Towards Low Energy Buildings through a Prototype of Desert Rural House in Alwadii Algadid in Egypt

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Abstract:

Desert Vernacular architecture is one of the maximum important factors for the retrofit of the desert rural house. Vernacular architecture primarily based totally on increase thermal comfort and reducing energy consumption to improve indoor air quality inside the spaces. Alwadi Algadid (New Valley) Governorate establishes 46% of Egypt area. So, we should obtain profit of this greater zone to decrease the pressure over the Nile valley. In addition, this research aims to categorize the influence of desert vernacular architecture of desert rural house. Design/methodology/approach – The architecture of Alwadi Algadid contains the particular architectural form of a warm zone, which previously had an operational tradition aimed to a sustainable architecture and improvement through cultural, economic, geographical, and climatic criteria, to use the local materials, treatments within the basic principles of sustainability, at the lowest possible cost to minimize utilities running cost of these communities. The prototype house was designed by Design-Builder simulation software depend on an awareness of desert vernacular architecture. Findings – In conclusion, the simulation findings of the prototype building models were evaluated with the base case building with more than 50% reduction in energy consumption. The results gained in this research could supply valuable ideas for the desert rural house design of residential buildings. Practical implications – Applied of using local materials, local technique and local treatment to confirm district suitability of the desert vernacular house outcome. Originality/value – The value of this research is to design guidelines for future vernacular settlement of desert rural house and establishments with respect to old ones.

Keywords:

Vernacular architecture, Prototype building models, Energy consumption.

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Introduction:

In the distant local areas in Egypt, the distinctive vernacular architectural atmosphere is disappearing by the shade usage of the developed building materials. Residents in desert vernacular homes, for example, are permitting their houses to suffer and moving away from their ancient village. The research was examined that desert vernacular arrangement in Alwadii Algadid Desert of Egypt were defiance histrionic problems (Ahmed, 2015).

Nowadays, the standing and continuing desert vernacular architecture in distant societies and communities in Egypt is about to disappear. Conventional desert vernacular settlements are being disused, are weakening and destroyed purposely. However, the architectural improvements in The Village are enchanting many forms. Gaps within the extraordinary dwelling environments that occur in The Village are obvious. Later
the conventional constructing strategies are dealing with technical and affordable demanding situations which have an effect on its sustainability (Riham, 2012).

Figure.1 Graphic for the showed problem statement.

Energy Performance of Buildings in Egypt:

The individual certified basis of energy consumption information in Egypt is the department of electricity and renewable energy. This organization presents an annual report that arranges data of the electricity created and dispersed throughout the assumed year. In its newest announced information for the year 2013/2014, it specified that 51.3% of the general electricity consumed operates to the residential buildings as shown in figure 2.

Purpose of Usage	Quantity (GWh)
Industry	17303
Agriculture	5528
Government & Public Utilities	13622
Residential	61962
Commercial Shops	5003
Public lighting	5692
Others	11716
Total	**120826**

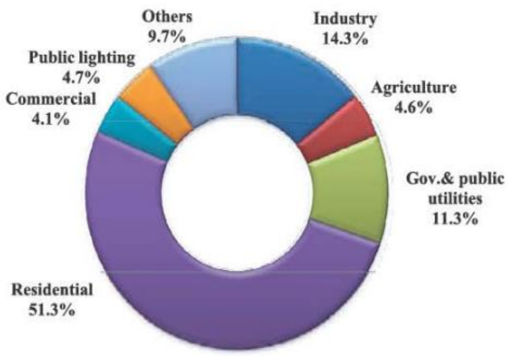


Figure.2 Total percentages of energy dumped according to resolve of usage (Eehc, 2015).

The study exposed that 74% of the electricity used is expended towards reaching thermal comfort, where 65% moves to cooling load objectives while 9% moves to heating load (Attia, 2013). Figure 3 displays the individual analysis of the energy usage according to Attia's study.

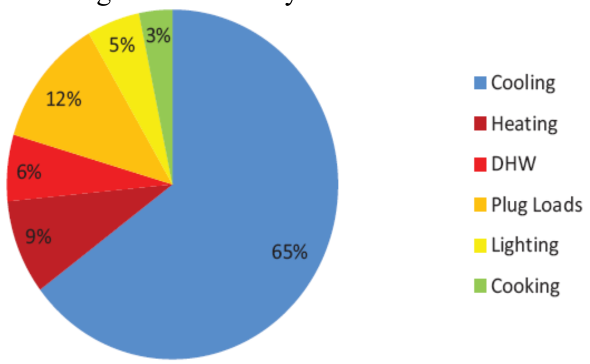


Figure.3 Energy consumption per domestic in an urban society in Cairo (Attia& Herde, 2007)

Principles of Green Architecture:

The next ideas review key rules approaches and technique which are connected with the five main components of green building strategy (Asad, 2009):

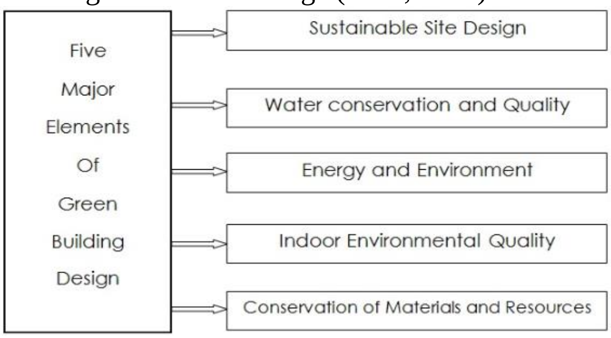


Figure.4 Element of Green Building Design.

- Planning an energy- efficient structure. Consume extreme quantities of insulation, high-performance windows, and tense structure (Poormokhtar, 2011).
- Scheme buildings to practise renewable energy. Day lighting, Passive solar cooling and heating, and natural Ventilation can be combined cost- successfully into maximum buildings. Additionally, study photovoltaic panel technique.
- Enhance material usage. Reduce waste by planning for typical ceiling heights and building dimensions (Hui, 2012).

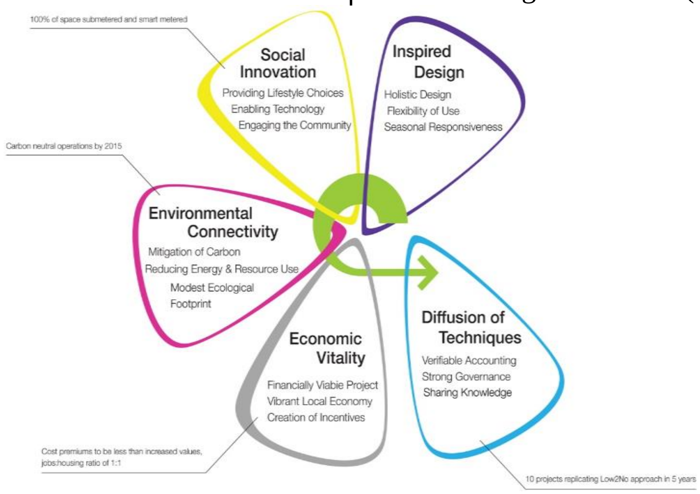


Figure.5 Sustainability Framework organizes the principles of green architecture into five main areas.

Rating Systems and Design Guides:

The establishment of green buildings has developed the creation of rating systems (Mao et al.2009). There is a stability between most of the rating systems in their construction and government. Wallhagen et al. (2011) stated that valuation tools set certain feature for the environmental performance of buildings through creating a regular of topics.

- Sustainable site planning
- Wáter efficiency
- Storm Waters
- Sewage outfall
- Environmentally friendly homeowner

- Energy efficiency
- Pollution
- Material Conservation
- Resources Conservation
- Transportation

- Improving indoor air quality
- Occupant satisfaction
- Innovación
- Waste and toxic materials
- Toxic material

Figure.6 Main rating system categories (Qin, 2016).

Green Pyramid Rating System:

The Green Pyramid Rating System (GPRS) is an Egyptian environmental rating system for buildings (HBRC, 2011). It evaluates environmental credentials of buildings and rates the buildings themselves (Green Building Code, 2013). It contains six groups with an extra point to Innovation (E.G.B.C, 2009):

1- Sustainable Site.
2- Energy Efficiency.
3- Water Efficiency.
4- Materials and Resources.
5- Indoor Environmental Quality.
6- Management the weights of categories are shown in figure 7.

Green Pyramid Categories	Category weighting	Percentage
Sustainable Site, Accessibility, Ecology	10 points	15%
Energy Efficiency	50 points	25%
Water Efficiency	50 points	30%
Material & Resources	20 points	10%
Indoor Environmental Quality	20 points	10%
Management	20 points	10%
Innovation and Added Value	10 points	Bonus
Sum	**110 points**	**100%**

Figure.7 Green Pyramid Categories and Their Weighting (Hanna, 2013)

Definition of Vernacular architecture:

The word “vernacular” has specific meanings, and implications relying at the context of its use (Alpagonolo, 2005). This phrase has been utilized by architects, annalist, archaeologists and others. The term develops from the Latin vernaculars, which intends native". Assumed that architecture is described vernacular structure as the science of building we can just say that the explanation of vernacular architecture is the "native science of building".

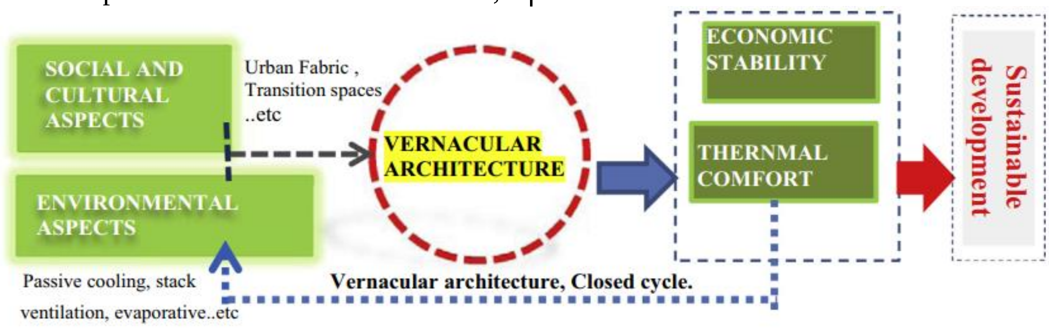


Figure .8 Vernacular architecture, closed diagram = traditional sustainable design.

Green Vernacular Architecture in the Oases of Egypt:

Traditional vernacular Egyptian architecture has exchanged a lot during various periods mainly at the oases, but architectural design appreciates nature in all times (Turan, 1990). Green architecture illustrations an evaluation of environment-friendly architecture under all conditions and includes some general agreement. Green building performs increases and supplements the traditional building design concerns of economy, value, strength, and comfort.

The Passive Strategies of “Vernacular Architecture”

Vernacular structure is a human assemble those

consequences from the interrelations among ecological, economic, material, political, and social factors. Passive design is ready taking benefit of herbal electricity flows to keep thermal comfort.
Selecting passive techniques in vernacular structure throughout one-of-a kind intervals thru many years mainly primarily based totally at the weather traits with inside the warm arid zones relying on:
- Selecting a suitable orientation.
- Arranging natural ventilation and self-shade in hot and temporary season.
- Electing a building skin material of extreme heat measurements and low-heat transfer coefficient.

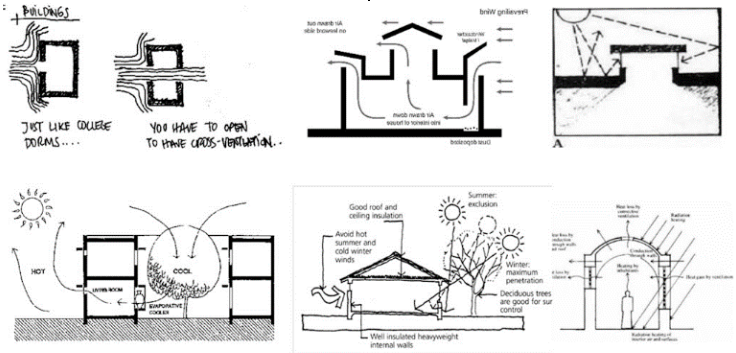


Figure .9 Various diagrams display the passive strategies depend on the climate properties in the hot arid zones.

Desert Vernacular Architecture and Urban Composition in Egypt:
By learning the discipline composition and concrete texture of hot and dry cities and villages within the western desert of Egypt, it's realizing that the climate issue plays a serious role within the formation the feel of cities and discipline composition in these areas and climatically factors have continually been a crucial material for the folks living in these areas (Atiya et al. 2003) These problems have guided people toward finding solutions over thousands of years which noticeably decrease annoying aspects of climate.

Vernacular buildings are built to breathe.
Most vernacular buildings are engineered with stone, soft bricks, timber and earth victimization earth or lime- based and mortars. These materials enable wetness to be absorbed then to without delay evaporate away, we regularly say it permits the building to 'breathe'. In such buildings the amount of damp within the building are 'controlled' by this prepared evaporation of wetness. Outwardly, the porous materials are dried out by the wind and sun. Internally, air movement- through the roof covering, windows and openings- all facilitate the evaporation of wetness from the inner porous surfaces. Wherever wetness will evaporate freely and also the vernacular 'breathing' performance isn't impaired (Guillaud, 2014), the walls of vernacular buildings can stay comparatively dry. Fig. 10, example of Vernacular Building.

Figure .10 View of Vernacular Building.

The principles of sustainability and the works of Hassan Fathy:
Many of the buildings Hassan Fathy designed, that are thought of as early samples of property and inexperienced design, are designed before the emergence of the notion of property (Steele, 1997a).
An individual initiative to preserve one amongst the homes designed by Hassan Fathy in New Gourna reveals Associate in Nursing understanding of Hassan Fathy's fine arts ideas. The conservation initiative has been administrated by Fikri Hassan, who has been involved the globe Heritage Centre's conservation project of the village, and who looks to possess been influenced by its projected approach to preserve the village per Hassan Fathy's ideas. The aim of the creativity was to re-establish the house into a hostel (Fig. 11).

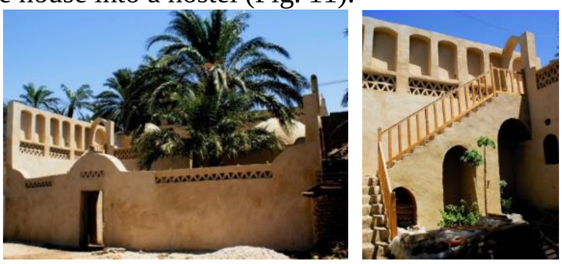


Figure. 11 The conservation initiative carried out on one of the houses designed by Hassan Fathy in

New Gourna, which resulted in the rehabilitation of the house into a hostel, b) The new staircase that has been installed in the courtyard of the house (Hassan, 2011).

These alterations involve the addition of a front court, and therefore the installation of a brand-new steps to the left of the new court. Not like Hassan Fathy's characteristic 2 vaults staircases, the new steps are supported by 3 vaults (Fig.8) (Ayman,2018) Through associate arched gate, the steps result in the higher floor which will be used as a hostel. Atop the higher floor, a tiny low dome and a dovecot made victimization red bricks are supplemental (Fig. 9).

The court incorporates a brand-new gate to the house, the look of which contains some ancient options akin to the maziara. The door leaf of the external entrance is associate recent one saved from one in every of the razed homes designed by Hassan Fathy see (Fig. 11).

Figure . 12 The gate of the house designed by Hassan Fathy in New Gourna, which was the subject of the conservation and rehabilitation works ,b) The new dome and dovecot added to the house during the conservation works.

In this article, we tend to take you thru a range of fifteen of the foremost vital comes of Hassan Fathy, Egypt's known creator since Imhotep, and winner of each the title Khan Chairman's Award for design and also the different Noble Prize in 1980.

New Gourna Village by Hassan Fathy:

The village of recent Gourna, that became partially designed among 1945 and 1948, might be the most renowned of all of Fathy's comes because of the global fine of his book, "Architecture for the Poor", revealed nearly twenty years once the expertise and concentrating totally on the ultimately tragic history of this single village. whereas the architect's explanations offered within the book are very compelling and ultimately persuasive (Abdel Tawab, 2015), New Gourna remains most important for the queries it raises instead of the issues it tried to resolve, and these queries still wait a radical, objective analysis (Fathy, 2000).

Figure. 13 New Gourna Village.

New Baris Village in Kharga, Egypt by Hassan Fathy:

No alternative project dominates this mature section of the architect's works the maximum amount because the village of latest Baris, in a very means that's akin to the infamy of latest Gourna twenty years before. This remote and forbidding geographic region outpost designed by him, that is nearly within the geographical center of Egypt, was planned to at first house 250 families of that over 0.5 were meant to be farmers and also the remainder to be service personnel. His previous expertise with such a project, and significantly his ability to create it inexpensively, made Fathy the logical choice as the architect for New Baris.

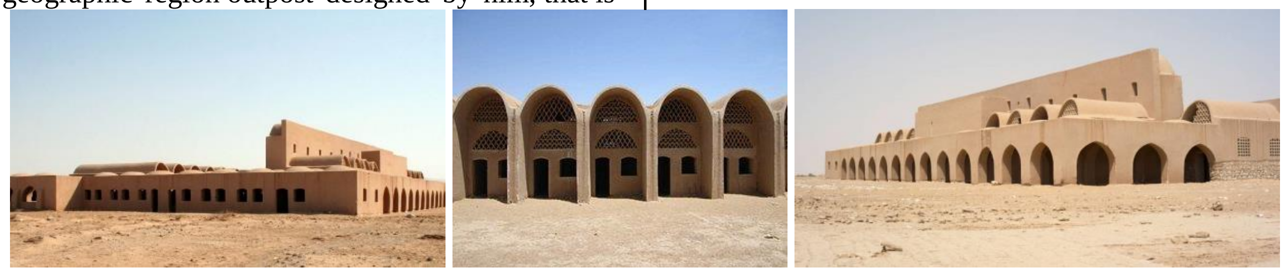


Figure. 14 General view of the Village.

Sadat Rest-house in Garf Hoseyn, Egypt:

Intended as a building to be used on official journeys to the isolated space around Lake Nasser in geographical region, the residence is truly created of 3 separate buildings consecutive organized in step with the standing of each.

Figure. 15 Exterior Facade of Sadat Rest house.

Akil Sami House in Dahshur, Egypt by Hassan Fathy:

This residence, and numerous others that accompanied it withinside the identical vicinity, had been constructed in nearby limestone due to a governmental ban on consuming mud- brick resulting the development of the excessive dam, in addition to unsatisfactory check effects for the structural electricity of the soil on this vicinity, mainly shown withinside the Fouad Riad project (U.S.G.S. Administration, 2003).

Figure 16 Exterior Façade of Akil Sami House.

Takhtabush and courtyard vicinity of the residence with wood pergola, consider the lattice work substantially used with inside the moastirli house in 1950 additionally with the aid of using him (Steele, 1997).

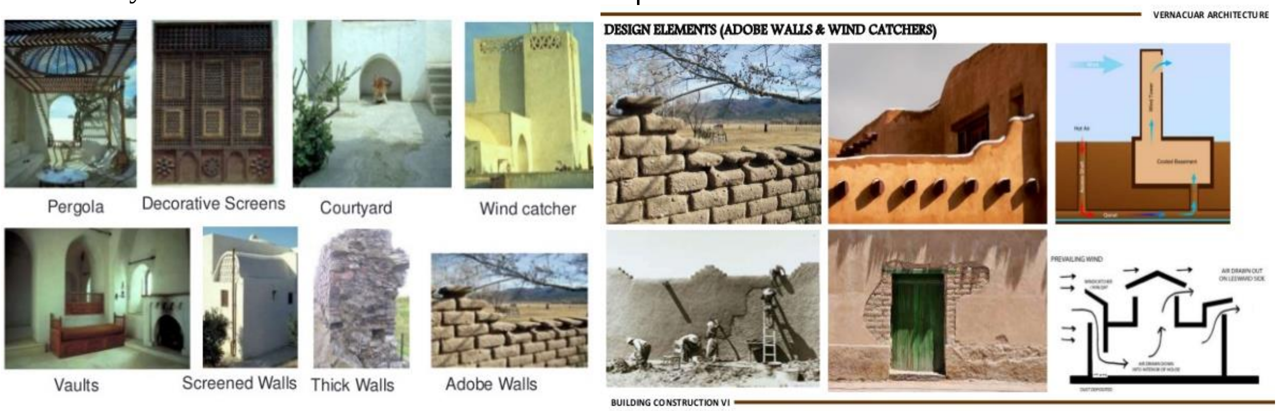


Figure. 17 Akil Sami House environmental strategies.

Alwadii Algadid Climate Condition:

Located in Southwestern Egypt, precisely the English New Valley desert muḥāfaẓah-governorate, Al-Wādī al-Gadīd encompasses an area that stretches from the Valley of Nile on the east to the Sudanese frontiers on the south and the Libyan borders on the west. The area is so large that it spans about two fifths of Egypt’s total land mass. Before 1958, the Al-Wādī al-Gadīd district was referred to as the Southern desert which translates in the local dialect to Al-Ṣaḥrāʾ al-Janūbiyyah. Al-Wādī al-Gadīd consists of five oases clusters sparsely distributed depending on the location of the artesian wells. The oasis clusters include Siwa (Sīwah) Oasis, Al-Baḥriyyah (Bahariya) Oasis, Al-Farāfirah (Farafra) Oasis, Al-Dākhilah (Dakhla) Oasis, and Al-Khārijah (Kharga) Oasis.

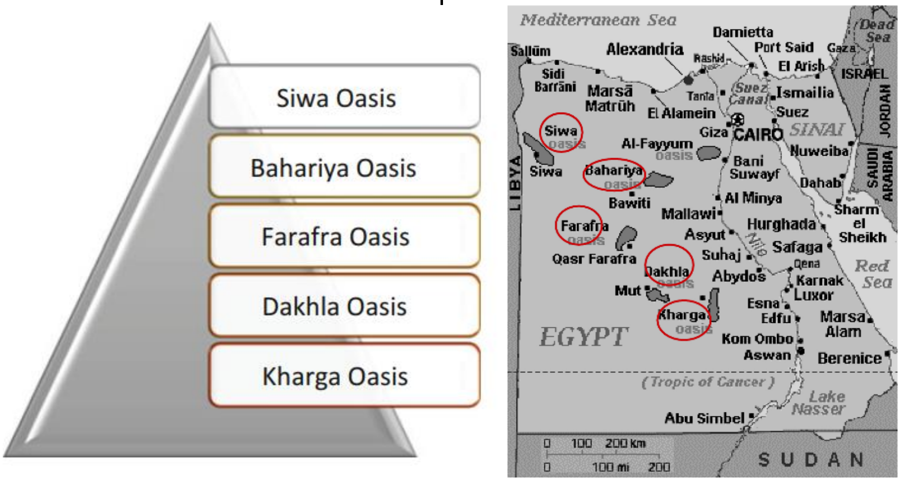


Figure. 19 Diagram shows the five main oases in the western desert of Egypt, Oases in the western desert of Egypt and the Nile Valley and Delta and Egypt's borders (MoHUUC, 2011).

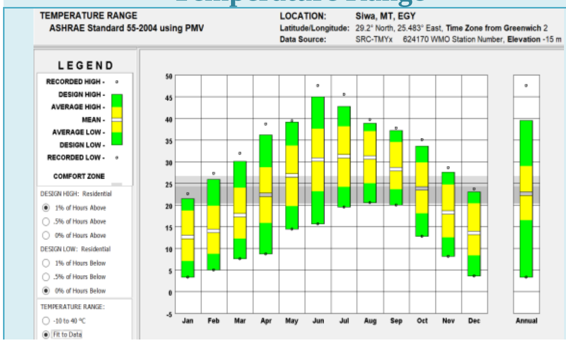
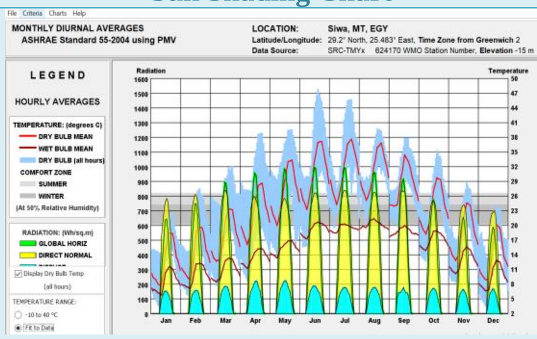
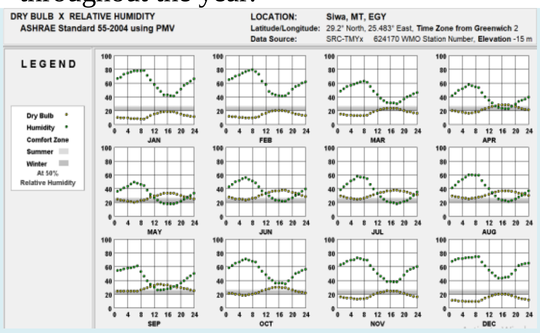
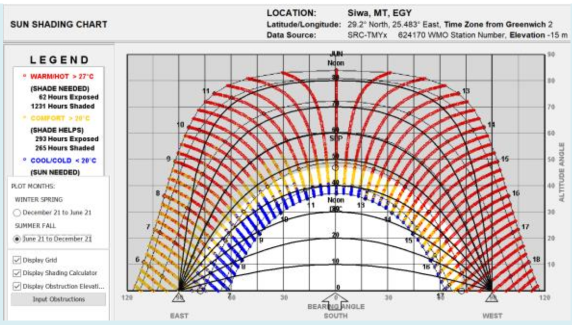
The environment of the New Valley is, in common, a hot, dry desert. The year is partitioned in two parts: The primary part: It is a hot time from April to September, reaching the minimum temperature is between 25 to 35 ° C ... and the temperature increases Until it extents 45 to 50 in the shade ... which equals 85 to 90 ° C in the direct sun.

The second part: the lowest temperature, which starts from October to March, when the temperature ranges between 0 and 5 ° C at night and near dawn, sometimes up to 3 Scores below zero and these scores vary from year to year. As for rain, it is almost non-existent and does not exceed 4 mm/ year.

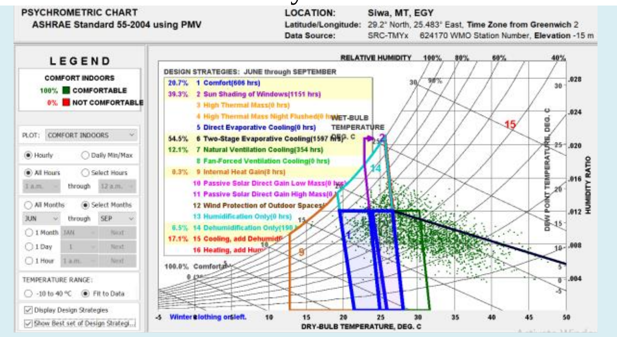
Climate studies:

Climate Consultant 6 will show dozen of various image photographs of numerous climate attributes and could recommend constructing layout techniques suitable for the precise traits of that climate (Olgyay, 1963).

Table (1): Basic information for the investigated basic shapes [13]

Temperature Range	Sun Shading Chart
	
• The figure expresses the mean and maximum and minimum temperatures during the months of the year and the average temperatures throughout the year.	• The path of the sun and its amount of shadow are expressed throughout the year.
	
Dry Buld x Relative Humidity	Sun Shading Chart

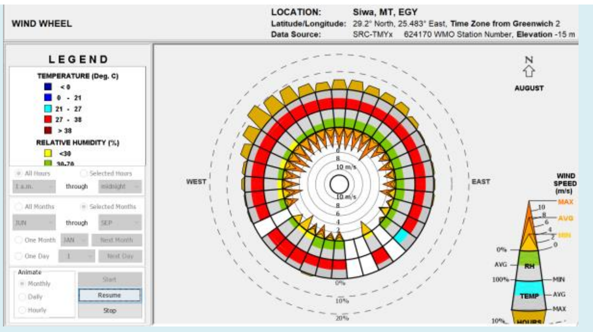
- The figure shows that from **April** to September there is an increase in temperatures over the thermal rest area for most of the year.



PSYCHROMETRIC CHART

- The rest of the month is high low at night.

- From November to March, a decrease in the level of solar radiation is observed, and from April to the end of October, an increase in the amount of radiation.



WIND WHEEL

- This results in a rise in temperatures, and the area is hot for most of the year

Methodology

Design builder is a relied-on device primarily based totally on Energy plus this is funded via way of means of the U.S. Department of Energy Building Technologies Office. It became selected as a simulation device because of its accuracy and correspondence to the bottom case. Design builder has a pleasant interface and supply correct effects in thermal simulation. The conceptual observe framework of these studies illustrates the 2 predominant methodological steps (Figure 20) undertaken on this observe: (1) version putting and choice of a consultant version as a base case for sensitivity evaluation, and (2) sensitivity evaluation to pick out the influential passive layout variables. A designated description of the observe technique is defined withinside the following sections.

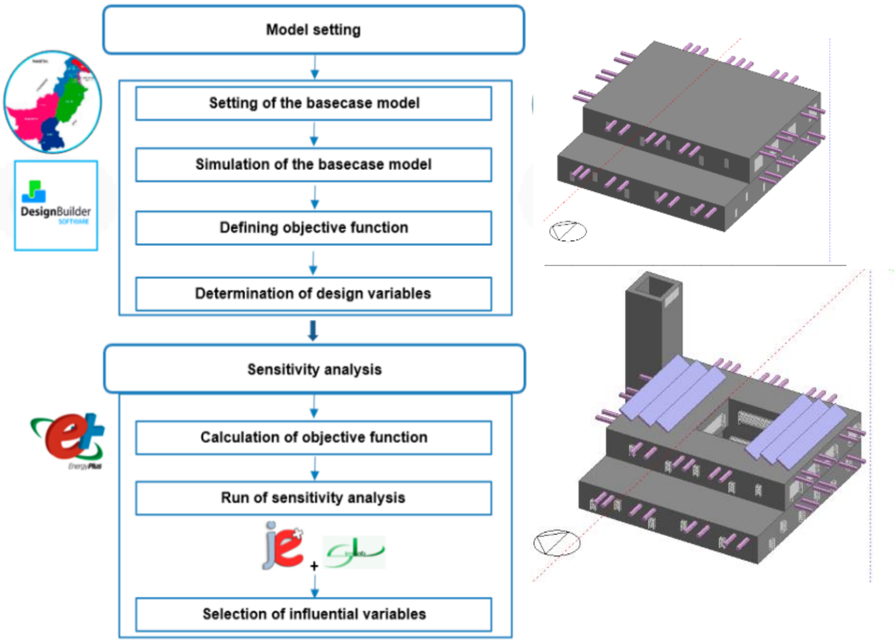


Figure. 20 Conceptual study frameworks.

Decisions taken to solve climate problems and retrofit the base case:

- Making double-layer glass windows to limit the sun's rays equipped with aluminum frames, heat treated to reduce heat transfer.
- Use double walls to isolate the heat.
- Making solar breakers to reduce the sun's rays.
- Add mashrabiya to controls the light passage, the airflow and it help to reduce the temperature.
- Add a Photovoltaic solar panels at the roof of the building.
- Add a Wind catcher at north direction to reduce electrical energy consumption and environmental pollution.
- Add courtyard in the centre of the building.

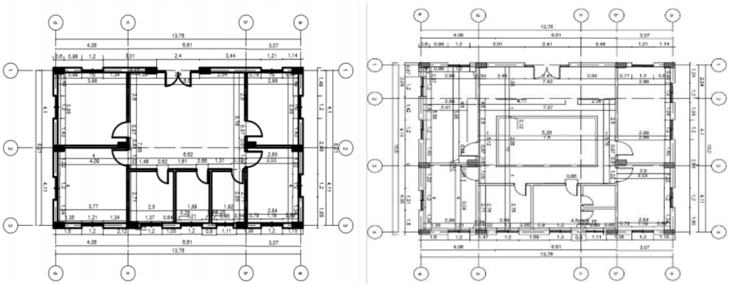


Figure 21. (a) architecture plan for Base case, (b) base case after retrofit.

A prototypical house was developed based on the investigation. The model is a single-family house known as a ‘villa’ of two floors. The villa primarily has guest sitting areas and a kitchen on the ground floor and private spaces on the first floor (Figure 21). The villa also has a typical traditional family plan of architectural element as seen in the developed 3D model (Figure 22). This type of household represents 80% of the building stock in Alwadii Algadid.

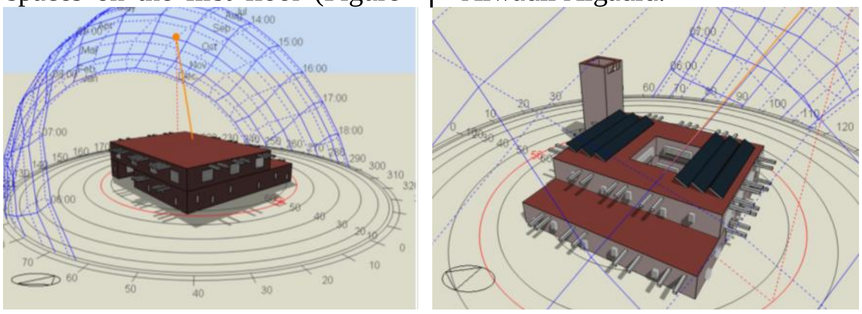


Figure 22. A) Architecture 3D view of base case model, b) Retrofit base case Models, Design Builder Screen shoot.

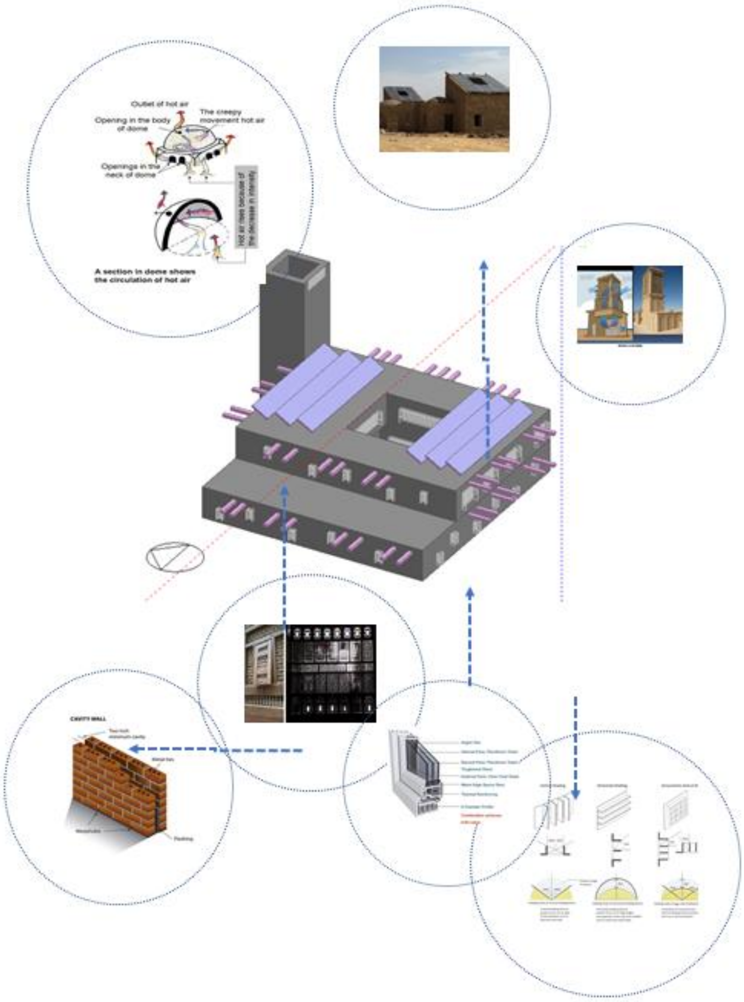


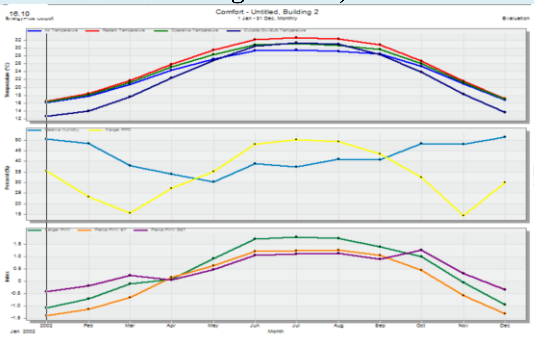
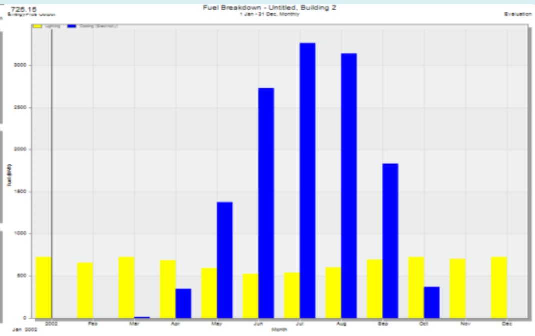
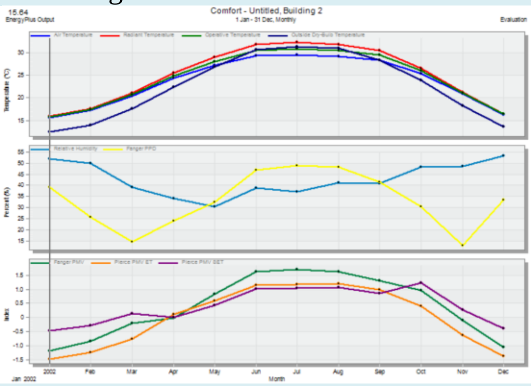
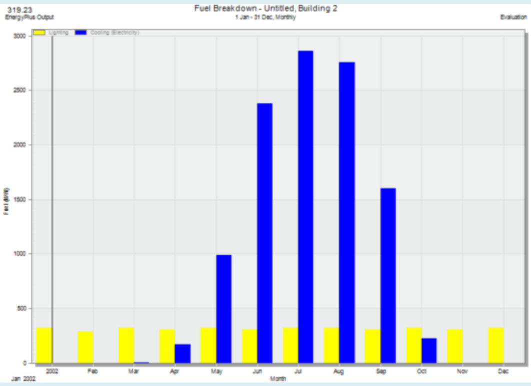
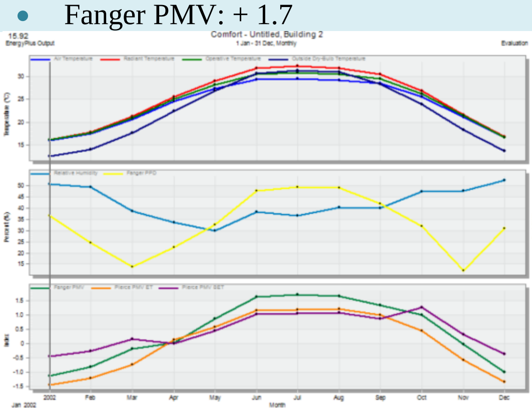
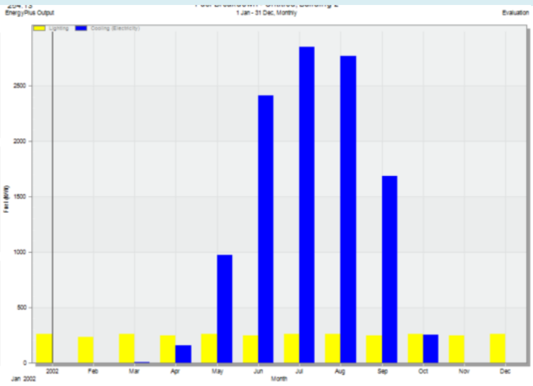
Figure 23. Strategies for implementing prototype house

Simulated Model Performance:

In general, the results of the simulation carried out in this research revealed the great potential of utilizing energy efficient practices in Alwadii Algadid. In addition, these energy efficient practices were proposed in this study through passive strategies and techniques, which massively improved the energy efficiency of the studied residential building. Moreover, the total energy consumption for cooling of the building decreased by 70%.

Table 2 shows the analyses of the six simulation runs, where the examined components are separated by a particular colour. For thermal comfort, the X-axis also represents the months while the Y-axis indicates various factors and they are Relative Humidity%, Operative temperature, and Fanger PMV. As for the Fuel breakdown, simulation includes lighting, and cooling consumption.

Table (2): Design strategies and output for the optimization analysis

Technique	**Monthly result -Value mean** **Thermal Comfort** (Comfort Range factors: Relative Humidity%/ Operative temperature c°/ Fanger PMV)	 **Fuel Breakdown** (Fuel Range factors: Lighting / Cooling(kWh))
Base Case		
	Analysis: Highest value achieved • Relative Humidity: 42% • Operative Air Temperature: 30.3 oC • Fanger PMV: + 1.6	• Analysis: Average value achieved • Lighting: 256.2 kwh • Cooling: 875 kwh
Double Wall		
	Analysis: Highest value achieved • Relative Humidity: 53% • Operative Air Temperature: 30.7 oC • Fanger PMV: + 1.7	**Analysis:** Average value achieved • Lighting: 313.22 kwh • Cooling: 914.98 kwh
Court Yard		

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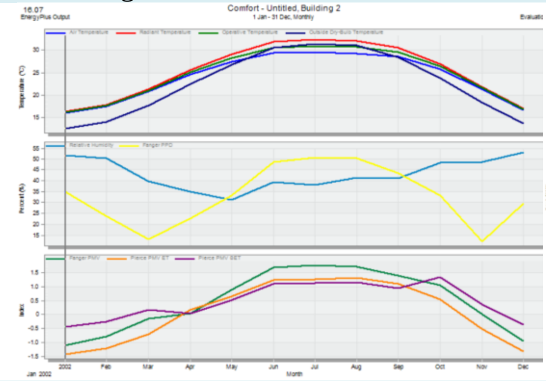
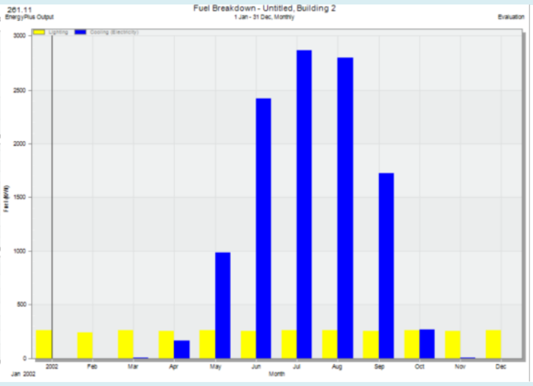
Analysis: Highest value achieved
- Relative Humidity: 52%
- Operative Air Temperature: 30.7 oC
- Fanger PMV: + 1.7

Analysis: Average value achieved
- Lighting: 249.34 kwh
- Cooling: 924 kwh

Wind Chater

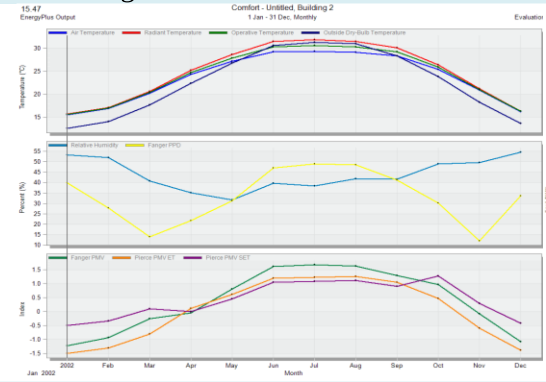


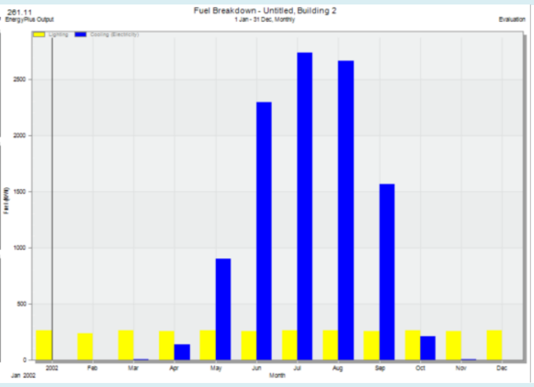


Analysis: Highest value achieved
- Relative Humidity: 53 %
- Operative Air Temperature: 30.8 oC
- Fanger PMV: + 1.7

Analysis: Average value achieved
- Lighting: 262.11 kwh
- Cooling: 949.5 kwh

Sun Breaker

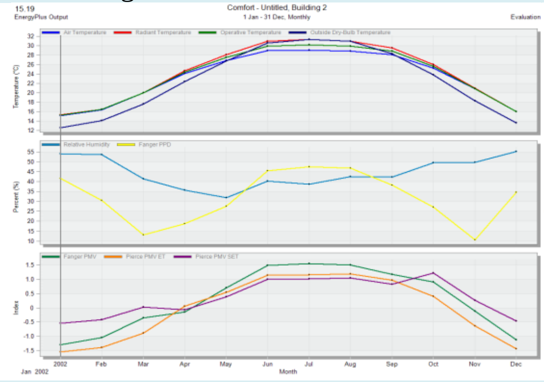


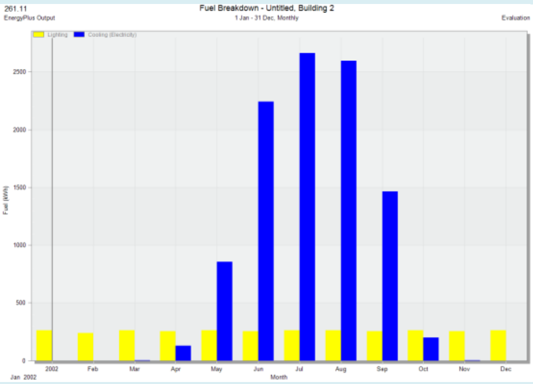


Analysis: Highest value achieved
- Relative Humidity: 42%
- Operative Air Temperature: 30.3 oC
- Fanger PMV: + 1.6

Analysis: Average value achieved
- Lighting: 256.2 kwh
- Cooling: 875 kwh

PV cell (Solar panel)





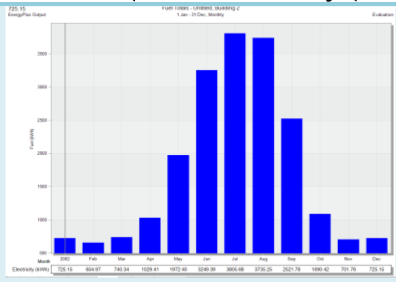
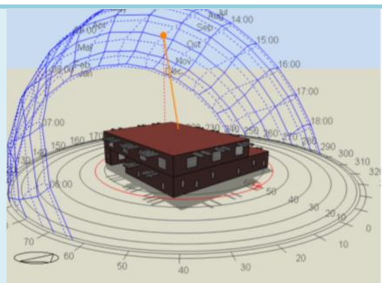
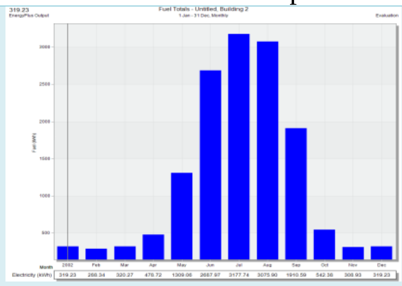
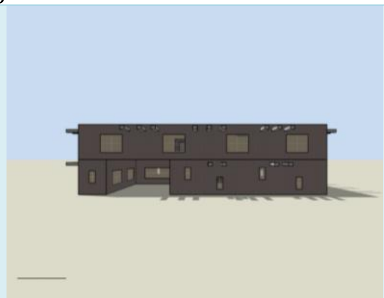
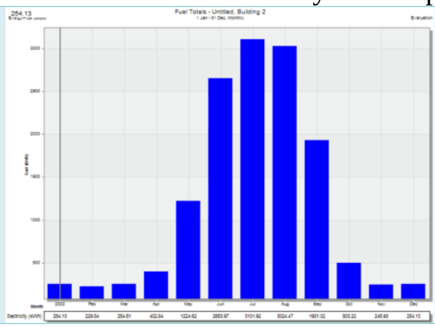
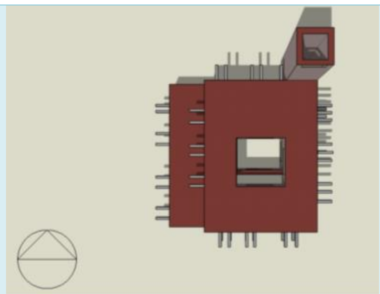
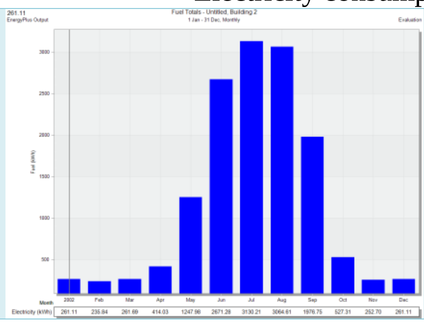
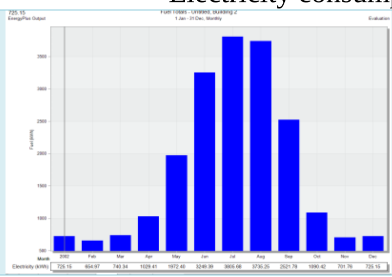
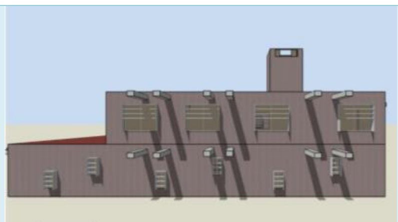
Analysis: Highest value achieved
- Relative Humidity: 55%
- Operative Air Temperature: 30.2 oC
- Fanger PMV: + 1.4

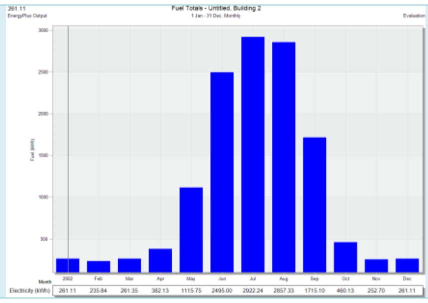
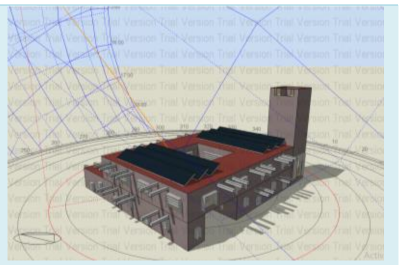
Analysis: Average value achieved
- Lighting: 256.2 kwh
- Cooling: 845.5 kwh

Energy Consumption (Internal Gain):

The tests conducted illustrated that the adaptation of PV cell technique on the building consumed the least energy (671 kwh), the sun breaker technique (684 kwh), On the other hand, the wind chater technique (721 kwh) with obvious difference, the courtyard technique (675 kwh), furthermore the double wall achieve (839 kwh) compared to the base case with (1745) kwh.

Table (3): Fuel Total for the simulation investigation

Fuel Total **(Total Electricity (kWh))**		
Base Case		
	Analysis: Highest value achieved Air Temperature: August – 29.2 ºC	
Double Wall		
	Analysis: Average value achieved Electricity consumption:1228.19 Kwh	
Courtyard		
	Analysis: Average value achieved Electricity consumption:1173.36 Kwh	
Wind Chater		
	Analysis: Average value achieved Electricity consumption:1211.5 Kwh	
Sun Breaker		
	Analysis: Average value achieved Electricity consumption:1131.25 Kwh	

PV cell (Solar panel)		
	Analysis: Average value achieved Electricity consumption:1101.68 Kwh	

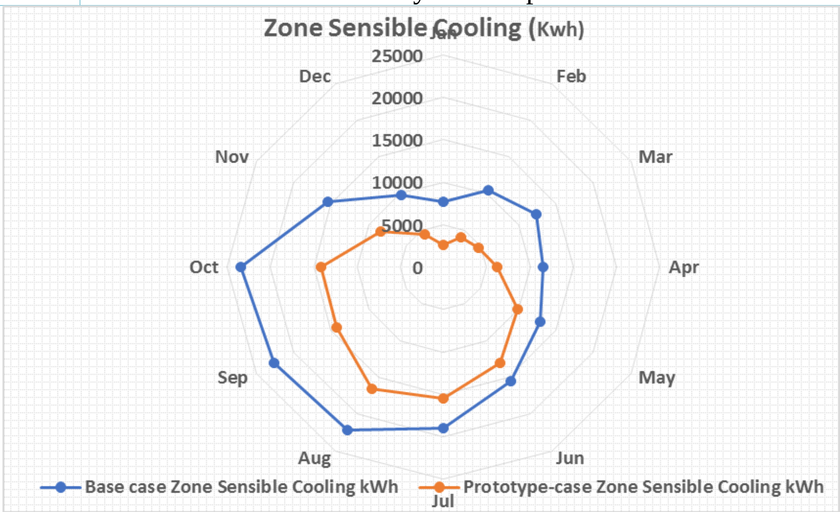


Figure 25. Zone Sensible Cooling of base case and prototype building.

Thermal Comfort

The predictive mean value (PMV) is a metric scale that is used to indicate the degree of thermal comfort achieved in a certain space. According to the Egyptian code for energy, the value of this metric should range from 1 to -1 to reach the comfort zone, where zero is the optimum circumstance. In the simulation conducted, it was realized that the resulting numbers given by the design-builder for the air temperature co, relative humidity%, and operative temperature co. It was found that the various technique in achieving thermal comfort were the **Double wall, sun breaker, courtyard, wind chater and finally PV-solar** panels with almost similar results in the peak months as shown in table 2.

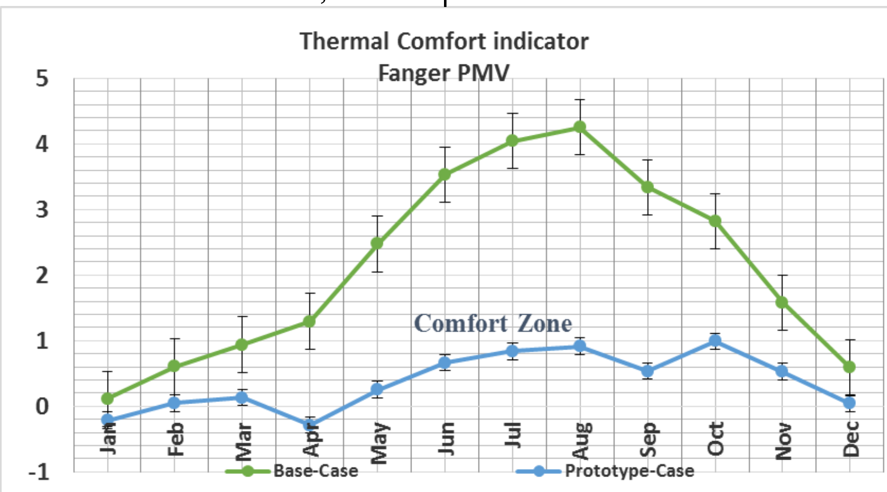


Figure 24. Monthly results of Fanger PMV for base case and prototype case. (prototype).

It was found that the thermal comfort achieves the best value using prototype model includes (PV, courtyard, sun breaker, wind chater, and double wall) with the annual average PMV; +0.26, with courtyard (annual average PMV; +0.42), and sun breaker (annual average PMV; +0.48), wind chater (annual average PMV; +0.46), and double wall (annual average PMV; +0.38) as shown in figure 24.

The graph shows that the consumption rate of the technique that follow in the adaptation of the simulation with the optimum value of 1800 (kWh) on august compared to the prototype building with 725 (kWh), as shown in Fig .25.

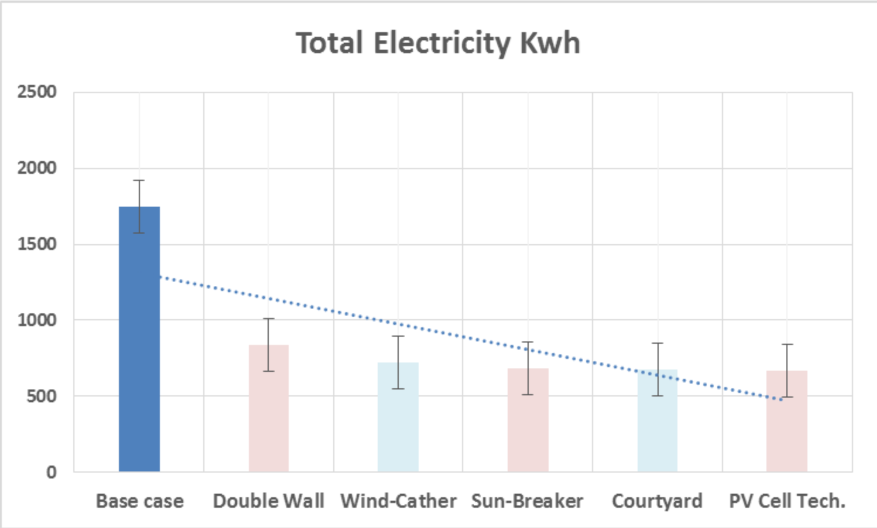


Figure 26. Cooling loads of prototype strategies.

By applying different environmental strategies, it was clear that achieved the best enhancement of zone sensible cooling energy efficiency of the building was the sun breakers, Double Wall, Dome technique and Wind Cather (25010.91, 17750.89, 12616.53 and 7579.99 Kwh) respectively compared to the base case 49215.29 (kWh), as shown in Fig .26.

Co2 Emissions

A carbon dioxide analysis has been conducted for the six strategies of the research, based on the building's fuel consumption for the mixed mode ventilation (natural and mechanical) and for the working of other activities such as lights and computer equipment. It was found that the prototype building achieve lowest emitting value of 667.5 Kg, On the other hand, the base case reach to 1058.2 Kg.

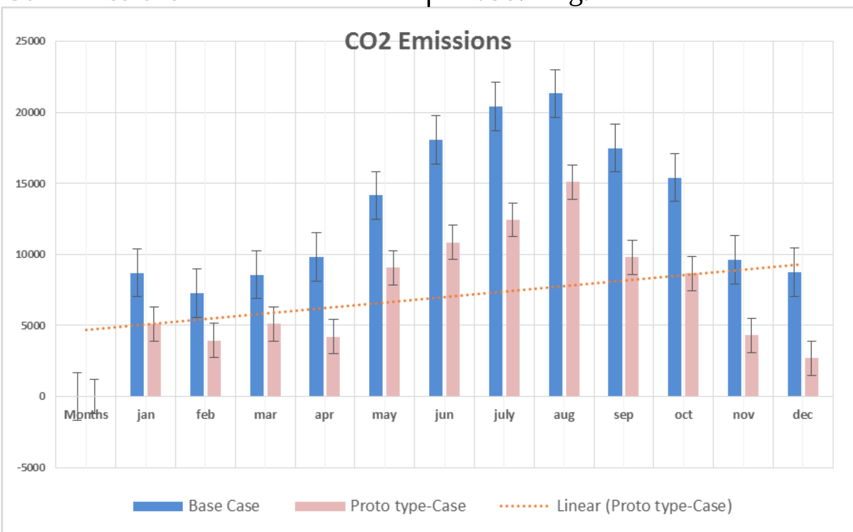


Fig.4. Co2 analyses results of the various shapes

Conclusion:

According to results, the building can consume up to 52% from its total energy load on cooling load only, so that building envelope impact on energy consumption should not be neglected.

We stay in an international that includes a huge type of vernacular buildings. Egypt is a rustic with a number of the best examples of barren region vernacular structure in the world. Although there may be an attention that vernacular is struggling all around the international, the styles of being concerned for this precious historical past frequently display little know-how of its actual value.

The approach provided the means to carry out a workable practical example to encourage locals to continue applying their vernacular knowhow solutions. The model application helped in solving the current identity problems prevalent in desert vernacular settlements. It showed the locals that they have the possibility to respond to the future with adaptations that can focus local attention on the significance of the vernacular architecture that is integral to their local culture.

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