in redesigning methods and the corresponding location.

Table 3. Passive design strategies according to building envelope Where; S is summer and W is winter.

Passive design strategies							
		Heat protection		**Heat collection**		**Heat rejection**	
		S	W	S	W	S	W
Building envelop	North Façade	x			x	x	
	South Façade					x	
	East Façade				x		
	West Façade					x	
	roof	x			x		

Table 4 summarizes the methods used for redesigning the passive design in the assigned educational building.

Table 4 Building design techniques used in the case study Where; S is summer and W is winter.

building Passive design techniques							
		Heat protection		**Heat collection**		**Heat rejection**	
		S	**W**	**S**	**W**	**S**	**W**
Building envelop	North Façade	movable Windows and Shading devices			Solar panel	green walls	
	South Façade					triple fix glazed windows	
	East Façade				Solar panel		
	West Façade					Shading devices	
	roof	Roof gardens		Wind turbine and solar panels			
site		Evaporative cooling				Evergreen trees	
materials		Wooden devices				Smart materials	

In order to reduce the energy demand, the building envelope should prevent, or minimize, heat flow due to temperature differences. Strategy Increasing the thermal resistance of the building envelope with the use of insulating materials for the envelope and insulated windows for the openings is the main strategy for heat rejection. The recommended insulation method is using Triple glazed windows as shown in Figure 10.

Figure 10: sample of Triple glazed window with the addition of low-E Coating.

Regarding the fenestration, the old façade has no openings. The absence of fenestrations in all the facades causes a permanent use of Heating, ventilation, and air conditioning (HVAC) systems that lead to high energy consumption. For redesigning the building, a new façade of the windows was added to the facades as shown in Figure 11. Adding windows will provide simple, direct natural ventilation into the building and improve

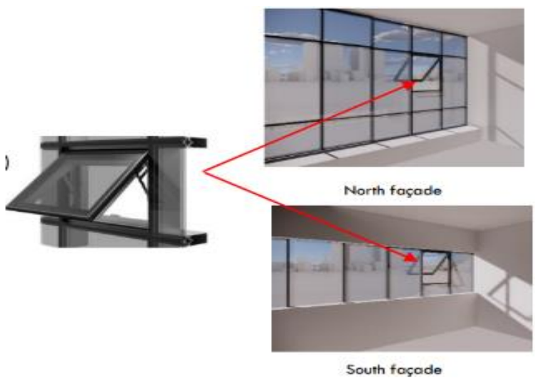
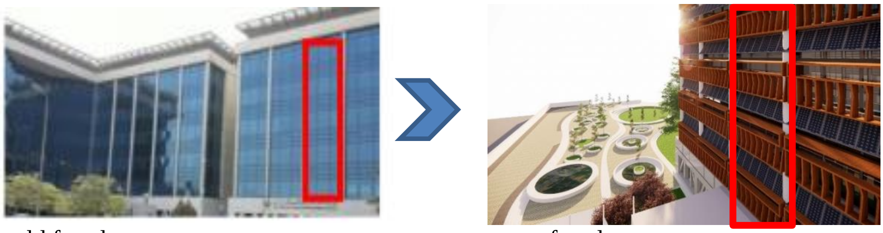


Figure 11: diagram describes the difference in methods between the north façade and south façade.

indoor air quality by reducing condensation. Increasing the sill height in the south façade to minimize the heat entering the building while leaving space for the openings to enter air and light.

Concerning shading devices, using tensile shades in the south area to avoid glare from the sunlight. Using Horizontal shading at the south and north facades to protect from the sun at high angles. Avoiding penetration of solar radiation into the building in summer, while allowing the needed solar gains in winter, which leads to better thermal comfort. Furthermore, wooden shading devices in the north façade reduce the building temperature as presented in Figure 12.



old façade new façade

Figure 12: Shading devices provided to building façade

Figure 13: green roof design

Using Green roofs can significantly reduce the amount of rainwater that would otherwise run off an impervious roof surface. It helps reduce building energy usage and noise levels while increasing the durability and lifespan of the roof compared to conventional roofs as shown in Figure 13. A green roof provides a rainwater buffer, purifies the air, reduces the ambient temperature, regulates the indoor temperature, saves energy, and encourages biodiversity.

The employment of green walls and facades can reduce heat gain in summer by directly shading the building surface as presented in Figure 14.

Figure 14: green façade design.

A water feature, as an Evaporative cooling technique, enhances the appearance of a landscape, purifies the air, reduces noise pollution, and reduces the heat island effect. In fact, rather than draining natural resources, water features can enhance a project's sustainability by harvesting rainwater and cleaning stormwater runoff. Evaporative cooling utilizes sunlight to evaporate water and thus remove heat and lower the air temperature of the air to be used for cooling. Figure 16 shows the evaporating cooling techniques to be used in the assigned case study.

Figure 15: Evaporative cooling.

In addition, the availability for generating electricity from wind energy helps in reducing electricity usage. Figure 16 illustrates a tool that could be used for this purpose.

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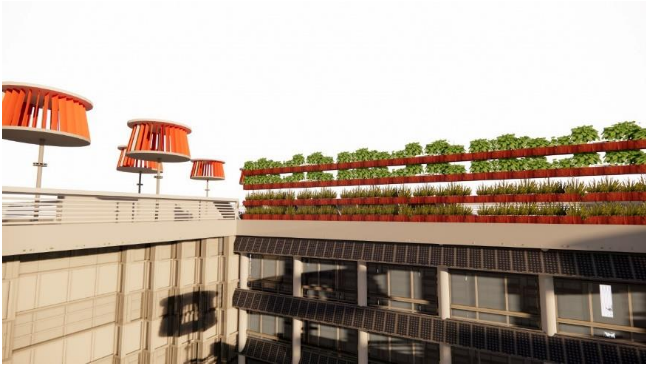

Figure 16: roof wind turbine.

An alternative method for Generating electricity is by using roof solar panels. PV cells are utilized in solar panels. When the sun shines onto a solar panel, energy from the sunlight is absorbed by the PV cells in the panel. This energy creates electrical charges that move in response to an internal electric field in the cell, causing electricity to flow. Windows can be opened in the north façade to enhance ventilation and reduce the usage of Heating, ventilation, and air conditioning (HVAC) and electricity. Figure 19 and Figure 20 present most of the sustainable solutions and green architecture methods used for redesigning.

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Figure 18: roof solar panels.

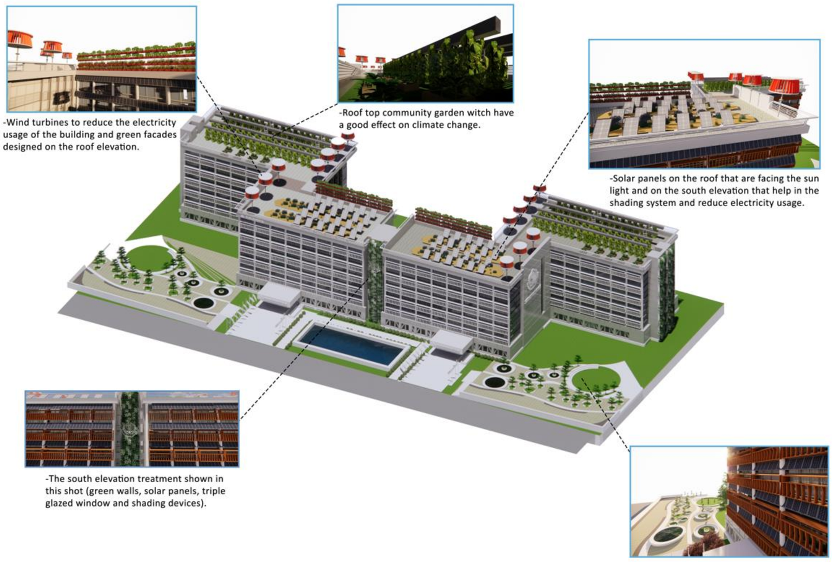

Figure 19: The layout shows most of the sustainable solutions that are fixed and green architecture methods.

Figure 20: south new façade.

6. Conclusion

Sustainable buildings can not only minimize negative impacts on the environment, by using less water, energy, or natural resources, but they can have a positive impact on the environment by generating their energy and exporting it also. In addition, we should embed the idea of sustainability in the design, considering the environmental aspect in all phases of the project according to UN sustainable development goals to minimize or prevent the carbon emissions that come from heating and cooling spaces and powering multiple appliances and devices.

Ecologically sustainable redesign encloses the process of enriching the proficiency in which building and their location consume water, energy, and resources all while minimizing the effect on the human Benefit and ecological system throughout the complete lifespan of the structure. Sustainable building theories expand past the walls of edifices and may encompass site design, neighborhood as well as land designing conflicts. Moreover, there are various areas in which sustainable buildings are considered to be advantageous such as enhancing internal air condition, Minimizing rates of operation, and decreasing waste flows. In addition, students spend up to 90 % of their day indoors, so they benefit from buildings with natural daylight, fresh air, and access to views. Researchers found that the quality of the teaching environment was a greater factor in teaching than salaries.

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