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DESIGN PROCEDURE FOR NEAR ZERO ENERGY BUILDING IN SAUDIA ARABIA

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ABSTRACT

The Zero Energy Building (ZEB) concept ensures that building electrical loads are controlled in such a way that the net energy consumed from the utility grid over a period of time (monthly / yearly) is near or almost zero. Recently, the number of residential buildings in the Kingdom of Saudi Arabia has increased with the increase in governmental support for citizens to own private homes. This results in increasing the energy consumption in the country. It is noted that, the energy consumption in the Kingdom of Saudi Arabia from residential buildings is about 40 percent of the total Consumption. The main objective of this work is to propose a design approach for engineers working in building design in order to implement a Near Zero Energy Building (NZEB) when solar energy is available at residential buildings. The work includes a study for implementing an Economic Building using the NZE concept, in accordance with policies to support renewable energy in the Kingdom of Saudi Arabia. Throughout this work, an example of a real estate developer working in the Saudi market, specifically in the city of Riyadh, will be analyzed and improved. The Design Model for a Residential House in Riyadh is introduced and analyzed. Architecture conceptual design, electrical design and sustainability analysis are given in details. Optimization for thermal isolation, and electric loading are used to reduce energy consumption. A solar PV system is proposed in order to achieve NZEB for a 350 m^2 house and the money payback period is estimated using 3D residential Revit software.

KEYWORDS: NZEB, PV system, on grid PV systems, off grid PV systems, EUI.

I- INTRODUCTION

I-1 NZEB Concept and definition

The residential sector is considered as one of the most electricity consuming sectors related to other sectors. In some countries, especially Saudi Arabia it reaches up to 60% of its total consumption.[1] Renewable energy has become attractive solutions of producing energy at low cost, including solar and wind sources.[2] In recent years the concept of nearly zero energy buildings (NZEB) has received widespread international attention.[3] In Europe, the Energy Performance in Buildings Directive (EPBD) 2010/EU/31 (European Parliament 2010) defined the nearly zero energy building (NZEB) concept in general terms as a new type of low energy building that would result in the construction sector.[4] An accepted definition for NZBE is that a net zero energy buildings refer to buildings that can generate all the energy they consume over a given period.[5] The following situations may lead to NZEB: very low energy demand, the greater possible demand of the building is met with renewable energies, and they produce this energy as close to the building as possible. By the end of 2020 all new buildings in the European Union are assumed to comply with the NZEB standard as defined by each country member.[4] In 2018, a new version of the EPBD UE2018/844 was released consistent with the Energy and Climate Policy Framework for 2030, which aims to reduce greenhouse gas emissions by at least a further 40% by 2030 compared with 1990. To promote the NZEB design and its evolution, the positive energy building (PEB) model is also introduced by the EU programs. This represents an improvement on NZEB and consists of buildings that produce more energy than they consume. The strategies to achieve PEBs are under discussion,[5] but they will likely be based on the NZEB buildings that are currently in use. Figure.1 shows the European NZEB model that introduces the challenge of its evolution towards PEB.

I-2 Techniques Used for Achieving NZEB

I-2.1 Integrating Renewable Energy Sources

In the past decade, there was an interest in electrical energy that feeds the residential units from renewable energy sources without relying on the electrical grid. This led to develop an effective and feasible solutions for developing energy efficient buildings that integrate renewable energy sources (RES) combining with properly selected energy storage systems (ESS). In addition, they use intelligent and advanced model-based energy management systems (EMS) in order to efficiently regulate the operation of the buildings' appliances.[6,7]

I-2.2 Using Demand Side Management (DSM)

When implementing Demand Side Management (DSM) in power system problems, the load cannot be considered as a constant value and should be modeled as a variable. Demand Side Management (DSM) programs load growth and the increasing cost and time required bringing new generation into service.[8] In a period of electricity shortage, a small amount of demand response (DR) can make the difference between a reliable system and rolling blackouts.[9] Demand side management provides the ability to monitor and control energy consumption for the consumers.[10] This is crucial because as the world population grows the electricity demand will also increase, but at the same time, we need to reduce our electricity consumption to combat the global warming.

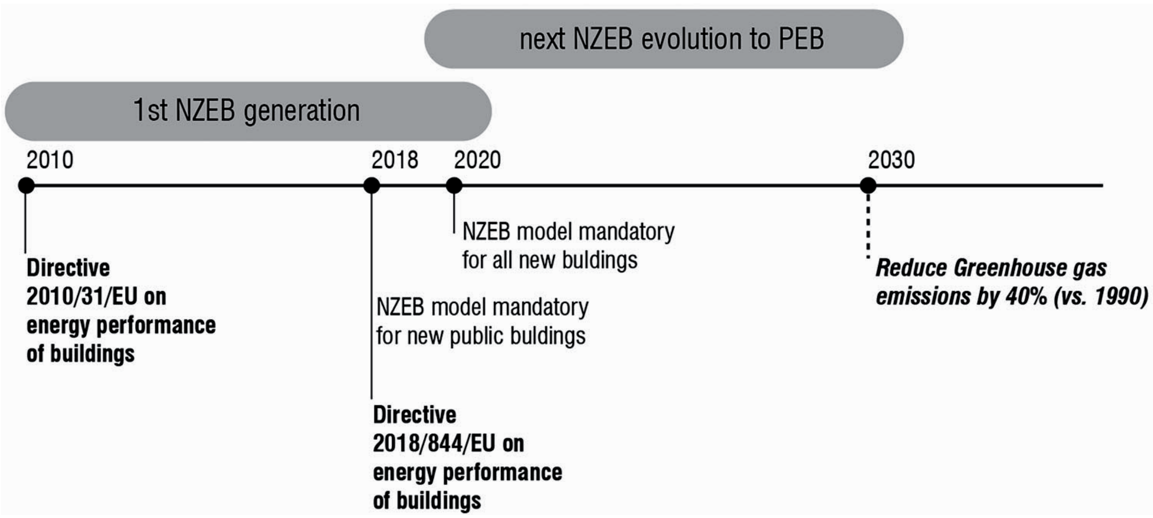


Figure 1: European NZEB model.

I-2.3 Using Load Side Management (LSM)

Load Side Management (LSM) is an important technique that can significantly increase the efficiency of the future power systems. It is a key component of smart grids that can bring a lot of benefits to power system operators and customers. Utilizing the available energy from the nature resource with considering the (LSM) strategy could help in optimizing the supply and demand.[11] Load side management is divided into 3 models: Demand Response (DR), Energy Efficiency (EE) and Distributed generation (DG). Consumers will have an incentive to create power on their own with the use of solar panels, and the excess energy can be sold for electricity Company. A lot of researches are being made to improve the system and reduce its cost and size. As a result, the photovoltaic **(PV)** system is becoming much easier to be installed.

I-2.4 Introducing the NZEB Regulations in Constructional Design

Most buildings today use a lot of energy to keep the lights on, cool the air, heat water, and power personal devices. Developments in architectural design and construction materials help in meeting the needs of the present and future generation of building intended for NZEB [12]. These buildings are also more comfortable, more reliable, and affordable to build and operate and better for the environment. For example, the design approach of new building will answer the following questions

- How can we design a house so that we benefit from sunlight - natural lighting-? . This is to reduce lightening energy consumption.

- How can we design a house so that we reduce the consumption of air conditioning by using the natural ventilation? This is to reduce cooling energy consumption.

- How can we design a house so that we reduce the consumption of heating and cooling energy by using building materials with good thermal isolation and low thermal leakage? This is to reduce both heating and cooling energy consumption**.**

I-2.5 Using energy saving appliances

Using and replacing old traditional appliances with modern, energy-saving, and high-efficiency appliances can highly reduce our electricity bills. LED (Light Emitting Diodes) lamps can save more than 80% of the lightening energy. Using motion detection switches to turn the light off in unused locations may help in reducing about 40% of lightening energy. The inverter type air condition units are now available from different manufactures where we can save about 60% of cooling energy. The concept of variable power drive water heater through PWM (Pulse Width Modulation) is recently introduced and can be used for LSM applications.[13]

I-3 Energy situation in Kingdom of Saudia Arabia

The Kingdom of Saudi Arabia seeks to pursue its vision to find alternative energy sources. As it works to keep pace with 2030 vision [14], in producing electricity using renewable energy sources.

The National Renewable Energy Program has been launched, which is a strategic initiative under the umbrella of 2030 Vision and the National Transformation Program.[15] The program aims to increase the renewable energy in the total energy sources to reach 3.45 GW in 2020, which equals to 4% of the Kingdom's total energy production and 5.9 GW by 2023, which is 10% of the energy production of the Kingdom of Saudi Arabia. In 2018 it approaches 358,853 GWh, the consumed energy is around 300 GWh. The renewable energy share was only 2.8 GW.[16]

The portion of subscribers and individuals of the energy sold: energy per one individual portion is equivalent to 8954 kWh/person and energy per one subscriber portion is equivalent to 31712 kWh/subscriber.[17] Where the energy consumption in the residential sector is about 130.5 GWh, the commercial sector is 46.9 GWh, and the industrial sector is 58.2 GWh. The percentage of residential units that uses solar energy in 2019 was about 1.60% in all the Kingdom's regions, where only 1.82% of Riyadh's of residential units that uses it. 49.14% of Riyadh residents want to use solar systems in their homes, and 52.26% of the Kingdom's population desires that as well.[18] Fig.2 gives the share of electrical energy use for different applications during summer and winter in Saudia Arabia where we can notice that mostly cooling in summer and heating in winter has the greatest share among the other energy use. In addition, lightening share represents about 33% in summer and 25% in winter.[19] So for cooling, heating and lightening energy consumption have to be considered when designing residences for NZEB in Saudia Arabia. Design of building that may consume less energy in both cooling and heating applications beside using the concept of load Side Management (LSM) can highly participate in obtaining NZEB.

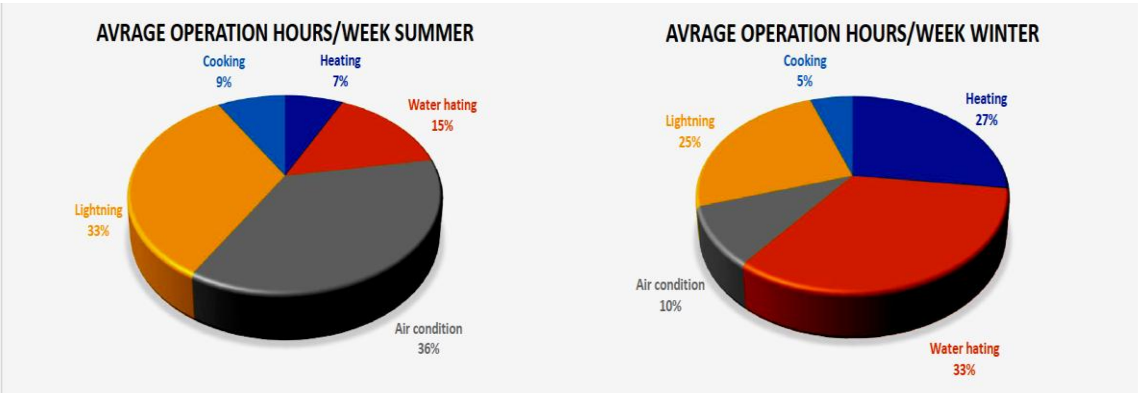


Fig. 2: Electrical energy consumption on average during summer and winter in Saudia Arabia.

II- Design Strategies for NZEB in Saudia Arabia

II-1 Real Estate Market in Saudia Arabia

In Saudi Arabia, the construction growth and the expansion of the real estate market are at the fore in the scene of the most active economic activities currently in Saudi Arabia. Since 2030 Vision, the Kingdom toke more comprehensive steps to diversify its economy and implement huge real estate in various parts of the Kingdom, including NEOM, Historic Diriyah, Qiddiya, Red Sea and other giant projects. In the year 2021 Real estate activities recorded a GDP (Gross Domestic Product) of about 35 billion U$.[20] with a contribution rate of 5.4% of the total kingdom GDP, and a growth rate of 3.4% compared to 2018. The inclusion NZEB concepts in new building design becomes one of the attractive solution for real state companies to promote their products and achieve higher contracting rates. A design guide for NZEB in the city of Riyadh (Capital of Saudia Arabia) will be introduced and analyzed in the following sections.

In this paper energy analysis performance of residential house in Riyadh will be introduced using BIM-based simulations such as Revit, Insight, and Green Building Studio. BIM is a fully immersive 3D modeling environment that integrates information for multiple disciplines, companies and project phases. These tools were used to study the energy performance and thermal comfort of an existing building to reduce the dependence on the electrical and mechanical system of the building through retrofitting strategies. The BIM tools helped the designers to experiment with all possible design alternatives before the execution for the final design solution, which saves money, time and energy while simultaneously contributing to more energy-efficient building design. The base model was developed in Revit and simulated in Autodesk Insight and Autodesk Green Building Studio. The study summarizes the design parameters for effective building envelope design from the simulation results to reduce the dependency on active means of electrical and mechanical systems, which in turn helps to improve thermal comfort. Design Process for NEZB in Riyadh will use design sequences given in Fig.3.

II-2 Design Model for a Residential House in Riyadh

Approximately 60% to 70% of the residential lands in Saudi Arabia and the residential unit's sizes are from 300 m2 to 500 m2.[20] Based on this, a residential villa was designed with an area of 350 m^2, as the length of the building façade is estimated at 15 meters, and the width at 24 meters. Due to the climatic condition (very hot in summer months and very cold in winter) all average residential houses in Riyadh have to be equipped with an efficient air conditioning system for both cooling and heating. The Design Model of a given building for NZE must include:

Architecture concept and design, Light Current Electrical Design, Mechanical System Design, and Sustainability system design: Thermal Insulation and Solar power system configurations.

Throughout this paper the sustainability system design will be considered in details while other design parameters will be given in brief description.

II-2.1 Architecture concept and design

One of the most important architecture concepts is the optimization of the roof area where the PV array may be installed. This will be positively reflected on the residents, as it will provide them with a large amount of energy, which will contribute to save the electricity bill, and will also reflect positively on the country, because this will contribute in saving the largest possible amount of energy, which will reduce carbon emissions that harm the environment. With Saudi Arabia supporting the sustainability, it would be a good idea to use this model and apply it to real estate developers. Roof analyzes and studies were carried out to support this research, where two scenarios were made as shown below. Based on the house area given above a total surface area of about 196 square meters is available an estimated 26 m^2 of the total roof area was occupied (ladder space), and the remaining 170 $m^2$of the roof may be used to place PV panels on it. Any additional service that may occupy a part of the roof surface will reduce the energy gain from the PV panels. A summary of the Architecture design is given in table1. Other factors related to Architecture design and help in NZEB are:

1. Building orientation for optimal ventilation that reduces excess of energy air conditioning system.
2. Make use of natural sun light for internal illumination to avoid using electric bulbs illumination during the day light. Table 1 summarize area distribution of the building.

II-2.2 Electrical design

This includes lighting system, outlets for light current appliances such as TV, computers mobile charger… etc and heavy loads appliances like water heaters electric cookers and microwave ovens, washing machines, refrigerators, air condition units. Low power consumption units have to be used even if their prices are relatively higher. For example, inverter type air condition units are now available with 20 % higher in price over convential types; however, it can save about 60% of the energy consumed. For lighting LED lamps are available now that can reduce lightening energy by a factor of 70%. Table 2 shows some comparison between Low power consumption loads and conventional consumption loads.

Table 1: Building area distribution Conventional.

	Floor	Area (m^2)
1	flat construction	350
2	Ground	215
3	First	196
4	Roof occupied	26
5	Roof free	170
5	**Total floors**	**436**

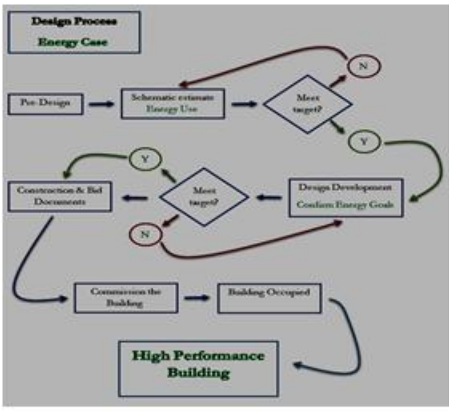


Fig.3 ZEB design process

II-2.3 Sustainability system design

This includes Thermal Insulation and Solar power system configurations.

II-2.3.1 Thermal Insulation

Thermal Insulation contributes in reducing the percentage of air conditioners consumption at rates of up to 40%. Isolation may be achieved through sealing the holes to prevent the entry of hot or cold air, using double glass windows. The thermal insulation design for the building must comply with the requirements of the Saudi Building Code.[23]

1. Area of the vertical window layouts shall not exceed 25% of the total external wall area.
2. External walls and ceilings should be light in color, with a solar reflection index (SIR) of 0.5 or more.
3. Using heat transfer coefficient (U) to determine requirements of the building envelope from the upper roof, external walls, windows, domes and external doors.

II-2.3.2 Thermal Insulation Calculation Methods

All U-factor designs are based on the proportion of air inside and outside the building for achieving the minimum values of thermal resistance, with the Continuity of thermal insulation and attaining the upper limit of the heat transfer coefficient for the entire envelope. The thermal properties declared by the manufacturer (thermal conductivity or thermal resistance is given by:

$$R=X/K \quad (1)$$

R = layer Thermal Resistance (m^2. k/W), X = Layer thickness (m),

and K = thermal conductivity (W/m. k)

$$U= 1/\Sigma R \quad (2)$$

Table 3 summarize the thermal resistance for both the roof and the walls of the given building while using isolation layer according to the Saudi Building Code.

From table 3 we can calculate the heat transfer coefficient U for the roof and the walls as:

$$\mathbf{URoof} = \frac{1}{\sum R} = \frac{1}{3.693} = \mathbf{0.271} \text{ (W/m2. k)} \quad (3)$$

$$\mathbf{UWall} = \frac{1}{\sum R} = \frac{1}{2.572} = \mathbf{0.389} \text{(W/m2. k)} \quad (4)$$

Where this value conforms to the requirements of the Saudi Building Code for energy efficiency in all kingdom regions. Typical insulating materials used to achieve the thermal resistance given above are shown in table 4.

III Solar power system configurations

Fig.4 gives the design flowchart for the solar system. The first step in designing the solar system for a residential building is to know the nature and quantity of the load demand, as well as knowing the hours of sunrise in Riyadh city, which is estimated at 5.757 hours per day throughout the year. It is also necessary to know and calculate the loss in Energy like (shadows and...). Charge Controller must be selected in order to adjust the current resulting from the intensity of sunlight. Then design and determine the size of batteries and inverter. The solar system may be designed for On grid, Off grid or Hybrid grid solar system installation. It is recommended to use the On Grid Solar System, because sometimes the housekeepers may be on a long vacation or they are not at home for long periods of the day, which will reflect positively on the public network, so there will not be waste on the produced energy from the solar panels. From this point of view, the Saudi Electricity Company launched the smart meters.

Table 2: Comparison between Low power consumption loads and conventional consumption loads.

System	Type	Low power Consumption	Conventional Consumption
		Power Watts	Power Watts
Lighting	Spot light	5.5	25
	Recessed mounted luminaries	6	40
	Double recessed mounted luminaries	12	80
	Track mounted luminaries	6	40
Heating and cooling			
	Elec. mini oven	2400	3900
	Elec oven	5000	7200
	Garage control	280	280
	Washing m. and dryer	1000	1500
	Refrigerator	150	300
	Fridge	190	300
	Ceiling mounted fan	65	100
	Water heater	1000	1500
	Air condition unit 1.5 HP	560 Gree GWC19AGD-D3NTA1B)	1160 **Panasonic Standard Non-Inverter Air Conditioner CS-SV12RKH (CU-SV12RKH)**

Table 3: Heat transfer thermal resistance of the outer surface.

ROOF		**WALLS**	
Class	**Thermal resistance (m2.k/W)**	**Class**	**Thermal resistance (m2.k/W)**
Outside air	0.030	Outside air	0.030
Roof tiles	0.009	Exterior paint	0.028
Cement mortar	0.013	Clasped despair	0.010
Sand	0.067	Water drainage	0.001
Thermal insulation material	3.214	Thermal insulation material	2.273
Bitumen waterproofing	0.059	Moisture and fume retardant layer	0.003
Reinforced structural Concrete	0.118	solid concrete block	0.088
Delicacy	0.013	Interior despair	0.020
Indoor air	0.170	indoor air	0.12
Total thermal resistance	3.693	Total thermal resistance	2.572

Table 4: Typical insulating materials used in the proposed design for NZEB.

	Wall	Roof	Glass
Thermal insulation material type	Insulated concrete blocks for walls with a single layer of polystyrene material	Polystyrene roofing sheets Thickness = 10 cm Pressure = 35 Psi	Double heat insulated glass

III-1 Sun Set Study and Solar Preview

It is preferable to make the residential building façade on the eastern façade, because the sun falls on the facade only in the early morning. As shown in Fig.5 the sun's rays focus on the building, the blue color is the most exposed to sun and suitable for the use of solar panels, the green is the average exposure, and the red indicates the presence of a large amount of shade and is not suitable for the use of solar panels. This orientation allows an optimized area for fixing the solar panels.

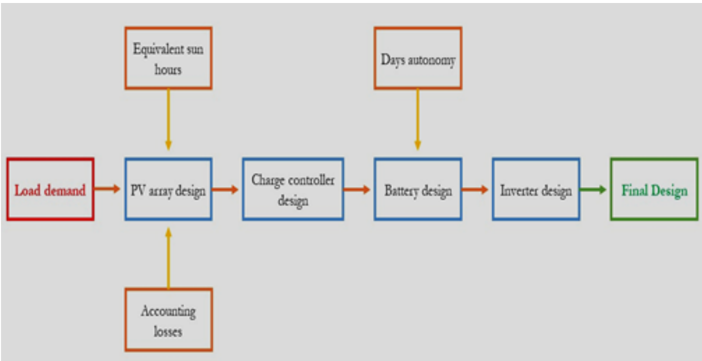


Fig.4 solar system design flow chart

III-2 Modeling & Optimization A Residential Solar Power System

Typical residential solar panel dimensions today are about 160 cm by 100 cm, with some variation among manufacturers. Moreover, an economic study is performed to determine the cost of electricity (COE) produced from this system so as to determine its competitiveness with the conventional sources of electricity. The global formula to estimate the annual energy output E is:

$$E = A\ r\ H\ (PR) \qquad (5)$$

Where: E = energy (kWh), A = total solar panel area (m^2) ,

r = solar panel yield or efficiency (%)

H = annual average solar radiation on tilted panels, PR = performance ratio, coefficient for losses (between 0.5 and 0.9).

Defining PR ratio (depends on the site, technology, and system sizing). Table 5 gives the ratios of losses due to several factors related to the system design while equation (6) gives the overall PR. Table 6 gives the ratios of losses due to several factors related to the PV system design.

PR ratio = (1-0.08) (1-0.08) (1-0.01) (1-0.01) (1-0.05) (1-0.03) (1-0.02) = 0.75 (6)

The PV area in addition to the walls filling will affect the energy production, the energy saving and the Payback period as summarized in table 6 for three different situations. The result that was extracted through Revit and Insight software [21] and the value of E was verified using equation (5) and (6). Fig.5 gives Sun rays' distribution for the eastern façade while Figure 6 a, b, c demonstrates the three different situation of table 6.

Table 5: The ratios of losses due to several factors.

Losses	Ratio	Approximate Ratio*
Inverter	6% to 15 %	8%
Temperature	5% to 15%	8%
DC cables	1 to 3 %	1%
AC cables	1 to 3 %	1%
Shadings (specific to each site)	0% to 40%	5%
at weak radiation	3% to 7%	3%
weather conditions (dust, snow...)	2%	2%

* This nominal ratio is given for standard test conditions (STC).

Table 6: A comparison of energy production and payback period.

Area used for PV	walls	PV energy production (KWh/year)	Energy saving (Dollars)	Payback (years)
116 m^2	1.8 m Bricks	20171	3026	18.1
116 m^2	1.8 m glazed	27246	4087	12.9
170 m^2	1.8 m glazed	42836	6425	11.9

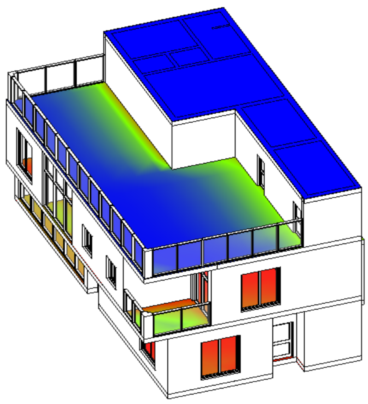


Fig. 5: Sun rays' distribution for the Glazed eastern façade.

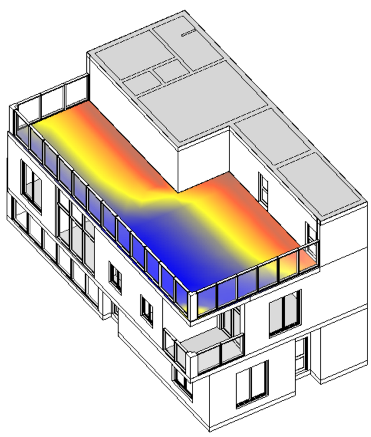


Fig.6: a 1.8 m Bricks Walls.

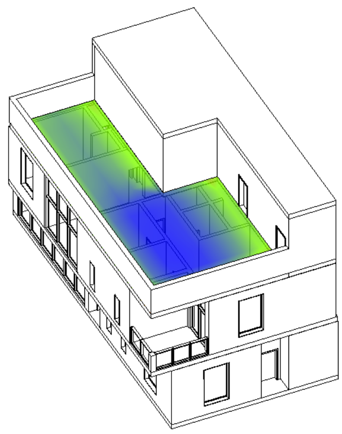
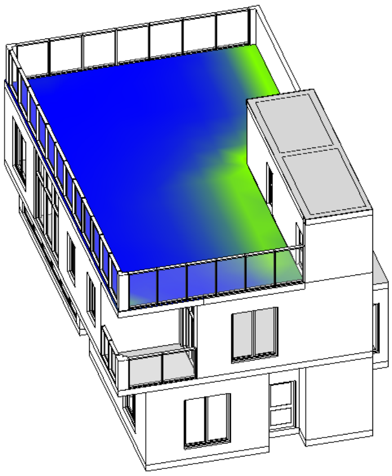


Fig.6: b 1.8 m Walls.



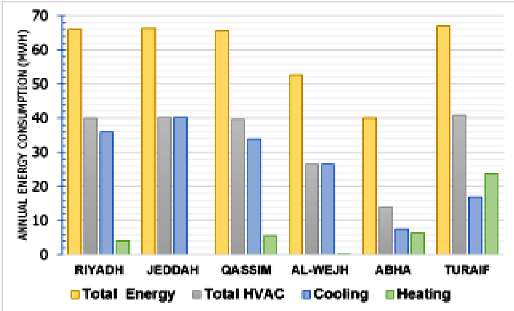


Fig. 6: c 1.8 m Glazed Walls. Fig. 7: Total annual Energy for a 245 m^2 villa in different cities in Saudi Arabia.[22]

IV Energy Model Analysis

When you benchmark your building in Portfolio Manager, one of the key metrics used is the Energy Use Intensity, or EUI. Essentially EUI expresses a building's energy use as a function of its surface area and type of energy utilizations. Fig.7 gives the total annual energy consumption for a 245 m^2 villa in different cities in Saudi Arabia,[22] where we can calculate the EUI for Riyadh city,

$$\text{EUI Riyadh} = 68000/245 = 270 \text{ (kWh/ m}^2\text{/year)} \tag{7}$$

The EUI is calculated for two cases using insight and Revit software, these two cases are:

Case A where consensual building and electric appliances are used and the EUI value is as given by equation (7).

Case B Where advance building techniques and low power consumption appliances are used.

For Case A the EUI is about 270 (kWh/ m2/year), which is equivalent to 117720 (kWh/year), 9810 (kWh/month), 327 (kWh/day). The electricity tariff in Saudia Arabia is 0.18 SR (0.048 U$)/ kWh for consumption slice below 6000 kWh/month and 0.3 SR (0.08 U$) / kWh for slices above 6000 kWh/month. So the annual cost of the electricity is equivalent to 7113.6 U$/year, 592.8 U$/ month.

For Case B the EUI is about 160 (kWh/ m2/year), which is equivalent to 69760 (kWh/year), 5813(kWh/month), 193.8 (kWh/day).

So the annual cost of the electricity is equivalent to 3348.5 U$/year, 279 U$ /month. The building plan profile and energy performance evaluation was carried out using Insight and Revit software. Input parameters from the location weather database, the building energy model (envelope u-values, infiltration rates, indoor design temperatures and approximate occupancy schedule) to estimate annual energy consumption of the whole building. Operation parameters of the HVAC plant were also considered. Table 7 gives the building parameters used through the simulation taking into consideration the construction materials, window glass isolation, lighting system and HVAC system.

Table 7: The building parameters.

#	Consumption parameters	Classical design	Advanced design
1	Window wall ratio (glazing) from façade	50% – 95%	30 – 40%
2	Window glass	Single clear window	Double thermal insulated glass
3	Wall construction	Concrete bricks 200mm	Doubled thermal insulation 300mm
4	Roof construction	Concrete bricks	Doubled thermal insulation
5	Infiltration	Air leakage	Prevent air leakage
6	Lighting efficiency	Halogen lamps (High heat consumption)	LED lamps (Low heat consumption)
7	Day lighting	No system	Intelligent day light sensor systems
8	Plug load efficiency	All appliances used (28 W/m2)	Rationing the electrical devices consumption (11 W/m2)
9	HVAC system	ASHRAE package system	Residential 17 SEER/9.6 HSPF Split HP
10	Operating schedule	24hours / 7 days	Normal use (between 24hours & 12hours) / 7days

V Design of Solar System for NZEB

Meteorological data such as solar radiation, sunshine hours, ambient temperature, relative humidity, and amount of cloud cover are important for estimating average global solar radiation. The duration of sunshine varies between a maximum and minimum of 6.67 and 4.95 h/day and average daily sunshine duration is approximately 5.757 h/day. So the Panel Shining Hours (PSH) used in Riyadh is 5.757 hours/day.

V.1 Number of PV panels needed

In order to reach the Net Zero Energy Building the PV panels installed have to supply a total of 69760 (kWh/year). The number of solar modules required if a 300 Wp (0.3 kWp) modules are used are assuming 365 days / year will be

$$\mathbf{No.\,of\,panels} = \frac{(\text{total energy})/360\ \text{days}}{(\text{PR ratio})(\text{PSH})\ (\text{module power})} = \frac{(69760/360)}{(75\%)(5.757)\ (0.3)} = \mathbf{150\ modules} \quad (8)$$

The module will be arranged in arrays as shown in Fig.9 with 25^{O} tilting angle. If we consider the effect of partial shadowing due to array interleaving, we have to leave a space between arrays. From data sheets the module dimension is around 1m width and 1.6 m height which gives 1.6 m^2 PV net area / module. The needed space around each array is found by simulation to be about 30% of the PV area (10m^2 is approximately needed for each 1kWp PV array). This will result to an equivalent area of each module to about 2.144 m2 as given by equation (9)

$$\mathbf{single\ module\ area = 1.6\ x\ 1.33 = 2.144m^2} \quad (9)$$

And the total area required will be:

$$\mathbf{Total\ Area\ required\ = (2.144)(150) = 321.6\ m^2} \quad (10)$$

Since the available roof area is limited to about 196 m2 including the area above the roof building (26 m^2) the number of modules can not be reached to 150 modules as given by equation (10). Also, the 26 m2 area above the roof building is reserved for the air-condition split outdoor units and the upper water tank. So only170m^2 are available for PV installation. In this case the total number of modules that can be installed will be:

No of modules =170m2/2.144m2 = 79.29 = 79 modules (11)

Then the total generated energy will be about 374087 kWh/year. This situation is far from the NZEB objective and we have to find other solution to increase number of PV modules and hence approach the situation of NZEB. Fig.9.b Shows the proposed solution where the modules are arranged in a single frame structure with the same tilting angle. The frame dimensions in this case are:

Width (W) = 17.5 m and length (L) = 13.1 m which allows the installation of 17x8 modules = 136 modules. The height of the frame from the roof surface will be:

$H = 13.1 \sin 25^{O} = 5.53$ m (12)

The maximum value of H is limited to 6 m to avoid shadowing of the neighbor building. This height will allow the utilization of the 26 m2 area above the roof building for mounting the air-condition outdoor units and the upper water tank. The total energy generated in this case is increased to:

Total energy = 136 x0.3 kW (module power) x 0.75 (PR) x 5.757(PSH) x365 days

= 64300 kW/year (13)

The above value for the total generated energy/year is considered as the Near Zero Energy situation. If we consider at least one-month vacation per year, the proposed design can reach Net Zero Energy Building.

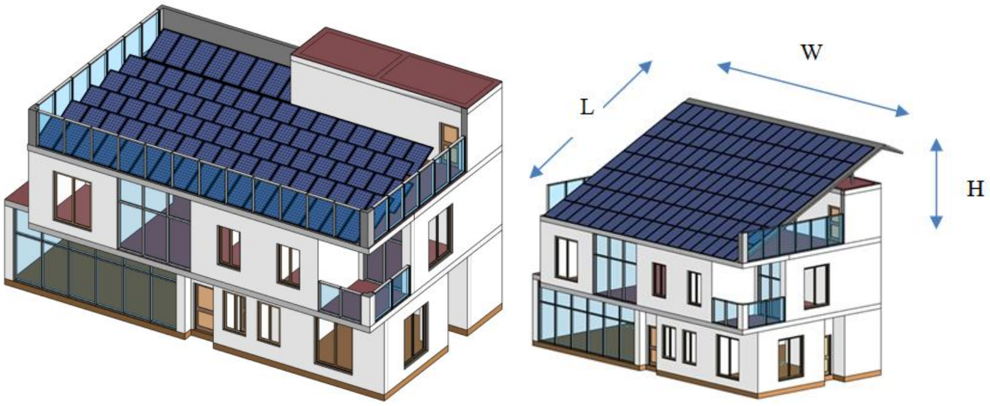


Fig. 9-a: PV module arranged in interleaved arrays. Fig.9-b: module arranged in single frame.

V-1 Cost analysis and payback period

We can roughly calculate the total cost of the proposed installation by using the average cost of the system components. On the average we can use the following price list given in table 8:

The annual cost of the energy consumption /year = 69760 kWh x 0.048 U$/kwh = 3.348.48 U$

Then the payback period will be: Total Cost/ annual consumption cost:

= 28448U$/3.348.48 U$= 8.5 years. (14)

Of course the above estimated cost and hence the payback period are on the average and may be increased or decreased depending on other factors such as: manufacture, delivery cost, manpower salaries and accessories quality.

Table 8: Price List and total cost.

Serial	Item	Quantity	Average cost /unit	Total cost/item
1	PV Module 300W	136 modules	120 (0.4 U$ /Wp)	16320 U$
2	Inverter 10kW	4	1000	4000 U$
3	Cabling, connectors, circuit breaker .etc	Packages	20% of the components cost	4064 U$
4	Installation manpower and testing	Packages	20% of the components cost	4064 U$
5	Total			28448 U$

VI CONCLUSION

The Zero Energy Building (ZEB) concept becomes an important issue to be considered in modern residential building today because of the increasing cost of the electricity bills. Recently, the number of residential buildings in the Kingdom of Saudi Arabia has increased with the increase in governmental support for citizens to own private homes. The energy consumption in the Kingdom of Saudi Arabia from residential buildings is about 40 percent of the total Consumption. In this paper a design approach for engineers working in building design in order to implement a Near Zero Energy Building (NZEB) is introduced and analyzed. Solar energy is available at residential buildings and may be used to achieve the design requirement while using good thermal isolation and minimal electrical loads. The work includes a study for implementing an Economic Building using the NZE concept, in accordance with policies to support renewable energy in the Kingdom of Saudi Arabia. An example of a real estate developer working in the Saudi market, specifically in the city of Riyadh, is given. and analyzed. Architecture conceptual design, electrical design and sustainability analysis are given in details. The proposed design reduces the EUI from 277 kwh/m2/year to only 160 kwh/m2/year. That total cost is also estimated and the money payback period is in the order of 9 years.

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