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The role of photovoltaic processors as an Approach to sustainable urban design of residential neighborhoods

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Abstract — recently, -Since the Industrial Revolution, the world has observed vast technological achievements, population growth, and corresponding increases in resource use. So we are now facing increasing energy consumption in buildings and cities and dependence non- renewable energy resources. This research sheds light on the remarkable development in recent, as explore the new in technology, which led to appearance photovoltaic (solar cell) which become associated with the field of architecture. This research sheds light the evolution of solar cell types, compare the efficiency of each type of solar cell in Buildings and the possibility of applying solar cells to residential neighborhoods
So my objective of this research using Photovoltaic processors to achieve Sustainable Urban Design of residential neighborhoods by energy efficient and optimal design of high-performance buildings in residential neighborhoods with multi-functional solar PV systems so as to achieve reduced electric lighting energy consumption and maximum generation of renewable solar power and achieving Sustainable development , low energy consumption and the balance of energy needs supplied by renewable technologies in residential neighborhoods.

Index Terms— Photovoltaic processors ▯ Types of photo voltaic cells ▯ Sustainable Urban Design ▯ residential neighborhood ▯ Design Builder simulation program ▯ calculation electricity consumption ▯ percentage saving electricity.

1 INTRODUCTION LITERATURE REVIEW

Prior to the evolution and arrival of humans on Earth, changes in the Earth's atmosphere, lithosphere, hydrosphere, cry sphere, and biosphere had been occurring for billions of years. Global environmental change is nothing new, but what is new are the rates of change that the Earth systems are currently experiencing because of human activities. The rate of change in these systems since the arrival of the human species is more rapid than any other time in history. These more recent changes are related to humans and their natural resource needs and requirements. The retrieval, production, distribution, consumption, and disposal of these natural resources along with the continued growth and distribution of the human population As we are in a new century, we are realizing the "side results" in our activities: pollution, landfills at capacity, poisonous waste material, global warming, tool, ozone depletion, and deforestation. [1]

-Global research shows that the buildings sector accounts for about 40 per dollar of global energy usage and is in charge of roughly one-third of greenhouse gas emissions. Accounting for about half the building sector's energy impacts. [2]

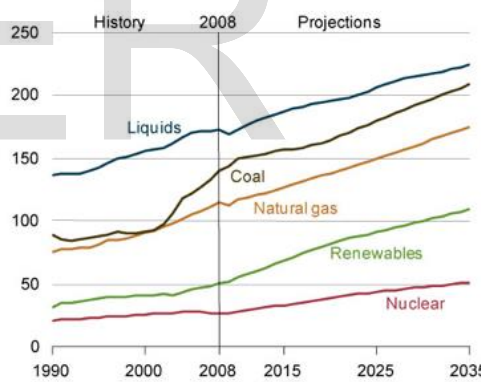


Fig. 1.1 World energy consumption by fuel 1990-2035 in United StateChain and India, [3]

- Solar power is an unlimited source of energy, which, if harnessed effectively, could provide an enormous and relatively constant source of energy and cheap costs of oil.

-Photovoltaic cells are devices that convert sunlight into electricity. These cells have no Moving parts for maintenance and produce no pollution, so they are a very promising Energy source for the future. The Commercial production of photovoltaic cells has increased by 265 percent since 1995. [2]

-The best sustainable design is approximately equilibrium between these components. To make cities more suitable for people, all areas of feasible city necessary to be engaged and runs efficiently with in design or system formula Places. Cities should be made to make its people secure and happy, because of this aim cities must become greener, robust with a well-balanced ecosystem.

-The neighborhood is a basic planning entity in modern residential planning theories. On the other hand open spaces as an essential constituent of the neighborhood's physical structure, have an important role to play. These are the arena of both, neighbors' outdoor interactions-consequently building the neighborhood's sense of community- and the micro ecological sphere - setting its parameters and configuring its fundamentals.[4]

2. SUSTAINABLE URBAN DESIGN

Sustainability and sustainable design Defined:-

2.1. Sustainability is that the conception of meeting present needs without compromising the ability of future generations to meet their own needs.

The World Commission on Environment and Development (London: Oxford University Press, 1987).

2.2.Sustainable design is achieved through an integrated design and delivery process that Enhances the natural and built environment by using energy sensibly with a goal toward Carbon neutrality improves air and water quality, protects and preserves water and Other resources, and creates environments, communities, and buildings that are livable, Comfortable, productive, diverse, safe and beautiful to stir our imagination. [5]

2.3. Principles of Sustainable Design

We propose three principles of sustainability in architecture:-

1-Economy of Resources is concerned with the reduction, reuse, and recycling of the natural resources that are input to a building.

2-Life Cycle Design provides a methodology for analyzing the building process and its impact on the environment.

3-Humane Design focuses on the interactions between humans and the natural world. These principles can provide a broad awareness of the environmental impact, both local and global, of architectural consumption.[6]

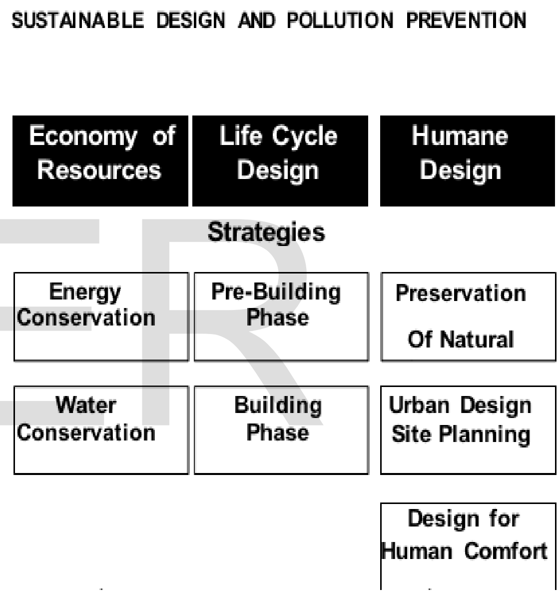


Fig. 2.1 Conceptual framework for Sustainable Design and Pollution Prevention in Architecture.

2.4. Urban design: While it varies both in how it is defined and how it is put into practice, Urban Design has gained prominence across world urban design can be divided to four dimensions.

1-Urban designer requires : interdisciplinary input with balanced representation of multiple fields including engineering, ecology, local history, and transport planning. [7]

2-Urban planning * Organizes the physical components of the city * Deals with functional relationships between your elements of the location uses of the properties- streets- transportation- facilities.... * concentrate on function, not on aesthetics.

3-Architectural Design large scale urban planning limited scale so, there is a need to an intermediate scale. [8]

4-Urban Design * Deals with groups of buildings and also the urban spaces between these buildings *open spaces like "streets-gardens- squares- pedestrian paths ..." * with cares that of physical environment" landscape- furniture of open spaces…* and focuses on the users of these spaces. [8]

2.5. Element of urban planning: -

(Buildings - Public Space-Streets Transport and Landscape). [9]

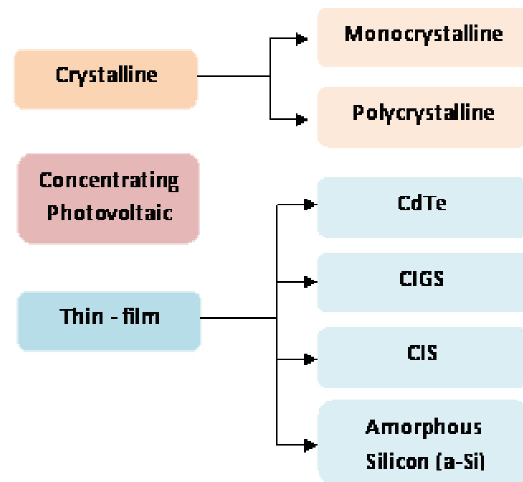
3-PHOTO VOLTAIC CELLS (PV).

3.1. The solar cell or photovoltaic (PV) cell is a device that converts light energy into electrical energy.

A PV panel is a collection of photovoltaic modules (a number of cells electrically connected and packaged) that are mechanically fastened together, wired, and designed to be a field-installable unit. [10]

-Photovoltaic technology makes use of the abundant energy of the sun and converts it into electrical energy with little impact on the environment. It is commonly accepted that PV systems are useful in small buildings and in applications in which there is not that much electrical power required. A variety of successful cases can be found around the world where PV panels on the roof were able to supply the electrical load of the building. For example, Park Mount housing in Belfast, Northern Ireland, consists of 60 apartments that are equipped with PV panels. [11]

3.2. Types of photo voltaic cells.



3.2.1 Mono-crystalline cells.

Mono-crystalline cells are cut into thin wafers from a singular continuous crystal that has been grown for this purpose, are also called single crystal cells hence. To minimize waste, the cells may be fully they or round may be trimmed into other shapes, retaining more or less of the original circle. As each cell is cut from a single crystal, it has a uniform color [12] mono-crystalline silicon modules normally appear as a solid colour, ranging from blue to black. A wide variety of colours is available but these are of lower efficiency. eg: magenta or gold results in a loss of 20% efficiency [13],,[11]. These cells are around 10 x 10 cm2 and 350 micron in thickness with an efficiency of up to 14-17%. They produce, on average in European weather, 900-1000 kWh per each kW installed [14], [11]

3.2.2 Poly-crystalline cells.

Polycrystalline cells are made from similar silicon material to that of the mono-crystalline except that instead of being grown into a single crystal, they are poured and melted into a mold. This forms a square block that can be cut into square wafers with less waste of space or material than round single-crystal wafers. As the material cools, it crystallizes in an imperfect manner, forming random crystal boundaries [12] Polycrystalline cells with equal dimensions reach a performance of up to

12% and would produce on average 750-850 kWh per each kW installed in European weather [14],,[11]

3.2.3 Thin-film cells:-

This latest technology of thin film is either from silicon or produced from a new base materials, such as Gallium- Arsenide (GaAs), Cadmium-Telluride (CdTe) or Copper-Indium-Diselenide (CIS). These cells also called amorphous [11] protected by means of encapsulation with front glass and back protection, resulting in PV modules. Thin-film cells have efficiencies up to 5-8% and produce in average 600-800 kWh per each kW installed and are available in range of colures. [14], [11]

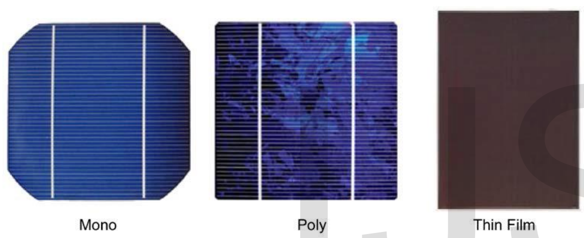


Fig. 3.1 type of photovoltaic cell.

Table (1): Efficiencies of different types of cells:-[15], [11]

Source: Roberts and guariento, Thomas (et al., 2001)

	Type	Appx. Cell Efficiency	Appx.modular Efficiency	Area Requirement
1	High performance hybrid silicon		17-18%	$6\text{-}7m^2/kW_p$
2	Mono-crystalline silicon	13-17%	12-15%	$7\text{-}9m^2/kW_p$
3	Polycrystalline silicon	12-15%	11-14%	$7\text{-}10m^2/kW_p$
4	Thin-film CIS		9-99%	$9\text{-}11m^2/kW_p$
5	Thin-film CdTe		6-8%	$12\text{-}17m^2/kW_p$
6	Thin-film amorphous silicon		5-7%	$14\text{-}20m^2/kW_p$

Source:(Roberts and Guariento; Thomas et al., 2001)

4- Case Study: Models of the Youth Housing in the new Assiut city.

4.1-Models of the Youth Housing in the new Assiut city

-The new city of Assiut is located 20 km away from Assiut. The percentage of buildings is about 60% of the total area and 40% of the green area.

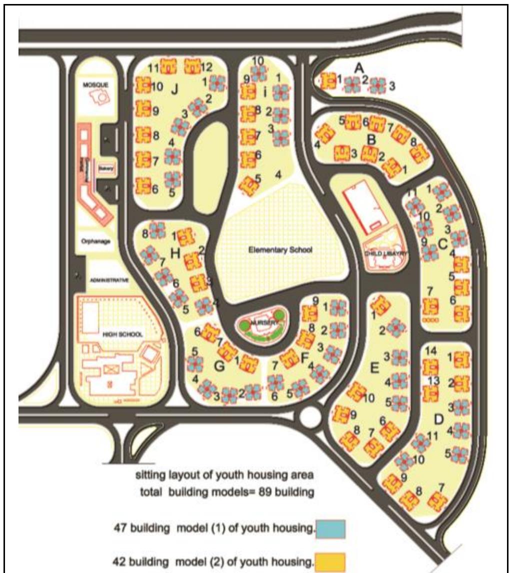


Fig. 4.1 Youth Housing Area in new Assiut city.

-The new city of Assiut was chosen as a case study for the Following reasons:

1 - The climatic factors of the city to help the application of the solar system. Anew Assuit City has high temperature and radiation.

2- Problems of electricity supply in new cities.

3-Encourage people to live in new cities.

-We selected the youth housing area in new Assiut city because it was had a typical urban design. It contains two models of design. Model (1) represents 47 buildings and model (2) represents 42 buildings.

Total number of Model (1) = 20 units (4 units* 5 floors). **Total number of Model (2)** =21 units.

So, we can be calculated the solar system for model (2). And applied the system to all similar models in same residential neighborhood, by taking consideration the orientation of each model. [16]

Fig. 4.2 model (2) of the youth housing. Total area = 63 m2 per unit.

Fig. 4.3 model (2) typical plan of the youth housing.

4.1.1Energy consumption in residential buildings

The Energy consumption in residential buildings consists of the following items:-

1) Lighting units.

In recent periods we have seen the emergence of many types of lighting units such as (LEED lamp) to reduce the consumption of electricity.

2) Household appliances.

As for the **Household appliances.**, that include (washing machine, a refrigerator, a TV and a heater ……….) the device of the industries imposed the existence of the energy efficiency card on the product, where the card contains a rating of A, B, C, D and E, where A means the highest quality and lowest consumption of electric energy, and also contains the card on the monthly consumption of the product of energy electrical.

3) HVAC.

Air conditioning equipment plays a key role in the region's energy consumption.

So, in this study, the new city of Assiut was chosen to conduct an assessment of thermal behavior of buildings. [17]

4.1.2. Research Methodology

1) Use the Design Builder to evaluate the thermal behavior of for selected models in case of study.

2) Calculate the electricity consumption of 4 units for model (2).

- Unit orientation (1): Northeast.
- Unit orientation (2): Northwesterly.
- Unit orientation (3): Southeastern.
- Unit orientation (4): Southwesterly.

3) Install the processors on the units to reduce the thermal loads on the facades of buildings of processors on the units to reduce the thermal loads on the facades of buildings.

4) Calculate the power consumption after the work of processors.

5) Calculate the percentage of savings in consumption achieved by each treatment.

6) Choose the best percentage saving electricity consumption.

7) Study the effect of shading the buildings on some of them (inter-buildings) to reduce the thermal loads on the building facades.

8) Choose one of the sources of renewable energy which is solar cells and calculate the quantities of electrical energy produced by those solar cells.

4.2. Input data of design builder program

4.2.1 New Assiut City Climate data

The city of Assiut is located at latitude (27 05 ˚N) and long circuit (31 02°E).by The study of the Change in precipitation during the months of the year for dry temperature and relative humidity for the thermal comfort limits of Assiut city, we find that The average maximum temperatures in the summer range from (42°C to 40°C) and The average minimum temperature between (20°C and 18°C) .While the average maximum temperature during the winter to about 25°C and minimum temperature 8°C.

The (figure 4.4) shows that the average relative humidity during the summer ranges from 30% to 75% and winter range from 40% to 75%.

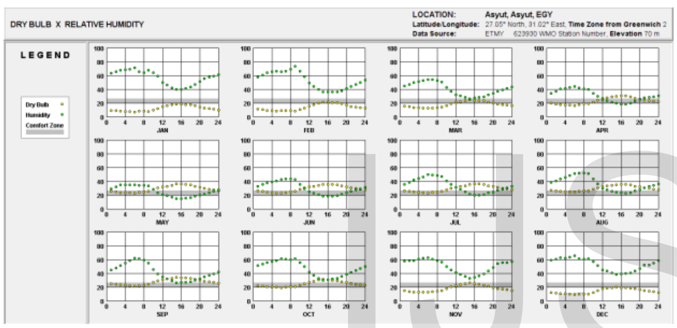


Fig. 4.4 Change in precipitation during the months of the year for dry temperature and relative humidity for the thermal comfort limits of Assiut city.

In The below (figure 4.5) we show that the average of change in the months of the year for dry and wet temperature, relative humidity, and total, direct and dispersal solar radiation of new Assiut city.

We find from the (figure 4.5) that the solar radiation on the horizontal surface ranges between 850 to 1100 watts / m 2 and continues over 800 watts / m 2 most of the day. High solar radiation is also observed as a result of atmospheric clarity.

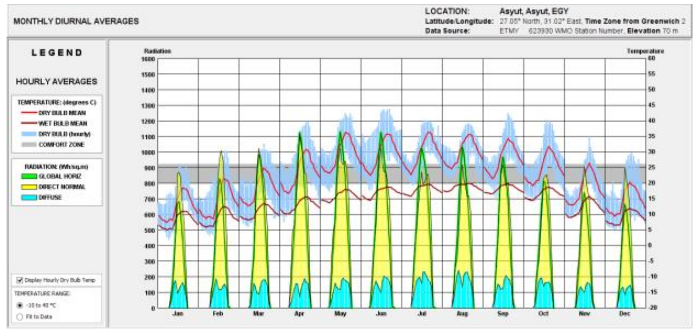


Fig. 4.5 the average of change in the months of the year for dry and wet temperature, relative humidity, and total, direct and dispersal solar radiation of new Assiut city.

4.2.2- Drawing of building model (2)

-Perspective shown in **Fig .4.6**.

- Main elevation shown in **Fig 4.7.**

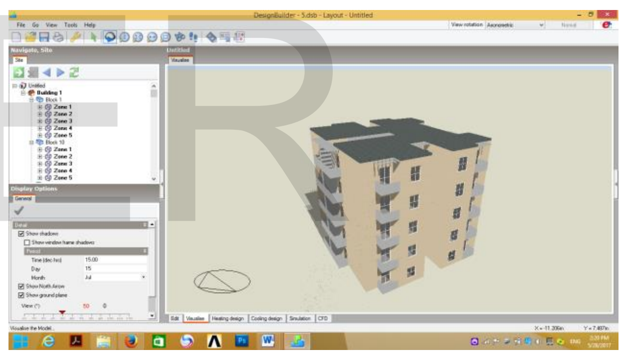


Fig. 4.6 Perspective shown.

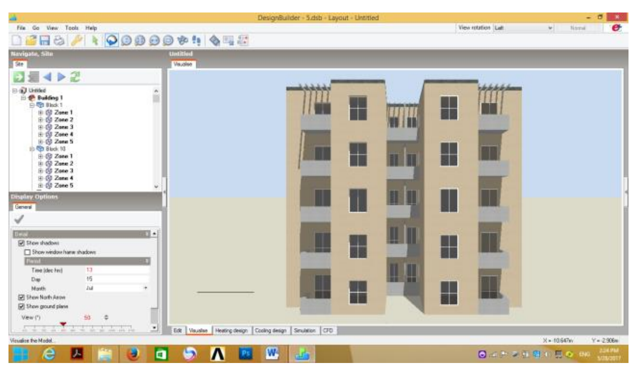


Fig. 4.7 Main elevation shown.

4.2.3. The Building Construction

4.2.3.1 Wall: The solid parts are formed from hollow Cement brick with density1850 (kg / m3) and mortar cement with density 1858 (kg / m3) and outdoor, indoor painting. The total solid thermal resistance value for the wall is 0.41 (m2. c ° / Watt.) [18]

Table (2): physical Characteristics of wall Component

Component	layer L (cm)	Density ρ (kg/m^2
1-Cement mortar	2cm	1858
2-hollow Cement brick	20 cm	1850
3-cement mortar	2 cm	1858
U-value	2.4 (W/m^2.K)	
R	0.41 (m^2.K/ W)	

4.2.3.2 Roof: The roof is composed Roof from seven layers with a total value of thermal resistance equal to 0.55(m^2.K/ W). [18] Table (3) shows roof characteristics components.

Table (3): physical Characteristics of roof Component

Component	layer L (cm)	Density ρ (kg/m^2
1-Cement mortar	2cm	1858
2- Concrete, Reinforced (with 1% steel)	20 cm	2300
3-Bitumen, felt/sheet	0.4cm	1100
4-Cement mortar	2cm	1858
5-sand	5cm	1800
6-Cement mortar	2cm	1858
7-Concrete Tiles (roofing)	0.5cm	2100
U-value	1.8 (W/m^2.K)	
R	0.55(m^2.K/ W)	

4.2.3.3 Window and opening: Curtain wall in the building envelop is made of a system of structural glared which is a single-glazed with thermal resistance 6.12 (W / m2. C), with solar heat gain coefficient factor 0.81 and visible transmission 0.88.

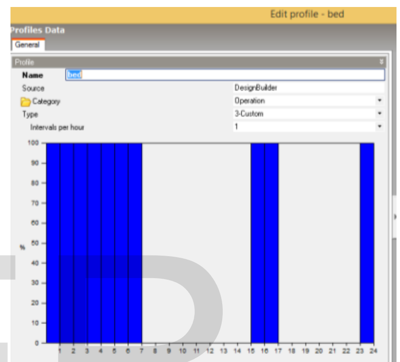
4.2.4 Activity operation

a) HVAC:-Air conditioning system used in the building (split no fresh air). Each unit have HVAC: reception, 2 bed room and NO HVAC: kitchen, bath room

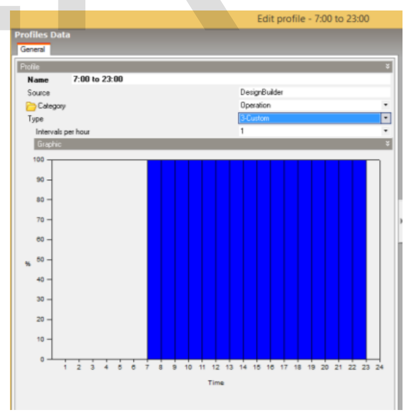
b) Building operation

Schedule operation:-The operating hours vary within one unit from place to another of bedrooms and reception. Adjust the operating hours of building throughout the week in bed-room and reception.

1 bed room:-



2 - Reception:-



4.2.5 Unit orientation

- Unit orientation (1): Northeast.
- Unit orientation (2): North westerly.
- Unit orientation (3): Southeastern.
- Unit orientation (4): Southwesterly.

4.3-Output data

The simulation program calculates the building energy consumption after the input data (climate data – building drawings - physical properties of wall and roof - physical properties of window and opening -operation schedule - set point temperature) has been added to the program. Thereby, the annual consumption as well as the monthly consumption of the electric power could be calculated. Fig (4.8) shows the annual consumption of the electric power

Table (4): the annual consumption of the electric power of wall and roof.

Unit orientation	Total annual consumption wall (K.W.H)	Total annual consumption Roof (K.W.H)
Unit (1) Northeast (NE).	5884	8454
Unit (2) Northwest (NW).	7454	9678
Unit (3) southeast (SE).	8417	9923
Unit (4) southwest (SW).	8520	11022

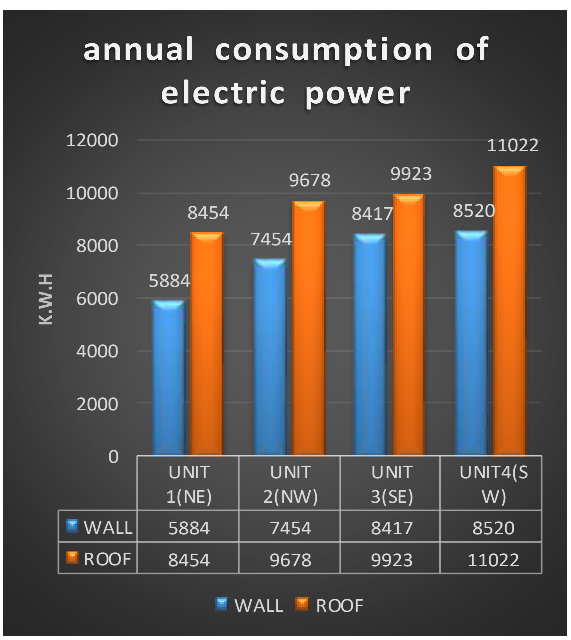


Fig. 4.8 The annual consumption of electric power.

4.5. Alternative for energy saving

4.5.1-Using thermal insulation in the wall and roof

a) Using thermal insulation in Northeast (NE) orientation.

In case we use the thermal insulation in the wall. The Consumption will be decreased 8.2% if we add (1cm insulation) in NE and when we add (2cm insulation) in the wall, the energy Consumption will be decreased 12.3%.

After we use thermal insulation in roof, we add 1cm **EPS (expanded polystyrene)** materials in northeast (NE) orientation. The Consumption will be decreased 9.4%.

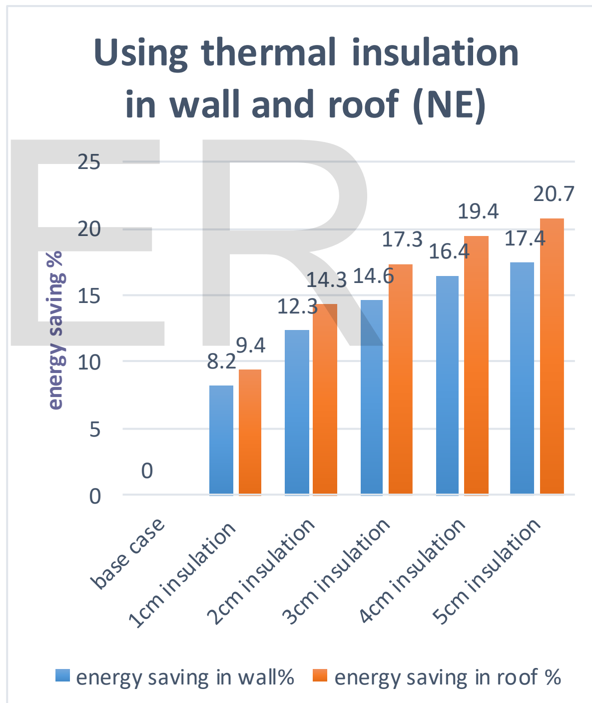


Fig. 4.9 using thermal insulation in wall and roof (NE)

It was found that Using thermal (5cm insulation) in the wall, the energy consumption was decreased by 17.4% And Using thermal (5cm insulation) in the roof, the energy consumption was decreased by 20.7% in (NE) Orientation

B) Using thermal insulation in Northwest (NW) orientation- When we increased thick of thermal insulation in the wall, the energy Consumption will be decreased **as shown fig (4.10).**

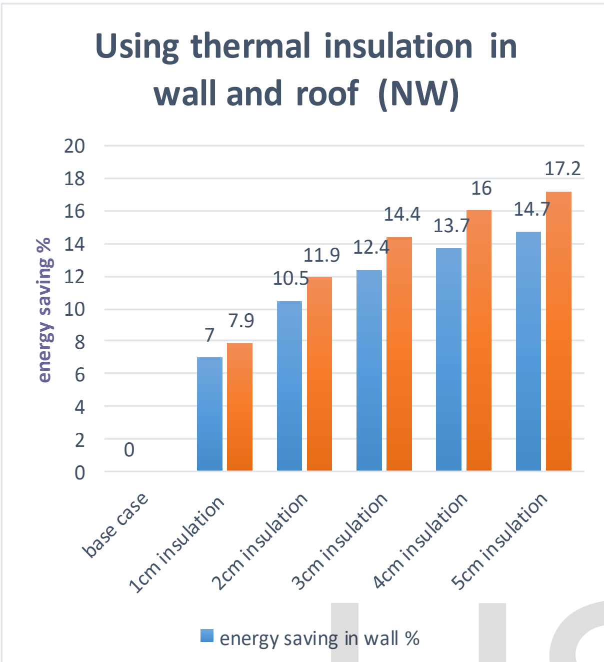


Fig. 4.10 using thermal insulation in wall and roof (NW).

It was found that Using thermal (5cm insulation) in the wall, the energy consumption was decreased by 14.7% and the energy consumption in the roof was decreased by 17.2% in (NW) Orientation.

c) Using thermal insulation in southeast (SE) orientation. The Consumption will be decreased 9.8% if we add (1cm insulation) in SE and when we add (2cm insulation) in the wall, the energy Consumption will be decreased 14.7% **as shown in fig (4.11).**

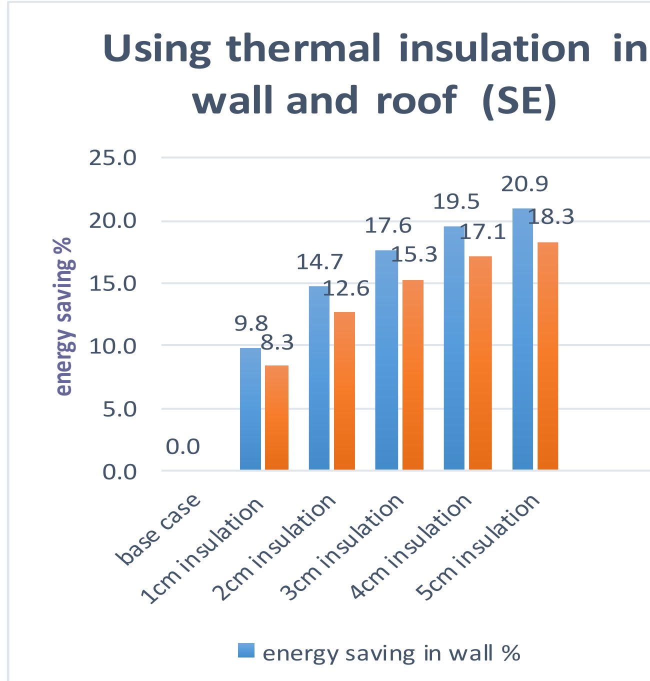


Fig. 4.11 using thermal insulation in wall and roof (SE).

It was found that Using thermal (5cm insulation) in the wall, the energy consumption was decreased by 20.9% and the energy consumption in roof was decreased by 18.3% in (SE) Orientation.

d) Using thermal insulation in southeast (SW) orientation.
Total energy consumption and energy saving for SW:-

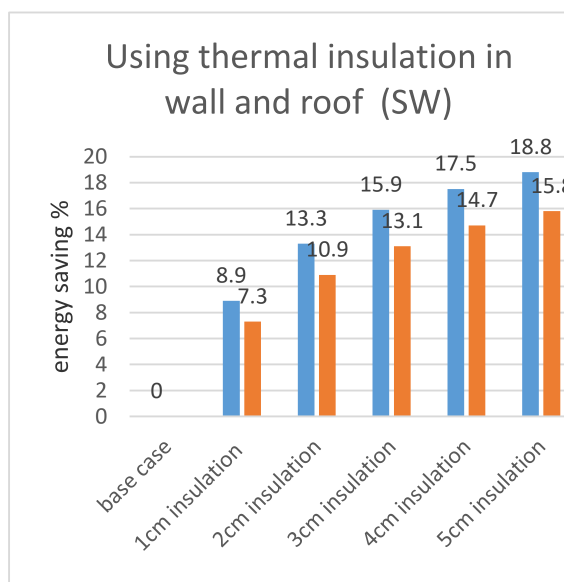


Fig. 4.12 using thermal insulation in wall and roof (SW).

It was found that Using thermal (5cm insulation) in the wall, the energy consumption was decreased by 18.8% and the energy consumption in roof was decreased by 15.8% in (SW) Orientation.

4.5.2Using double glass in wall.

A) Using double glass in (NE) wall.

The following chart show that effect of using different glass and energy saving for (NE):-

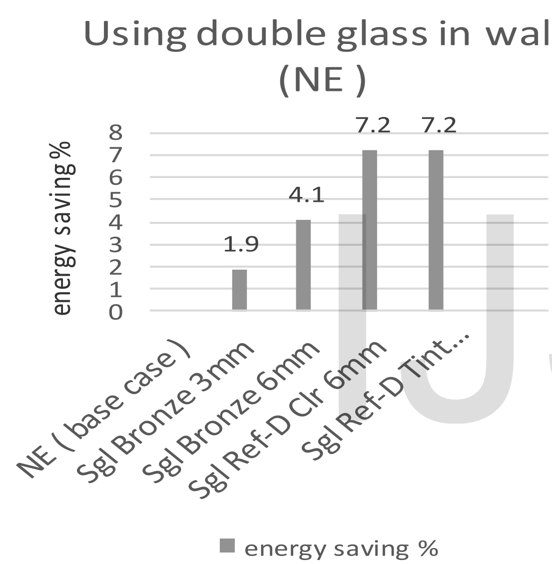


Fig. 4.13 using double glass in wall (NE).

It was found that Using double blue glass (NE), the energy consumption was decreased by 7.2 % as shown fig (4.13).

B) Using double glass in (NW) wall

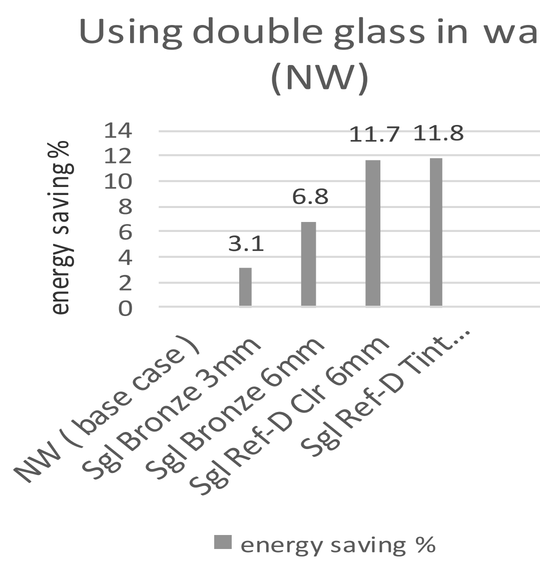


Fig. 4.14 using double glass in wall (NW).

It was found that Using double glass (NW), the energy consumption was decreased by 7.2% as shown in fig (4.14).

C) Using double glass in (SE) wall.

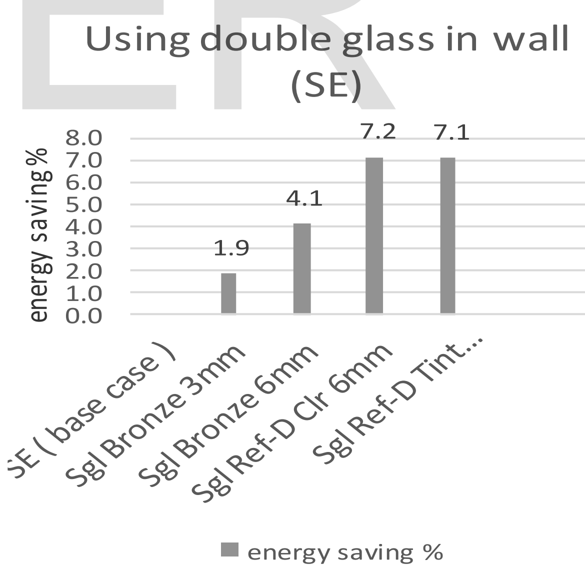


Fig. 4.15 using double glass in wall (SE).

It was found that Using double glass (SE), the energy consumption was decreased by 7.1% as shown in fig (4.15).

D) Using double glass in (SW) wall

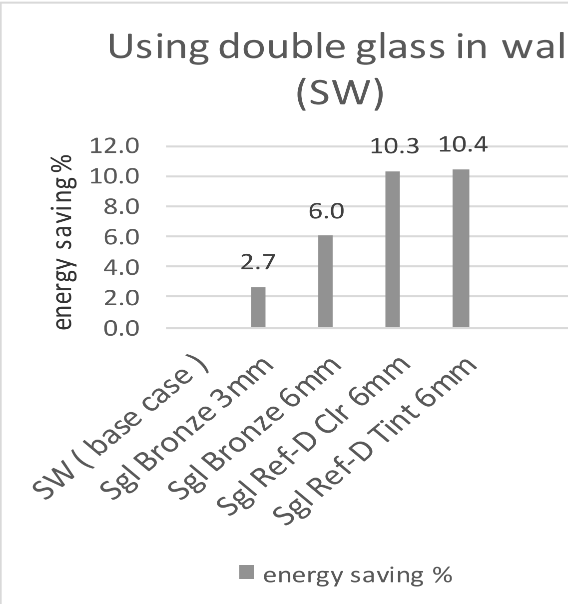


Fig.4.16 using double glass in wall (SW).

It was found that Using double glass (SW), the energy consumption was decreased by 10.4% as shown in fig (4.16).

4.6. Total energy saving for the building (model 2).

Through the previous results of Alternative for energy saving walls, roof and glass, we find the stability and convergence of energy saving between (4 to 5 cm) thermal insulation in the walls and roof and also the stability of the proportion of energy saved when used (Sgl Ref-D Clr 6mm to Sgl Ref-D Tint 6mm) in glass .

4.6.1. Energy saving for different orientation (Typical &Roof floor).

In case we use (4cm thermal insulation) in the wall and roof and we use (Sgl Ref-D Clr 6mm) glass in (NE) unit. And calculate Total energy consumption and energy saving in typical floor and roof floor.

The following table (5) show that total energy consumption And energy saving for (NE), (SE), (NW), (SW):-

Typical & roof	Total energy consumption (k.w.h)	Energy saving (%)
NE (base case)	5884	-
NE- roof	8454	-
NE (typical) Sgl Ref-D Clr 6mm+wall 4cm insulation	3925	33.3
NE (roof) Sgl Ref-D Clr 6mm+wall-roof 4cm insulation	5179	38.7
NW (base case)	7454	-
NW Roof	9678	-
NW (typical) Sgl	4898	34.3
NW (roof) Sgl	6043	37.6
SE (base case)	8417	-
SE Roof	9923	-
SE (typical) Sgl	5403	35.8
SE (roof) Sgl Ref-	5908	40.5
SW (base case)	8520	-
SW Roof	11022	-
SW (typical) Sgl	5400	36.6
SW (roof) Sgl	6767	38.6

Total energy consumption for model 2 (k.W.h) =

[no. of unit (NE)*energy consumption of typical (NE) +energy consumption of roof (NE)]+[no. of unit (NW)*energy consumption of typical (NW) +energy consumption of roof (NW)]+ [no. of unit (SE)*energy consumption of typical (SE) +energy consumption of roof (SE)] + [no. of unit (SW)*energy consumption of typical (SW) +energy consumption of roof (SW)]=

Total energy consumption for base case (k.W.h) = [(4*5884) +8454]+ [(4*7454 +9678]+

[(4*8417) +9923]+ [(4*8520) +11022] = **160177 k.W.h**

It was found that Using thermal (4cm insulation) in the wall and roof, and installed (Sgl Ref-D Clr 6mm glass). The total energy consumption was decreased.

Total energy consumption for model 2 (k.W.h) =

20879 +25635+27520+28367= **102401 k.W.h**

Total energy saving for model 2 (%) =

(160177-102401)/ 160177**=** 0.3607* 100 = **36.07 %**

4.6.2 **Energy saving after** using solarcells in roof.

The annual energy product of 5 m^2 of solar cell =

solar cell power (k.w.h)* no. of daily operation hours *

No. of days in year = 0.5 (k.w.h) * (6-7) h * 320 =**1120 k.w.h**

The cost of solar cell 10000 pounds without battery, if we add battery to solar cell system, the cost will be 14000 pounds for cover 5 m^2 Area solar cell. **[**6]

The annual energy product of 120 m^2 of solar cell = 26880 k.w.h

Total energy consumption for model 2 = Total energy consumption after insulation - annual energy product of 120 m^2 of solar cell

Total energy consumption for model 2 =

102401 – 26880 = 75521 k.w.h

Total energy saving for model 2 (%) =

(160177- 75521) / 160177 = 52.3 %

It was found that Using thermal (4cm insulation) in the wall and roof, and installed (Sgl Ref-D Clr 6mm glass) and using solarcells in roof**, the total energy saving was decreased 52.3%.**

6. Conclusions

1- The use of thermal insulation in the walls and roofs reduces the thermal loads on the buildings by 30-40%.

2- The study case can be applied to similar models by study 4 different orientation one building in the residential neighborhood and reduced of the electricity consumption.

3- The importance of studying the application of photovoltaic cells to achieve the balance of energy needs supplied by renewable technologies in residential neighborhoods.

4 - The applications of photovoltaic cell technology in architecture can vary widely from early stages of design to the final touches of finishes as one of the finishing materials.

5- It is an opportunity we must seize, and the governments shall put in place the public goods such as a world-class science and technology base, incentives for knowledge transfer and high educational standards, to enable companies to put innovation at the center of their strategies for the development of technology.

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